FOREWORD

These standard specifications shall govern for projects initiated after September 1, 2017. Please note that if a dispute should arise over the interpretation of a specification the County Engineer's determination shall be considered final.

SUMMARY OF SPECIFICATIONS

The Harris County Standard Specifications are reviewed annually and only specification items that require revisions are addressed. When a specification is revised, the underlined text reflects the portion of the specification that has been changed from the previous version. A specification item that is modified due to grammatical, typographical, and/or errors that do not change the intent of the item shall not be considered as a revision.

The following eleven (11) Items have been revised for the September 2017 Revisions to the Standard Specifications:

- 250 – Hot Mix Asphaltic Concrete Base Course (Black Base)
- 360 – Concrete Pavement
- 410 – Prestressed Concrete Piling
- 420 – Concrete Structures
- 423 – Prestressed Concrete Units
- 460 – Reinforced Concrete Pipe
- 471 – Precast Concrete Manholes and Junction Boxes
- 480 – Precast Reinforced Concrete Box Sewers
- 491 – Reinforced Concrete Slope Paving
- 530 – Concrete Curb, Concrete Curb and Gutter, Sidewalks and Driveways
- 673 – Constructing Detours for Maintaining Two-Way Traffic
100 ITEMS

- 102 – Clearing and Grubbing
- 104 – Removing Old Concrete
- 110 – Roadway Excavation
- 120 – Excavation for Channels and Other Drainage Facilities
- 130 – Borrow
- 132 – Embankment
- 160 – Topsoil
- 162 – Sodding for Erosion Control and Stabilization
- 164 – Seeding and Erosion Control Blanket
- 165 – Hydro-Mulch Seeding (for Erosion Control and Stabilization)
- 166 – Fertilizer
ITEM 102

CLEARING AND GRUBBING

102.1 Description. This Item shall govern for conducting clearing and grubbing operations within the project limits from right-of-way line to right-of-way line. For the purpose of this Item, the project limits shall include roadways, roadside ditches, channels, outfall ditches, detention ponds, and other drainage facilities, temporary and permanent easements and other areas as shown on the drawings. Clearing shall consist of removing all trees, brush, overhangs, logs, tires, appliances, trash, rubbish and other debris, including any deleterious materials, that exist within the limits of the project. Grubbing shall comply with the requirements of the third paragraph of Section 102.2 below.

It shall be the responsibility of the Contractor to visit the project site and ascertain the clearing and grubbing requirements as included in the bid documents prior to submitting a bid on the project. Any necessary trimming of overhangs that encroach into the right-of-way and interfere with the facilitation of construction or the operation or maintenance of the executed project shall be required and will not be paid for separately.

102.2 Construction Methods. The project limits shall be cleared of all trees, brush, stumps, overhangs, logs, rubbish, shrubs, and other trash. Items and certain areas designated by the Engineer for preservation shall be carefully protected from abuse, marring or damage during construction operations and preserved in accordance with the bid documents.

Parking and/or servicing of equipment, or stockpiling of construction materials within 3 feet of the drip line of trees designated for preservation, will not be permitted.

On areas required for roadway, detention pond, channel, or structural excavation, grubbing shall be conducted to remove all stumps, roots, etc., to a depth of approximately 2 feet below the lower elevation of the excavation. On areas required for embankment construction, grubbing shall be conducted to remove all stumps, roots, etc., to a depth of approximately 2 feet below the existing ground surface. All holes remaining after clearing and grubbing shall be backfilled with suitable onsite material and compacted to 95 percent of Standard Proctor Density (ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³)”) at a moisture content of between optimum and +/- 3 percent of optimum as directed by the Engineer and the entire area bladed to prevent ponding of water and to provide drainage; except in areas to be immediately excavated, the Engineer may direct that the holes not be backfilled. On
areas required for borrow sites and material sources, stumps, roots, etc., shall be removed to the complete extent necessary to prevent such objectionable matter becoming mixed with the material to be used in construction.

102.3 Disposal of Materials. All cleared and grubbed materials shall be disposed of offsite. The Contractor shall be responsible for obtaining any necessary disposal permits. The Contractor shall not bury any refuse on Harris County property. The disposal site shall not be an environmentally sensitive area, “Waters of the United States”, wetland, or floodway. It is the responsibility of the contractor to contact the proper authorities to determine land use classification and to obtain any necessary permits. If the disposal site is defined in the plans, then the County shall be responsible for ensuring that the appropriate Department of the Army permit has been obtained for the activity, as necessary. No burning shall be allowed unless otherwise noted.

The Contractor shall refer to Item 560 “Maintenance and Cleanup of the Project Site” for schedule and frequency of cleanup of materials for disposal.

102.4 Limit of Operation. No clearing or grubbing shall be done outside the Project limits or the right-of-way. Any work done outside the Project limits or the right-of-way limits, for any purpose, shall be done at the Contractor’s expense and it shall be the Contractor’s responsibility to negotiate and secure the permission of the property owner for such operation. The Contractor shall provide sufficient evidence to Harris County that such permission has been obtained.

102.5 Schedule of Clearing. The Contractor shall schedule his clearing operations so that clearing has been completed for a distance of 2,000 feet ahead of any point where excavation is to be started. After starting excavation, the Contractor shall keep a minimum of 1,000 feet of cleared right-of-way ahead of the excavation operation.

102.6 Measurement & Payment. Clearing and grubbing will be paid for at the unit price bid per lump sum, acre, or station (100 foot), as designated in the proposal and/or drawings, and shall be full compensation for furnishing all labor, materials, permits, supervision, equipment and supplies required to complete all items of work specified herein.

Removal of concrete structures shall be measured and paid for in accordance with Item 104 “Removing Old Concrete” and Item 495 “Removing Old Structures”.
Tree protection and tree trimming shall be measured and paid for in accordance with Item 501 “Tree Protection and Trimming”.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

- Item 104 “Removing Old Concrete”
- Item 200 “Stripping”
- Item 495 “Removing Old Structures”
- Item 501 “Tree Protection and Trimming”
- Item 560 “Maintenance and Cleanup of the Project Site”

END OF ITEM 102
ITEM 104

REMOVING OLD CONCRETE

104.1 Description. This Item shall govern for breaking up and satisfactorily disposing of concrete pavement, slope paving, riprap, median strips, driveways, sidewalks, combined curb and gutter, or curb.

104.2 Construction Methods. Existing concrete to be disposed of, consisting of pavement, slope paving, riprap, median strips, driveways, sidewalks, combined curb and gutter or curb, shall be removed and legally disposed of offsite. The use of explosives for breaking up old concrete will not be permitted, unless authorized by the Engineer, and when so authorized, adequate precautions shall be given to prevent damage to adjacent property. Reinforcing steel shall be cut as necessary for satisfactory disposal.

Where only a portion of the existing concrete is to be removed, special care shall be exercised to avoid damage to that portion of the concrete to remain in place. The existing concrete shall be cut to the neat lines shown on the plans or established by the Engineer and any existing concrete, beyond the neat lines so established, which is damaged or destroyed by these operations shall be replaced at the Contractor's entire expense. Saw-cutting, full depth or as shown on the drawings, will be required and shall be incidental to the removal of old concrete.

Where indicated on the plans, old concrete which is removed shall be loaded, hauled and disposed of at permitted locations outside the project limits, or used as needed for riprap onsite. Broken concrete reused as riprap onsite will be incidental to this Item. The Contractor shall provide the disposal locations and the total quantity of all excavated material, and the total quantity of disposed material. The disposal site shall not be an environmentally sensitive area, “Water of the United States”, wetland, or floodway. It is the responsibility of the Contractor to contact the proper authorities to determine land use classification and to obtain any necessary permits. If the disposal site is defined in the plans, then the County shall be responsible for ensuring that the appropriate Department of the Army permit has been obtained for the activity, as necessary.

Work performed under this Item shall be initiated at such time and prosecuted in such a manner as to cause a minimum of inconvenience to traffic or adjacent property owners.

104.3 Measurement. Existing concrete pavements with or without curbs, slope paving, driveways, sidewalks, median strips, and riprap, removed as
prescribed above, will be measured by the square yard in its original position, regardless of its thickness or the depth of covering.

Existing combined concrete curb and gutter and concrete curb, not on concrete pavement, removed as prescribed above will be measured by the linear foot in its original position, regardless of the dimensions of same. Monolithic concrete curb or dowelled-on concrete curb will be considered as part of the concrete pavement to be removed and will not be measured separately.

104.4 Payment. The work performed as prescribed by this Item, measured as provided under "Measurement" will be paid for at the unit price bid for "Removing Old Concrete" (of the type specified), which price shall be full compensation for:

A. Full depth saw-cutting or

B. Partial depth saw-cutting and breaking up the concrete, cutting reinforcing steel when required, loading, hauling and disposing of the material offsite and for all labor, tools, equipment, manipulations and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 205 “Subgrade”

END OF ITEM 104
ITEM 110

ROADWAY EXCAVATION

110.1 Description. This Item shall govern the required excavation within the roadway limits, including roadside ditches, and either of the following:

A. proper re-use of the suitable material for embankment within project limits, or

B. removal and disposal of excess or unsuitable excavated materials.

This Item includes stripping, constructing, shaping, and grading of all earthwork along the entire length of the roadway including approaches to the same. Both structural and channel excavation are excluded from this Item.

The roadway excavation shall conform to the required lines, grades and typical cross-sections as shown on the construction drawings, and conform to the requirements of this Item.

All suitable excavation material available at the time of need shall be used for embankment before using borrow material. Stripped material is unsuitable for re-use as embankment within the project. Compaction of embankments shall be as outlined in the Item 132 “Embankment”.

The roadway limits are defined as being from right-of-way line to right-of-way line, and from beginning station to ending station.

110.2 Construction Methods. All roadway excavation and corresponding embankment construction shall be performed as specified herein and in accordance with the Item 132 “Embankment” and the completed roadway shall conform to the established alignment, grades and cross-sections.

All suitable excavated materials shall be utilized, insofar as practicable, for constructing the required roadway sections or embankments, flattening slopes, etc., or as directed by the Engineer. Materials suitable for onsite use shall be defined by the Engineer. Unsuitable roadway excavation and roadway excavation in excess of that needed for construction shall be considered as waste and shall become the property of the Contractor to be disposed of legally outside the project limits.

No disposal site(s) shall be located within an environmentally sensitive area, “Water of the United States”, wetland, or floodway. It is the responsibility of the Contractor to contact the proper authorities to
determine land use classification and to obtain any necessary permits. If the disposal site(s) is defined in the plans, then the County shall be responsible for ensuring that the appropriate Department of the Army permit has been obtained for the activity, as necessary. Unsuitable material encountered below the top of subgrade elevation, shall be replaced with suitable material from the roadway excavation, or from other suitable material sources (see “Special Roadway Excavation below).

During construction, Item 560 “Maintenance and Cleanup of the Project Site” shall be implemented for the duration of the Contract. The roadbed and ditches shall be maintained in a condition to insure proper drainage at all times. Ditches shall be so constructed and maintained as to avoid damage to the roadway section.

All roadway excavation utilized as embankment shall be placed in accordance with Item 132 "Embankment".

In those cases where the Contractor has over-excavated beyond the lines and grades shown on the drawings, or designated by the Engineer, it shall be the Contractor’s responsibility to replace the material and recompact it at his own expense. The material shall be replaced in accordance with the Item 132 "Embankment".

At the location of pipeline crossings, the Contractor shall suspend machine excavation at a location 5 feet before reaching the pipeline right-of-way, until a company representative is present to identify pipeline locations and to further direct excavation operations. The notification to the pipeline company of the Contractor's operations and the request for their representative’s attendance shall be the responsibility of the Contractor. The Contractor shall not be reimbursed directly for any work or expenditure as a result of intersecting any pipeline operation. Any contingent costs therefore shall be anticipated in the preparation of the bid and included as distributed items of cost in the price for roadway excavation.

110.3 Special Roadway Excavation. When geotechnical conditions dictate, the Engineer may direct the Contractor to remove material which will not properly support the roadway, and replace it with suitable backfill material. Measurement will be by cubic yard of material as computed by volumetric calculations based on actual measured dimensions of the over-excavated area.

When Special Excavation is required by the Engineer, the cubic yardage calculated will be added to the plan quantity.
Payment shall include hauling, placing, compacting and any other incidentals necessary for completing the work. The backfill used to replace the unsuitable excavation shall be either of the following:

A. suitable onsite material

B. imported material, when directed by the Engineer, in accordance with sections 130.2 & 130.3 of Item 130 "Borrow" and shall be paid for as provided under "Borrow" The material shall be placed in accordance with the Item 132 "Embankment".

110.4 Contesting Earthwork Plan Quantities. For all earthwork items (110, 120, 130) that are designated as “plan quantity” pay items, the following procedures shall apply for contesting the plan quantities:

If, after project award, the Contractor believes there is an error in the estimated quantities for earthwork items as shown on the bid sheet, the Contractor shall provide, at no expense to Harris County, sufficient documentation in the form of recoverable cross-sections and supporting computations. If the Contractor is required to re-survey a portion of the project for the purpose of contesting the quantity shown on the plan, the cross-sections must be taken at the same locations and orientation of those presented in the plan set, and using the same control points. The quantities shall be determined using the Harris County Earthwork Quantities Worksheet. The Engineer shall, at the County’s expense, designate a representative, either a Consultant’s or Harris County’s surveyor, to verify the re-survey process meets the above requirements. The Contractor’s documentation shall be provided prior to proceeding with any items of earthwork. No adjustments to the plan quantity will be allowed once any excavation, including stripping, has begun.

The Contractor may submit a written notice of protest for earthwork at any time after the award date, but shall submit all required documentation no more than 30 calendar days after the latter of the following:

A. Project start date, or

B. Establishment of horizontal and vertical control points

If the documentation provided by the Contractor is deemed by Harris County to be sufficient, and is representative of actual field conditions, then the quantities derived there from shall be the basis of payment.

If the documentation provided by the Contractor is deemed by Harris County to be insufficient, additional supporting information may be required at no expense to Harris County. The Contractor shall submit the
additional documentation no more than 14 calendar days after being notified of the County’s request.

Incentivized Project.

The time of early completion for receiving the incentive will not be extended on any incentivized project for any reason, including any time associated with a Contractor’s protest of earthwork quantities. If the Contractor chooses to protest earthwork quantities on an incentivized project, and is successful in gaining acceptance of the revised earthwork quantities, he may be granted extra days on the project in the same manner discussed below for “Non-Incentivized Project” as well as revision of the plan quantity, but that result shall not affect the early completion incentive time as per the “Supplement to Harris County General Condition (For Roads, Bridges, and Related Work)”.

Non-Incentivized Project.

If the Contractor’s protest of earthwork quantities is accepted, the Contract Time may be adjusted for the contract time lost due to any of the following which falls after project start date:

A. Contractor’s time for submitting the original documentation after the project start date up to a maximum of 30 calendar days.

B. Additional calendar days may be granted for any part of Harris County’s original review period that occurs subsequent to the project start date.

C. Any additional days which were required for providing additional documentation pursuant to Harris County’s request, up to a maximum of 14 calendar days.

D. Any additional days which were required for Harris County to review additional documentation and render a decision.

If the Contractor’s protest of earthwork quantities is rejected, neither the Contract Time nor the plan quantity shall be adjusted.

Measurement and Payment. The quantity of excavation to be paid for shall be the number of cubic yards of material computed by theoretical cross-sections, obtained from the drawings and natural ground lines, including stripping, using the average end area method. This result represents a plan quantity amount that is paid for as such by the Roadway Excavation bid item.
With the exception of “Special Roadway Excavation” (as documented in Section 110.3) all work performed as required by this Item and measured as provided above, shall be paid for at the unit price bid for "Roadway Excavation", which price shall be full compensation for preparing and maintaining roadside ditches, trimming of slopes, hauling and storage of excavated material for other uses, disposal of unsuitable or surplus materials (wastage), preparation and completion of subgrade, shoulders, roadway, any necessary hauling, placing, compacting and the furnishing of all labor, tools, equipment and incidentals necessary to complete the work.

Re-grading of existing roadside ditches outside the limits of roadway excavation shall be measured in its original condition along the centerline and the total length be computed, in linear feet and shall be full compensation for furnishing all labor, supervision, supplies, materials, permits, and equipment required to complete the work, including all items of excavation, disposal, haul, compaction, grading, and ditch dressing as specified, in the project documents.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 130 "Borrow"
Item 132 “Embankment”
Item 200 "Stripping"
Item 205 “Subgrade”
Item 560 “Maintenance and Cleanup of the Project Site”

END OF ITEM 110
EXCAVATION FOR CHANNELS AND OTHER DRAINAGE FACILITIES

NOTE: This item is intended for use for constructing drainage facilities which will not be maintained by the Harris County Flood Control District. Facilities for Flood Control maintenance are governed by the applicable HCFCD standards.

120.1 Description. This Item shall govern the required excavation for all channels, detention ponds, and other drainage facilities, channel changes and ditches as shown on the plans, the removal and proper stockpiling or disposal of all excavated materials; including strippings on the entire length of channel or drainage facility, in conformity with the required lines, grades and typical sections and in accordance with the specification requirements herein outlined. Stripping is unsuitable material. Excavation for roadways and roadside ditches are specifically excluded. Ditches shall include inlet and outlet ditches to structures, and all ditches outside the confines of the roadway slopes. This excludes constructing embankment for channels and ditches shall be as outlined under the Item 132 “Embankment”.

120.2 Construction Methods. All suitable materials removed from the excavation shall be used, insofar as practicable in the formation of embankments as required by the Item 132 “Embankment”. Excavated material shall neither be permanently nor temporarily placed on the channel top of bank, nor will temporary shelves be cut into the channel side slopes, without the approval of the Engineer. All channel excavation utilized as embankment shall be placed in accordance with Item 132 “Embankment”.

Unsuitable and/or excess excavation shall become the property of the Contractor and shall be disposed of by the Contractor outside of the limits of the right-of-way. The Contractor shall be responsible for disposal of all excavated material not used for backfill or grading berm areas. The disposal site shall not be an environmentally sensitive area, “Water of the United States”, wetland or floodway. It is the responsibility of the Contractor to contact the proper authorities to determine land use classification and to obtain any necessary permits. Refer to Section 120.3 regarding Disposal Permits. However, if the disposal site is defined in the plans, then the County shall be responsible for ensuring that the appropriate Department of the Army permit has been obtained for the activity.
Cut-off channel meanders shall not be backfilled unless so indicated on the plans.

Any temporary construction access that crosses a channel shall be constructed so as to allow a continuous flow at all times. The channel flow line shall not be blocked or raised at any temporary construction access. Temporary construction access across a channel shall require a permit. If a permit is not included in the contract, the Contractor is not entitled to construct such access without securing a required permit.

When the plans indicate the fill of a channel side slope, the earthen fill material shall be placed in layers not to exceed 8 inches and shall be benched or notched into existing slopes and compacted by suitable rolling equipment to 90 percent of standard proctor density, per ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort of (12,400 ft-lbf/ft³)” at a moisture content between +/- three percent of optimum.

Any earthen fill material, whether from onsite sources or imported, shall be free from roots, trash, silt and objectionable debris. Soils classified by ASTM D2487 “Standard Practice for Classification of Soils for Engineering Purposes” as clayey sands (SC), sand clay mixtures, or inorganic clays (CL) with a plasticity index from 15 to 40 are approved as fill materials. Each layer shall be compacted to 90 percent of standard proctor density (ASTM D698), at a moisture content between +/- three percent of optimum. The channel side slopes, in fill areas, shall be cut to the finished dimensions after completion of the fill process. Any imported earthen fill material shall comply with Item 130 “Borrow”.

At the location of pipeline crossings, the Contractor shall suspend machine excavation at a location five feet before reaching the pipeline right-of-way, until a company representative is present to identify pipe location and to further direct excavation operations. The notification to the pipeline company of the Contractor’s operations and the request for their representative’s attendance shall be the responsibility of the Contractor. The Contractor shall not be reimbursed directly for any work or expenditure as a result of intersecting any pipeline operation. Any contingent costs therefore shall be anticipated in the preparation of the bid and included as distributed items of cost in the price for channel excavation.

At locations where lateral ditches or swales enter the channel, the Contractor shall perform grading as may be required to maintain the lateral ditches or swales within the easement area as approved by the Engineer. The cost of all grading shall be considered incidental to the unit price bid and no extra payment will be made.
Prior to final inspection by the Engineer, the Contractor shall remove all sediment from the bottom of the channel and dispose of this material off site. The cost of sediment removal and grading shall be incidental to the unit price bid, and no extra payment will be made.

120.3 Disposal Permits. The Contractor shall provide copies of the disposal permits to the County and post all disposal location permits on the jobsite.

120.4 Measurement & Payment. The quantity of excavation for channels and other drainage facilities shall be paid for by the number of cubic yards of material computed by theoretical cross-sections, obtained from the drawings and natural ground lines using the average end area method. Field cross-sections will not be performed after construction has begun. Excavation in Storm Water Quality basins and created wetlands may be paid for per cubic yard or per acre as stipulated in the bid proposal and/or drawings.

After project award, if the Contractor feels there is an error in the estimated quantities for excavation, as shown on the bid sheet, the plan quantity may be protested as delineated in Item 110.4 “Contesting Earthwork Quantities”.

All work performed as required by this Item and measured as provided above, will be paid for at the unit price bid for excavation for channels and other drainage facilities which price shall be full compensation for preparation, trimming of slopes, storage and hauling of excavated material for other uses, disposal of surplus materials (wastage), any necessary hauling and the furnishing of all labor, tools, equipment and incidentals necessary to complete the work, as shown on the drawings.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 110 “Roadway Excavation”
Item 130 “Borrow”
Item 132 “Embankment”
Item 200 “Stripping”

END OF ITEM 120
ITEM 130

BORROW

130.1 Description. This Item shall govern proper utilization of fill materials secured from offsite sources obtained by the Contractor and approved by the Engineer. Compaction of borrow shall conform to the density control method as outlined in the Item 132 “Embankment”.

Borrow shall be used only when there is an insufficient quantity of suitable onsite material available as outlined by Item 132 “Embankment”. Borrow shall be used only as authorized by the Engineer, and shall be supplied from approved sources only.

130.2 Materials. Borrow material used for embankment shall consist of soil having a plasticity index not less than 12, nor more than 20 when tested in accordance with ASTM D4318 “Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index of Soils” or as directed by the Engineer. The maximum liquid limit allowed is 45, unless otherwise approved by the Engineer. The Contractor is required to inform the Engineer of the location of the pit or pits from which the fill material is to be taken and shall provide samples of the material for approval by the Engineer. In the event the material is not acceptable, as determined by the Engineer, the Contractor shall find other pit locations. All fill material shall be free from organic matter and deleterious material.

The use of a blend of cohesive and granular soils to achieve the required plasticity index will not be permitted.

130.3 Construction Methods. All suitable material obtained onsite and/or from borrow sources shall be used in the formation of embankments as required by the Item 132 "Embankment", or shall otherwise be utilized as indicated on the plans or as directed, and the completed work shall conform to the established alignment, grades and cross-section.

The Engineer shall be notified sufficiently in advance of opening any approved borrow source to permit necessary testing, prior to the use of the material as borrow.

The borrow site shall not be located within a “Water of the United States” or environmentally sensitive area. It is the Contractor’s responsibility to obtain any and all Federal, State or Local permits associated with operation of the borrow site; if it is not an approved commercial borrow site.
County Borrow Source.

During construction, the borrow source shall be kept drained, insofar as practicable, to permit final cross-sections to be taken when required.

The borrow source shall be left in a suitable condition, so as to provide proper drainage where practicable.

130.4 Measurement and Payment. Borrow is a plan quantity pay item that represents the excess embankment needed over the total excavated material from all onsite sources. These sources include, but may not be limited to:

A. roadway excavation (Item 110),

B. detention pond and/or channel excavation (Item 120),

C. storm sewer excavation,

D. and/or structural excavation (Item 400).

Roadway excavation and detention pond and/or channel excavation are calculated by cross sections using the average end area method, whereas storm sewer excavation and structural excavation are volumetrically calculated.

After project award, if the Contractor feels there is an error in the estimated quantities for excavation, as shown on the bid sheet, the plan quantity may be protested as delineated in Item 110.4 “Contesting Earthwork Quantities”.

All work performed as required herein and measured as provided above, will be paid for at the unit price bid for “Borrow”, which price shall be full compensation for furnishing all labor, for all materials, for all royalties and freight involved, for all hauling, delivery and spreading on the road and compacting complete and in place and for all tools, equipment and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 110 “Roadway Excavation”
Item 120 “Excavation for Channels and Other Drainage Facilities”
Item 132 “Embankment”
Item 205 “Subgrade”
Item 400 “Structural Excavation and Backfill”

END OF ITEM 130
ITEM 132

EMBANKMENT

132.1 Description. This Item shall govern for the placement and compaction of all suitable materials obtained from excavation of roadway right-of-way (Item 110), channels, and other drainage facilities (Item 120), structural and all underground utility excavation (Item 430), and borrow (Item 130), used in the construction of project fill and/or embankment.

132.2 Construction Methods. Prior to placing any embankment, all clearing & grubbing and stripping operations shall be completed on the excavation sources and areas over which the embankment is to be placed. Stump holes or other small excavations within the limits of the proposed embankments shall be backfilled with suitable material and thoroughly compacted by approved methods before commencing embankment construction. The surface of the ground, including plowed loosened ground or surface roughened by small washes shall be restored to approximately its original slope by blading or other methods and where indicated on the plans or required by the Engineer, the ground surface thus prepared shall be compacted in accordance with the Item 205 “Subgrade”.

Unless otherwise indicated on the plans, the surface of the ground of all unpaved areas, which are to receive embankment, shall be loosened by scarifying or plowing to a depth of not less than 4 inches. The loosened material shall be recompacted with the new embankment as hereinafter specified, and shall not exceed 8 inches in total depth.

Where indicated on the plans or as directed by the Engineer, the surface any slopes to receive embankment shall be loosened by scarifying or plowing to a depth of not less than 4 inches, or cut into steps, benched or notched before embankment materials are placed. The embankment shall then be placed in maximum 8 inch loose layers, beginning at the low side in part width layers and increasing the widths as the embankment is raised. The material which has been loosened shall be recompacted simultaneously with the embankment material placed at the same elevation.

Where embankments are to be placed adjacent to or over existing roadbeds, the roadbed slopes shall be plowed or scarified to a depth of not less than 4 inches and the embankment built up in successive layers, as hereinafter specified to the level of the old roadbed before its height is increased. The top of the old roadbed shall be scarified and recompacted with the next layer of the new embankment. The total depth of the
scarified and added material shall not exceed the permissible depth of layer.

Trees, stumps, roots, vegetation or other unsuitable materials shall not be placed in the embankment.

Except as otherwise required by the plans, all embankment shall be constructed in layers approximately parallel to the finished grade of the roadbed. Embankments shall be constructed to the grade established by the Engineer, and completed embankments shall correspond to the general shape of the typical sections shown on the plans and each section of the embankment shall correspond to the detailed section or slopes established by the Engineer. After completion of the roadway, it shall be continuously maintained to its finished section and grade until the project is completed.

Except as otherwise specified, earth embankment shall be constructed in successive layers for the full width of the individual roadway cross-section and in such lengths as are best suited to the sprinkling and compaction methods utilized.

Prior to compaction, the layers shall not exceed 6 inches in depth where pneumatic tire rolling is to be used and shall not exceed 8 inches in depth for rolling with other types of rollers. Layers of embankment may be formed by utilizing equipment which will spread the material as it is dumped, or they may be formed by being spread by blading or other acceptable methods, from piles or windrows dumped from excavating or hauling equipment in such amounts that the material is evenly distributed.

Each layer of embankment shall be uniform as to material and moisture content before compaction. Where layers of unlike materials abut each other, the materials shall be mixed so as to prevent abrupt changes in the soil. No material placed in the embankment by dumping in a pile or windrow shall be incorporated in a layer in that position, but all such piles or windrows shall be moved by blading or similar methods. Clods or lumps of material shall be broken up and the embankment material mixed by blading, harrowing, discing, or similar methods so that the material in each layer is uniform. Water required for sprinkling to bring the material to the moisture content necessary for maximum compaction shall be evenly applied and it shall be the responsibility of the Contractor to secure a uniform moisture content throughout the layer by such methods as may be necessary. In order to facilitate uniform wetting of the embankment material, the Contractor may apply water at the material source if the sequence and methods used produce the required results. Such procedure shall be subject to the approval of the Engineer.
Each layer shall be compacted to a minimum of 95 percent of standard proctor density per ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft$^3$ (600 kN-m/m$^3$))”, using a moisture content between optimum and +/- 3 percent of optimum.

After each layer of embankment or select material is complete, tests as necessary will be made by the Engineer. If the material fails to meet the density specified, the course shall be reworked, as necessary, to obtain the specified compaction.

Should the subgrade, due to any reason or cause, lose the required stability, density or finish before the pavement is placed, it shall be recompacted and refinished at the sole expense of the Contractor. Excessive loss of moisture in the subgrade shall be prevented by sprinkling, sealing or covering with a subsequent layer of asphaltic or other approved material.

132.3 Quality Assurance. The Contractor is responsible for the control of the quality of materials incorporated into the construction and the quality of completed construction. The County will engage materials engineering services to provide quality assurance testing and inspection to assist the Engineer in determining the acceptability of materials and completed construction. Quality assurance services provided by the County do not relieve the Contractor of his responsibility for quality control. The Engineer shall not have control of the means, methods, techniques, sequences, or procedures of construction selected by the Contractor.

The testing laboratory’s representative will determine the moisture-density relationships in accordance with ASTM D698 on material secured from each type of material encountered.

The testing laboratory’s representative will determine the in-place density in accordance with ASTM D6938 “Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)” or ASTM D1556, “Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.” The minimum level of testing will consist of at least 3 tests for each 1,000 feet per lane of roadway or 4,000 square feet of embankment, per lift.

132.4 Measurement and Payment. Embankment shall not be paid for directly, but shall be incidental to roadway excavation, excavation for channels and other drainage facilities, construction of underground utilities, including all sewers. This includes any transporting and stockpiling of material.
There are no line codes for this Item.

NOTE: This Item requires other Standard Specifications

Item 102 “Clearing and Grubbing”
Item 110 “Roadway Excavation”
Item 120 “Excavation for Channels and Other Drainage Facilities”
Item 130 “Borrow”
Item 200 “Stripping”
Item 205 “Subgrade”
Item 430 “Construction of Underground Utilities”

END OF ITEM 132
ITEM 160

TOPSOIL

160.1 Description. This Item shall govern furnishing and placing topsoil to the lines, grades and depth shown on the drawings or as directed by the Engineer. Topsoil is defined as the surface layer of material containing decaying vegetable matter and roots. It is not necessary to strip the section of topsoil containing fine, hairline roots, only soil containing moderate to severe root mat.

160.2 References.

A. AASHTO T194 “Standard Method of Test for Determination of Organic Matter in Soils by Wet Combustion"

B. ASTM D422 “Standard Test Method for Particle-Size Analysis of Soils"

C. ASTM D1140 “Standard Test Methods for Determining the Amount of Material Finer than 75-µm (No. 200) Sieve in Soils by Washing"


E. ASTM D4972 “Standard Test Method for pH of Soils"

160.3 Materials.

A. Topsoil shall be:

1. capable of sustaining native plant growth,

2. easily cultivated,

3. highly resistant to erosion,

4. free from objectionable material including gravel, large roots, stumps, wood, brush, debris, hard clods, clay balls, hardpan, refuse or other deleterious materials, and

5. of reasonably uniform quality.

B. If topsoil is required for the project, it shall be provided from an onsite source, or imported as directed by the Engineer.
C. Imported Topsoil shall conform to the following requirements:

### TABLE 1

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>UNIT</th>
<th>VALUE</th>
<th>APPLICABLE STANDARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Reaction</td>
<td>pH</td>
<td>5.5-8.5</td>
<td>ASTM D4972</td>
</tr>
<tr>
<td>Passing No. 4 Sieve</td>
<td>%</td>
<td>95-100</td>
<td>ASTM D422</td>
</tr>
<tr>
<td>Sand Size, 2.0-0.05 mm</td>
<td>%</td>
<td>10-70</td>
<td>ASTM D422</td>
</tr>
<tr>
<td>Silt Size, 0.05-0.005 mm</td>
<td>%</td>
<td>0-40</td>
<td>ASTM D1140</td>
</tr>
<tr>
<td>Clay Size, &lt;0.005 mm</td>
<td>%</td>
<td>20-50</td>
<td>ASTM D1140</td>
</tr>
<tr>
<td>Easily Oxidizable Organic</td>
<td>%</td>
<td>2.5-10^2</td>
<td>ASTM D2974 AASHTO T194</td>
</tr>
<tr>
<td>Matter</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Determine pH by Method A for an onsite source and Methods A and B for imported topsoil. If the onsite source topsoil does not satisfy the specified pH range, achieve the desired pH by amending the soil as recommended by the certified agronomist’s report of soil sample analysis.

2. Soil testing company shall identify test method used if different from the specified. The Engineer must approve alternate test methods.

D. Topsoil shall have Liquid Limit <50 and Plasticity Index <20.

160.4 Topsoil Delivery, Storage and Handling. Deliver, stockpile and handle topsoil in such a way as to not contaminate the material with other soils or objectionable materials.

The stockpile or disposal site shall not be located within an environmentally sensitive area, floodway, wetland, or in “Waters of the United States”. If the stockpile or disposal site must be located in wetland as defined in the plans, then the County shall be responsible for ensuring that the appropriate Department of the Army permit has been obtained for the activity.

160.5 Construction Methods.

A. Strip topsoil as specified on the plans or as directed by the Engineer from area to be excavated or filled and stockpiled for use on the final grades and ditch slopes. Install and maintain proper Storm Water Pollution Prevention Plan Best Management Practices
Item 160 FOR PROJECTS INITIATED AFTER MAY 1, 2016
Page -3-
REVISION 7

(SWPPP BMPs) to stockpiled topsoil at no additional cost to Harris County.

B. Prior to placing topsoil, scarify or plow the subgrade to a minimum depth of 4 inches until it is loose and uncompacted to provide bonding of topsoil layer to subgrade. Remove vegetation and foreign inorganic material. Place topsoil on loosened material and roll lightly with appropriate lawn roller to consolidate topsoil.

C. The Contractor shall place the topsoil to the lines and grades and to the depths shown on the drawings.

D. Remove spilled topsoil from curbs, gutters, and paved areas and dispose of excess topsoil offsite.

E. Place topsoil to promote drainage and compact with light roller. Water topsoil after placement until saturated for minimum specified depth. Fill in and recompact any areas of settlement.

F. Do not place topsoil when it is excessively wet or dry.

G. If the topsoil excavated from the site will be utilized for the construction of wetlands, then the Contractor shall store the material in piles less than 5 feet in height to ensure the survivability of the existing seed bank.

H. Topsoil may be used as approved by the Engineer to meet the requirements of Item 132 “Embankment” for the top 4 inches of fill for unpaved areas of the project. When so utilized, it will be included as part of the embankment, volume and its placement will be incidental to the Item 110 “Roadway Excavation”, as is the embankment itself. Compaction of topsoil shall comply with the compaction requirements of this Item, and not Item 132.

160.6 Submittals Required. Contractor shall submit certification from their supplier that their topsoil meets the material requirements of Section 160.3.

The Contractor is required to submit the location of the pit(s) and a sample from which the material is to be taken, for the Engineer’s approval. The Contractor shall submit the vendor’s technical description of the topsoil.

160.7 Quality Control. The Engineer may question the quality of material at any stage of work or location if changes in characteristics are apparent.
160.8 Measurement. When topsoil has to be imported from sources other than the job site, topsoil shall be measured per square yard of specified depth furnished, delivered and placed, in accordance with these Standard Specifications. Topsoil placed in accordance with Section 160.5 above is considered as Embankment.

160.9 Payment. Payment for imported topsoil when shown in the plans shall be made at the contract unit price per square yard of specified depth of topsoil, which price shall be full compensation for all labor, materials, equipment and incidentals necessary to furnish, haul and place the topsoil.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 132 “Embankment”

END OF ITEM 160
ITEM 162

SODDING FOR EROSION CONTROL AND STABILIZATION

162.1 Description. This Item shall govern for providing and planting Bermuda grass, St. Augustine grass, or other acceptable sod along or across such areas as are designated on the drawings and in accordance with the specification requirements herein outlined.

162.2 Materials. The sod shall consist of living, growing Bermuda grass, St. Augustine grass, or other acceptable sod, (ninety-five percent pure), secured from sources where the soil is fertile and has been fumigated. The sod shall have a healthy virile root system of dense, thickly matted roots throughout. The sod shall be cut from the field so that there is a minimum of 1/2 inch of soil on the roots of the sod, and so that no roots show on the bottom of the soil. Sod shall be dense, with the grass having been mowed to 1 inch height before lifting from field. Sod shall be in a vigorous condition, dark green in color, free of disease and harmful insects. The Contractor shall not use sod from areas where the grass is thinned out, nor where the grass roots have been dried out by exposure to the air and sun to such an extent as to damage its ability to grow when transplanted. The sod shall be free from obnoxious weeds or other grasses and shall not contain any matter deleterious to its growth or which might affect its subsistence or hardiness when transplanted. Unless the area has been closely pastured, it shall be closely mowed and raked to remove all weeds and long-standing stems.

Care shall be taken at all times to retain the native soil on the roots of the sod during the process of excavation, hauling and planting. Sod material shall be kept moist from the time it is dug, until planted. When so directed by the Engineer, the sod existing at the source shall be watered to the extent required, prior to excavating. Do not stack sod for more than 36 hours between the time of cutting and the time of installation. The Engineer reserves the right to reject any sod deemed unacceptable for installation.

All planting shall be done between the average date of the last freeze in the spring and six weeks prior to the average date for the first freeze in the fall, according to the U.S. Weather Bureau.

Fertilizer shall conform to the requirements of the Item 166 "Fertilizer" and shall be applied at the rate of 480 pounds per acre.

162.3 Construction Methods. Immediately after the finished grade has been approved, begin sodding operations to reduce excessive weed growth. If
the sod bed is dry, immediately prior to sod installation, dampen the surface with a fine mist of water.

Grass shall be turf sod, cut into 16 inch strip widths for those areas behind a curb. All other areas can receive various cut widths and lengths.

All areas to be sodded shall be raked to true lines, free from all unsightly variations, bumps, ridges or depressions. All sticks, stones, roots or other objectionable material which might interfere with the formation of a finely pulverized sod bed, shall be removed from the soil.

Lay sod so that adjacent strips butt tightly, with no spaces between strips. Lay sod on mounds and slopes, with strips parallel to contours. Stagger joints. Sodded areas shall be flush with adjoining seeded areas. All sod shall, of course, be laid green side up. Tamp and roll the sod thoroughly to make contact with the sod bed, or as directed by the Engineer.

Peg sod on slopes three-to-one or steeper with pegs driven through sod into soil, until pegs are flush with the turf. Space pegs 18 inches on center. Pegs to be 1 inch square, 6 inches long or, 6 inch lengths of lath.

Commercial fertilizer as outlined in the Item 166 "Fertilizer" shall be applied to the entire sodded area at the prescribed rates, immediately following laying the sod. Immediately after fertilizing, water the entire area until a saturated depth of 2 inches has been reached. If rain is imminent, then the application of fertilizer shall be postponed until weather conditions exist such that the potential for the runoff of fertilizer from the site is minimized.

Immediately after installation of the sod, remove sod clumps, soil, and any plant material from roadways and pavements. Edges along curbs and drives, walkways, etc., shall be carefully trimmed and maintained until accepted.

In areas where sod is dead, satisfactory growth may be accomplished with application of seeding or hydromulch seeding in lieu of replacing the dead sod, only as approved by the Engineer. Costs for labor, materials, tools and equipment for the application of seeding or hydromulch seeding over dead sod shall be incidental to this pay item.

162.4 Contractor's Maintenance & Guarantee Period. It shall be the responsibility of the Contractor to maintain all sodded areas until satisfactory growth has occurred as determined by the Engineer and for a period of 60 days after the successful completion of all punch list items. Maintenance shall consist of watering, weeding, repairing of all erosion, and resodding as necessary to establish a uniform growth of the specified
grass. A minimum of 95 percent of the area planted shall be covered with the specified grass with no bare or dead spots greater than 10 square feet.

The Contractor shall be responsible for 1 mowing per month between the months of April to October. The Contractor shall also be responsible for 1 mowing every 6 weeks between the months of November to March.

In addition, the Contractor shall water all sodded areas as often as necessary to establish satisfactory growth and to maintain its growth throughout the duration of the project; including in the 60 day period described above.

Contractor shall make as many repeat plantings as necessary to achieve a minimum of 95 percent of the area planted covered with the specified grass with no bare or dead spots greater than 10 square feet. Such replanting is to be performed within 14 calendar days of notification by the Engineer.

162.5 Submittal Required. The Contractor shall submit a statement from the supplier attesting that the sod meets the requirements stated herein.

162.6 Measurement. Work and acceptable material for Sodding for Erosion Control and Stabilization shall be measured by linear feet (with standard width of 16 inches behind curb), or by the square yard (for various widths), complete in place.

162.7 Payment. Work performed and material furnished under "Measurement" shall be paid for at the unit price bid for "Sodding for Erosion Control and Stabilization", which price shall be full compensation for furnishing materials, preparation of ground for planting, planting of sod, pegging of sod, raking, fertilizing, watering, sprinkling, maintenance, mowing, and for labor, tools, equipment and incidentals necessary to complete the work. Additional payment shall not be made for those areas that are replanted.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications.

Item 166 "Fertilizer"
Item 725 "General Source Controls (SWPPP)"

END OF ITEM 162
ITEM 164

SEEDING AND EROSION CONTROL BLANKET

164.1 Description. This Item shall govern for preparing the ground, sowing of seeds, applying a fertilizer, and stabilizing with a mulch, mat, or mesh consisting of straw, hay, wood, coir, paper, or other biodegradable fibers along and across such areas as are designated on the plans and in accordance with these Standard Specifications.

164.2 Material. Seed shall comply with the (Texas) Agriculture Code, Title 5, Subtitle A, Chapter 62 “Seed and Plant Certification”, Sections 62.009, 62.010, 621.011 and the U. S. Department of Agriculture Rules and Regulations – Federal Seed Act. Seed bags shall have tags affixed for inspection in the field. Bags without tags will be rejected. Seed shall be tested and certified by a commercial or state laboratory not more than nine (9) months prior to the date of planting. Tags on seed bags shall show the name of the seed, locality and year of harvest, percentage purity, germination and dormant seed, Johnson grass content and noxious weed content. Seed shall be provided in clean, unopened and undamaged bags. Seed shall be provided with no objectionable material, such as sticks, stems and unthrashed seed heads, which will hinder proper distribution. Seed that is wet, moldy, starting to germinate or otherwise damaged, will not be accepted by Harris County.

Standard seed plan, planting dates, plant species and planting rates shall be as indicated in Table 1:

<table>
<thead>
<tr>
<th>SEED PLAN</th>
<th>PLANTING DATES¹</th>
<th>SPECIES</th>
<th>PLANTING RATE PER ACRE</th>
</tr>
</thead>
</table>
| 1         | Oct. 1- March 31 (When soil temperatures fall below 75°F, or as directed) | Unhulled Bermuda Grass  
Tall Fescue  
&  
Durana Clover  
Crimson Clover | 50 lbs.  
25 lbs.  
5 lbs.  
5 lbs. |
<table>
<thead>
<tr>
<th>SEED PLAN</th>
<th>PLANTING DATES¹</th>
<th>SPECIES</th>
<th>PLANTING RATE PER ACRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>April 1-Sept. 30 (When soil temperatures rise above 65°F, or as directed)</td>
<td>Certified Bermuda Grass² or Common Bermuda Grass, minimum purity/germination of 95/85 Millet</td>
<td>50 lbs. or 50 lbs. PLS³</td>
</tr>
<tr>
<td>3</td>
<td>As directed</td>
<td>Certified Bermuda Grass² or Hulled Bermuda Grass, minimum purity/germination 95/85 and Pensacola Bahia Grass Brown Top or Fox Tail Millet</td>
<td>50 lbs. or 50 lbs. PLS³ and 20 lbs.</td>
</tr>
<tr>
<td>5</td>
<td>As directed</td>
<td>Annual Ryegrass &amp; Fescue or Millet</td>
<td>25 lbs. each</td>
</tr>
<tr>
<td>6</td>
<td>As directed</td>
<td>Improved Bermuda Grass Cultivars</td>
<td>50 lbs.</td>
</tr>
<tr>
<td>7</td>
<td>As directed</td>
<td>Legume or Grain</td>
<td>20 lbs.</td>
</tr>
</tbody>
</table>

1. Planting dates are approximate; Harris County will determine which seed to use prior to start of seeding.
2. Certified Bermuda Grass must have a Blue Tag and tested by an accredited seed testing lab.
3. Seeding rate for "Pure Live Seed" (PLS) is used to determine the actual application rate of bulk material to apply.
   a. Calculate PLS: \( \text{PLS} = (\% \text{ germination} \times \% \text{ purity}) \times 0.95 \times 0.85 = 0.807 \) PLS
   b. Calculate quantity: \( \text{Rate} \div \text{PLS} = \text{lbs. of seed needed for application} \)
      \( 50 \text{ lbs.} \div 0.807 = 61.95 \text{ lbs. of seed needed per acre} \)

164.3 Fertilizer. Commercial fertilizer as outlined in the Item 166 “Fertilizer”, shall be applied to the entire seeded area at the prescribed rates. The fertilizer shall be delivered to the site in bags or other convenient containers, each fully labeled, conforming to the applicable State Fertilizer Laws and bearing the name and warranty of the producer.

164.4 Straw Mulch. Straw mulch shall be oat, wheat, or rice straw. Hay mulch shall be prairie grass, Bermuda grass, oat, wheat or rice stems or other hay as approved by the Engineer. Do not use straw containing Johnson
grass or other noxious weeds and foreign materials. The mulch shall be kept in a dry condition and shall not be molded or rotted.

164.5 Fiber Mat. Fiber mat shall consist of machine produced woven mat of wood, coir, straw, or a combination of various biodegradable fibers as approved by the Engineer, with consistent thickness throughout the blanket. The fiber mat shall have a mesh or netting for support. The mesh or netting shall be biodegradable or photo-degradable and have a high wet strength. The mat shall not contain any weed seeds. Use blanket with a weight from 0.7 pounds per square yard to 1.0 pound per square yard. The mat shall be free of defects, rips, holes, flaws, deterioration, mold, rot, or damage.

Material type, size, shape, and spacing of wire staples, or fasteners, shall be in accordance with the recommendations of the manufacturer of the fiber mat erosion control blanket.

164.6 Paper Mesh. Use paper mesh consisting of knitted construction of yarn with uniform openings interwoven with strips of biodegradable paper, furnished in rolls which have suitable protection for outdoor storage. Use paper mesh of weight from 0.2 pounds per square yard to approximately 0.5 pounds per square yard. The mesh shall be free of defects, rips, holes, flaws, deterioration, mold, rot, or damage.

Material type, size, shape, and spacing of wire staples, or fasteners, shall be in accordance with the recommendations of the manufacturer of the paper mesh erosion control blanket.

164.7 Construction Methods.

A. General

Fertilizing & Seeding. After areas to receive fertilizing and seeding have been completed to the lines, grades and sections shown on the plans, apply fertilizer at the prescribed rates as outlined in the Item 166 “Fertilizer”. Thoroughly mix upper 3 inches of top soil with fertilizer until a uniform mixture of fertilizer and top soil is obtained. Sprinkle areas to be seeded with water, using fine spray to avoid washing or erosion of soil. Broadcast seed with sowing equipment at the rate specified above, using care to obtain uniform distribution. After broadcasting, lightly rake seeds into soil to a depth not to exceed 1/2 inch. Complete seeding by rolling with roller developing 15 to 25 pounds per inch of tread.

After applying seed and fertilizer, apply straw mulch, fiber mat, or paper mesh as described in the following sections. Keep seeded
areas moist for a period of 10 days immediately following placement and as necessary to meet Contractor’s maintenance and guarantee period. When watering seeded areas, use fine spray to prevent erosion of seeds or soil. Reseed any areas damaged by erosion and as necessary to obtain a satisfactory growth as determined by the Engineer.

If rain is imminent, then seeding and fertilization shall be postponed until weather conditions exist such that the potential for the runoff of fertilizer from the site is minimized. If high wind conditions exist then the subsequent application of the straw mulch, fiber mat, or paper mesh erosion control blanket shall be postponed until weather conditions exist such that the blanket can be installed properly.

B. Straw Mulch Erosion Control Blanket

1. Fertilizing & Seeding. After ditch or slope has been completed to lines, grades and cross-sections shown on the plans, apply fertilizer and seed in accordance with the above. When seed and fertilizer are to be distributed as water slurry, mixture is to be applied within 30 minutes after all components are placed in the equipment.

2. Mulch Application. Immediately upon completion of planting of seed and fertilizing, spray straw mulch uniformly over the area at the rate of 1-1/2 to 2 tons of hay or 2-1/2 tons of straw per acre. Mulching machine shall inject tacking agent into straw uniformly as it leaves the equipment at the rate of 0.05 to 0.10 gallons of tacking agent per square yard of mulched area. When watering seeded areas, use fine spray to prevent erosion of seeds or soil. Reseed any areas damaged by erosion for any reason. The mulching operation shall immediately follow seeding and fertilizing as a continuous operation.

C. Fiber Mat or Paper Mesh Erosion Control Blanket

1. Fertilizing and seeding shall be in accordance with the above.

2. Fiber Mat or Paper Mesh Installation. Place fiber mat or paper mesh within 24 hours after seeding operations have been completed. Prior to placing, clear the area to be covered of all rocks or clods over 1-1/2 inches in diameter and all sticks or other foreign material which will prevent
close contact of the blanket with the soil. Area shall be smooth and free of ruts or other depressions.

If as a result of a rain, prepared seed bed becomes crusted or eroded, or if eroded places, ruts or depressions exist for any reason, rework soil until smooth and reseed such areas. After area has been properly prepared, lay fiber mat or paper mesh flat, smooth and loosely without stretching or crimping material. Lay mat according to manufacturer’s recommendations, generally with the mesh or netting on the top side.

Apply materials with lengths running parallel to the flow of water, or as shown on the plans or as directed by the Engineer. When more than one width is required, butt or overlap edges as required by the manufacturer. In general, for overlaps, the top edge shall overlap the bottom edge to match the direction of the flow of water, not against it.

Hold the material in place by means of a wire staple driven into the soil at an angle to the surface. Staple material along each edge and in a grid pattern with a minimum of 3 feet on center each way. In ditches and on slopes, provide additional stapling as recommended by the manufacturer.

The placement of the fiber mat or paper mesh erosion control blanket shall immediately follow the preparation of the ground.

164.8 Contractor Maintenance & Guarantee Period. It shall be the responsibility of the Contractor to maintain all seeded and erosion control blanket areas until satisfactory growth has occurred as determined by the Engineer, and for a period of 60 days after the successful completion of all punch list items. Maintenance shall consist of watering and weeding, repair of all erosion and any reseeding as necessary to establish a uniform stand of the specified grasses. A minimum of 95 percent of the area seeded shall be covered with the specified grass with no bare or dead spots greater than 10 square feet.

The Contractor shall be responsible for 1 mowing per month between the months of April to October. The Contractor shall also be responsible for 1 mowing every 6 weeks between the months of November to March. In addition, the Contractor shall water all grassed areas as often as necessary to establish satisfactory growth and to maintain its growth throughout the duration of the project.
The Contractor shall make as many repeat seedings as necessary to achieve a minimum of 95 percent of the area planted covered with the specified grass with no bare or dead spots greater than 10 square feet. Such replanting is to be performed within 14 calendar days of notification by the Engineer.

164.9 Submittal Required. The Contractor shall submit copy of seed tag(s) and letter from the supplier attesting that the seed meets the requirements as stated herein. Certification shall include common name; botanical name, percent by weight of each plant species; year of harvest; percent purity, germination and dormant seed; percent noxious weed content; and date of certification.

164.10 Measurement & Payment. Measurement shall be by the acre or square yard of prepared area underlying the erosion control blanket. Payment for work under this Item to be made at the contract price for “Seeding and Erosion Control Blanket”, with price to be full compensation for the materials, tools, equipment, and labor necessary for preparing the area (including fine grading and rolling), seeding, fertilizing, placing and securing the fiber mat, and watering. Additional payment shall not be made for those areas that are repaired or reseeded.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications.

Item 166 “Fertilizer”
Item 725 “General Source Controls (SWPPP)”

END OF ITEM 164
ITEM 165

HYDRO-MULCH SEEDING
( FOR EROSION CONTROL AND STABILIZATION )

165.1 Description. This Item shall govern for furnishing all labor, materials, equipment, supplies, supervision and tools and performing all work necessary to:

A. seed,  
B. fertilize,  
C. water, 
D. maintain, and  
E. cleanup of side slopes and finished grades, 

in accordance with these Standard Specifications, for the purpose of temporary erosion control or final stabilization.

The hydro-mulch seeding operations, together with all necessary related work, shall conform to the requirements specified in this section. The area(s) to be hydro-mulch seeded shall be as shown on the construction drawings.

165.2 Materials. Seed shall comply with the U. S. Department of Agriculture Rules and Regulations – Federal Seed Act. Seed bags shall have tags affixed for inspection in the field. Bags without tags will be rejected. Seed shall be tested and certified by a commercial or state laboratory not more than nine (9) months prior to the date of planting. Tags on seed bags shall show the name of the seed, locality and year of harvest, percentage purity, germination and dormant seed, Johnson grass content and noxious weed content. Seed shall be provided in clean, unopened and undamaged bags. Seed(s) shall be provided with no objectionable material, such as sticks, stems and unthrashed seed heads, which will hinder proper distribution. Seed that is wet, moldy, starting to germinate or otherwise damaged, will not be accepted by Harris County.

Standard seed plan, planting Dates, plant species and seeding rate are as shown on Table 1:
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<tr>
<th>SEED PLAN</th>
<th>PLANTING DATES¹</th>
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<th>PLANTING RATE PER ACRE</th>
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<tbody>
<tr>
<td>1</td>
<td>Oct. 1- March 31 (When soil temperatures fall below 75°F, or as directed)</td>
<td>Unhulled Bermuda Grass, Tall Fescue, and Durana Clover, Crimson Clover</td>
<td>50 lbs. 25 lbs. 5 lbs. 5 lbs.</td>
</tr>
<tr>
<td>2</td>
<td>April 1-Sept. 30 (When soil temperatures rise above 65°F, or as directed)</td>
<td>Certified Bermuda Grass² or Common Bermuda Grass, minimum purity/germination of 95/85 Millet</td>
<td>50 lbs. or 50 lbs. PLS³</td>
</tr>
<tr>
<td>3</td>
<td>As directed</td>
<td>Certified Bermuda Grass² or Hulled Bermuda Grass, minimum purity/germination 95/85 and Pensacola Bahia Grass, Brown Top or Fox Trail Millet</td>
<td>50 lbs. or 50 lbs. PLS³</td>
</tr>
<tr>
<td>5</td>
<td>As directed</td>
<td>Annual Ryegrass and Fescue, or Millet</td>
<td>25 lbs. each</td>
</tr>
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<td>As directed</td>
<td>Improved Bermuda Grass Cultivars</td>
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</tr>
<tr>
<td>7</td>
<td>As directed</td>
<td>Legume or Grain</td>
<td>20 lbs.</td>
</tr>
</tbody>
</table>

1. Planting dates are approximate. Harris County will determine which seed to use prior to start of seeding.
2. Certified Bermuda Grass must have a Blue Tag and tested by an accredited seed testing lab.
3. Seeding rate for “Pure Live Seed” (PLS) is used to determine the actual application rate of bulk material to obtain.
   a. Calculate PLS: \( \text{PLS} = (\% \text{ germination} \times \% \text{ purity}) \)
      \[ 0.95 \times 0.85 = 0.807 \text{ (80.7\%)} \] PLS
   b. Calculate quantity: \( \text{Rate} \div \text{PLS} = \text{lbs. of seed needed for application} \)
      \[ 50 \text{ lbs.} \div 0.807 = 61.95 \text{ lbs. of seed needed per acre} \]
Commercial fertilizer as outlined in the Item 166 “Fertilizer”, shall be applied to the entire seeded area at the prescribed rates. The fertilizer shall be delivered to the site in bags or other convenient containers, each fully labeled, conforming to the applicable State Fertilizer Laws and bearing the name and warranty of the producer.

Mulch shall be virgin wood cellulose fiber made from whole wood chips. Rate of application shall be 2000 pounds per acre. Soil stabilizers shall be applied at a rate of 40 pounds per acre. On side slopes Terra Type III (or approved equal) shall be used. On all other areas Terra Tack I (or approved equal) shall be used. Alternatively, Ultra Bond 2002 (or approved equal) shall be applied at a rate of one gallon per square yard in three applications. First application shall be at a rate of 1/2 gallon per square yard followed by another application in about two weeks at a rate of 1/4 gallon per square yard. The third application shall follow in about two months at a rate of 1/4 gallon per square yard. The concentrate shall be diluted in 1:5 ratio with water or as recommended by the manufacturer.

Wood cellulose fiber mulch, for use in the grass seed and fertilizer, shall be processed in such a manner that it will not contain any germination or growth inhibiting factors. It shall be dyed an appropriate color to allow visual metering of its application. The wood cellulose fibers shall have the property of becoming evenly dispersed and suspended when agitated in water. When sprayed uniformly on the surface of the soil, the fibers shall form a blotter-like ground cover which readily absorbs water and allows infiltration to the underlying soil. Weight specifications from suppliers, shall refer only to the air dry weight of the fiber. The mulch material shall be supplied in packages having a gross weight not greater than 100 pounds and must be marked by the manufacturer to show the dry weight content. Suppliers shall be prepared to certify that laboratory and field testing of their product has been accomplished and that it meets all of the preceding requirements.

Water shall be free from oil, acid, alkali, salt and other substances harmful to the growth of grass. The water source shall be subject to approval, prior to use.

165.3 Execution. Immediately after the finished grade has been approved, begin hydro-mulching operations to reduce erosion and excessive weed growth.

Hydraulic equipment used for the application of fertilizer, seed and slurry of prepared wood fiber mulch shall have a built-in agitation system with an operating capacity sufficient to agitate, suspend and homogeneously mix a slurry containing up to 40 pounds of fiber plus a combined total of 70 pounds of fertilizer solids for each 100 gallons of water. The slurry
distribution lines shall be large enough to prevent stoppage. The discharge line shall be equipped with a set of hydraulic spray nozzles which provide even distribution of the slurry on the area to be seeded. The slurry tank shall have a minimum capacity of 800 gallons and shall be mounted on a traveling unit, which may either be self-propelled or drawn with a separate unit which will place the slurry tank and spray nozzles within sufficient proximity to the areas to be seeded, so as to provide uniform distribution without waste. The Engineer may authorize equipment with a smaller tank capacity, provided the equipment has the necessary agitation system and sufficient pump capacity to spray the slurry in a uniform coat.

Slurry preparation shall take place on the worksite. The slurry preparation should begin by adding water to the tank when the engine is at half throttle. When the water level has reached the height of the agitator shaft, good re-circulation shall be established and seed shall be added. Fertilizer shall then be added, followed by wood pulp mulch. The wood pulp mulch shall only be added to the mixture after the seed and when the tank is at least one-third filled with water. The engine throttle shall be opened to full speed when the tank is half filled with water. All the wood pulp mulch shall be added by the time the tank is two-thirds to three-fourths full. Spraying shall commence immediately when the tank is full. The operator shall spray the area with a uniform visible coat, by using the green color of the wood pulp as a guide.

165.4 Application. The Contractor shall obtain approval of hydro-mulch area preparation from the Engineer prior to application. If rain is imminent, then the application of hydromulch seeding and fertilizer shall be postponed until weather conditions exist such that the potential for the runoff of the slurry and fertilizer from the site is minimized.

Operators of hydro-mulching equipment shall be thoroughly experienced in this type of application. Apply the specified slurry mix to form a uniform mat at the specified rate. The Contractor shall avoid getting the hydromulch on paved areas. Keep paved and planting areas clean during maintenance operations. Contractor shall confine hydro-mulching within the areas designated on the plans and keep it from contact with other plant material. Immediately after application, thoroughly wash off any plants, planting areas or paved areas not intended to receive slurry mix.

If the Engineer notes any unmulched areas after hydro-mulching, the Contractor shall be required to seed the unmulched areas with the grasses that were to have been planted at no additional cost to Harris County.
165.5 Contractor's Maintenance & Guarantee Period. It shall be the responsibility of the Contractor to maintain all hydromulch seeded areas until satisfactory growth has occurred as determined by the Engineer and for 60 days after the successful completion of all punch list items. Maintenance shall consist of watering, weeding, repairing of all erosion, and reseeding, as necessary to establish a uniform stand of the specified grasses. A minimum of 95 percent of the area seeded shall be covered with the specified grass with no bare or dead spots greater than 10 square feet. The Contractor shall make as many repeat seedings as necessary to achieve the required level of coverage. Such reseeding is to be performed within 14 calendar days of notification by the Engineer.

The Contractor shall be responsible for 1 mowing per month in the months of April through October. The Contractor shall also be responsible for 1 mowing every 6 weeks in the months of November through March. In addition, the Contractor shall water all grassed areas as often as necessary to establish satisfactory growth and to maintain its growth throughout the duration of the project; including the 60 day period after the punch list is completed as described above.

165.6 Submittal Required. The Contractor shall submit copy of seed tag(s) and letter from the supplier attesting that the seed meets the requirements as stated herein. Certification shall include common name; botanical name, percent by weight of each plant species; year of harvest; percent purity, germination and dormant seed; percent noxious weed content; and date of certification. The Contractor shall certify on the application of the project.

165.7 Measurement. The unit of measurement for all work performed and materials furnished, as described herein, shall be by the acre or per station as indicated in the bid documents. Measurement shall be done upon completion of the work performed within the limits shown on the drawings and as described herein. The area measured for payment will be computed to the nearest 1/10 acre or station.

165.8 Payment. Payment for hydro-mulch seeding will be made at the contract unit price per acre or per station and includes final grading, mulch, seed, fertilizer, watering, maintenance and clean-up. Additional payment shall not be made for those areas that are reseeded as provided in Section 165.5 above.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications.
Item 166 “Fertilizer”
Item 725 “General Source Controls (SWPPP)"

END OF ITEM 165
ITEM 166

FERTILIZER

166.1 Description. This Item shall govern for providing and distributing fertilizer over such areas as are designated for sodding for erosion control and stabilization, hydro-mulch seeding, or seeding and erosion control blanket and in accordance with these Standard Specifications.

166.2 Materials. All fertilizer used shall be delivered in bags or containers clearly labeled showing analysis. A pelleted or granulated fertilizer shall be used with an analysis of 10-10-5 (nitrogen – phosphoric acid – potash), unless otherwise approved by the Engineer. The figures in the analysis represent the nitrogen, phosphoric acid and potash nutrients respectively as determined by the methods of the Association of Official Agricultural Chemists. The sources of nitrogen in the fertilizer shall be roughly balanced between ammonical (quick release) and nitrate nitrogen (slow release). Fertilizer shall be readily water-soluble.

Fertilizer of a different analysis may be substituted as approved by the Engineer. It shall be pelleted or granulated fertilizer with a lower concentration. The total amounts of nutrients furnished and applied per acre shall equal or exceed that specified for each nutrient.

166.3 Construction Methods. When fertilizer is included in the specifications, pelleted or granulated fertilizer shall be applied uniformly over the area specified to be fertilized and in the manner directed for the particular item of work. Fertilizer shall be dry and in good physical condition. Fertilizer that is powdered or caked will be rejected. Distribution of fertilizer for the particular item of work shall meet the approval of the Engineer.

Unless otherwise indicated on the plans, fertilizer shall be applied uniformly at the average rate of 480 pounds per acre for the Item 162 "Sodding for Erosion Control and Stabilization", 400 pounds per acre for the Item 164 "Seeding and Erosion Control Blanket" and for the Item 165 "Hydro-Mulch Seeding for Erosion Control and Stabilization".

166.4 Delivery, Storage and Handling. Deliver fertilizer in bags or containers clearly labeled with name and address of the manufacturer, weight and guaranteed analysis. Bulk fertilizer, if approved by the Engineer, must be accompanied by either an invoice or label showing the name and address of the manufacturer, guaranteed analysis, and appropriate means to accurately measure and record weight of fertilizer used.

Deliver fertilizer in clean, unopened and undamaged bags.
166.5 Measurement. Acceptable material for "Fertilizer" will be measured by pounds of guaranteed weight of sacks shown by manufacturer.

166.6 Payment. If the fertilizer is being utilized as part of construction project, no separate payment shall be made for materials furnished or work performed under this Item. Include the cost of the same in the contract price bid for work of which this is a component part.

If this Item is being utilized for material procurement, in which fertilizer is not already a requirement of another bid item, payment shall be made by the pound of guaranteed sack weight shown by manufacturer.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications.

Item 162 "Sodding for Erosion Control and Stabilization"
Item 164 "Seeding and Erosion Control Blanket"
Item 165 "Hydro-Mulch Seeding (for Erosion Control and Stabilization)"
Item 725 "General Source Controls (SWPPP)"

END OF ITEM 166
200 ITEMS

- 200 – Stripping
- 205 – Subgrade
- 220 – Lime Stabilized Subgrade
- 221 – Hydrated Lime and Lime Slurry
- 222 – Portland Cement Stabilized Subgrade
- 223 – Lime-Fly Ash or Fly Ash Stabilized Subgrade
- 224 – Quicklime (Stabilization)
- 230 – Crushed Aggregate Base Course
- 231 – Cement Stabilized Crushed Aggregate Base Course
- 250 – Hot Mix Asphaltic Concrete Base Course (Black Base)
- 251 – Base Repair with Hot Mix Asphaltic Concrete Base Course
- 252 – In-Place Full Depth Cold Flexible Pavement Recycling
ITEM 200

STRIPPING

200.1 Description. This Item shall govern stripping of existing topsoil to approximately 3 inches depth or as shown on the drawings and disposing of the stripped material off-site. Within the limits indicated, or in areas where existing grade is to be altered either by excavation or embankment, the Contractor shall strip existing topsoil to approximately 3 inches depth or as shown on the drawings and dispose of it at the Contractor's expense. Stripping shall include the removal and disposal of scrap iron, rubbish, logs, abandoned utilities, abandoned signs, and any and all other debris, if within the right-of-way or designated easements, whether above or below existing grade. Field cross-sections will no longer be obtained.

200.2 Construction Methods. The stripped material shall be removed as designated below regardless of the project area to be excavated or receive embankment. Strippings are unsuitable material and shall not be considered for use in the future construction. The strippings and any other unsatisfactory material shall be removed and disposed of outside the right-of-way, by the Contractor. No strippings shall be used in median or in areas from back-of-curb to R.O.W. Proper Storm Water Pollution Prevention Best Management Practices shall be applied to stripped areas.

When disposing of strippings and waste, off site, the Contractor shall not place the material in an "environmentally sensitive area, floodway or 'Water of the United States', including adjacent wetland", as defined in the Clean Water Act and the Rivers and Harbors Act, unless he has previously obtained the appropriate Department of the Army Permit authorizing the activity. If the stockpile or disposal site is defined in the plans, then the County shall be responsible for ensuring that the appropriate Department of the Army permit has been obtained for the activity.

200.3 Measurement & Payment. Stripping and any associated stockpiling, or disposal will not be paid for directly. Payment for stripping shall be incidental to excavation, borrow or embankment.

There are no line codes for this Item.

NOTE: This Item requires other Standard Specifications

Item 110 “Roadway Excavation”
Item 130 “Borrow”
Item 132 “Embankment”

END OF ITEM 200
ITEM 205

SUBGRADE

205.1 Description. This Item shall govern the proof rolling and compaction of the subgrade for pavements. When the road is to be surfaced or paved and after the earthwork has been substantially completed and after all storm sewer and drains have been laid, the subgrade shall be brought to the lines, grades and typical cross-section shown on the plans and in accordance with these Standard Specifications.

205.2 Construction Methods. After stripping, the Contractor shall proof roll the subgrade, i.e. verify that the subgrade is firm and able to support construction equipment and correct any soft or yielding areas by:

A. scarifying and aerating,

B. replacing unsuitable material with suitable material from the project site, or borrow as per Item 130 “Borrow” and authorized by the Engineer,

C. stabilization, etc.

Proof rolling equipment shall meet the requirements of Item 216 “Proof Rolling” of the Texas Department of Transportation’s “Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges”, Latest Edition.

Whenever unsuitable natural material is encountered below the top of subgrade elevation and cannot be economically amended to make it suitable, then the following requirements shall apply:

A. The unsuitable material shall be excavated to a depth deemed sufficient by the Engineer and the excavated material shall be disposed of legally outside the project limits as per Item 110.

B. The excavated area shall be filled to its original level with suitable material from the project site; or borrow as per Item 130 as directed by the Engineer. The fill material shall be compacted to 95 percent of standard proctor density in accordance with ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))”, using a moisture content between optimum and plus/minus 3 percent of optimum.

All holes and depressions shall be filled with approved material.
Stabilized Subgrade. If the subgrade is to be stabilized, refer to the appropriate Standard Specification Item for additional construction requirements.

Unstabilized Subgrade. If the subgrade is not to be stabilized, it shall be compacted to 95 percent of standard proctor density in accordance with ASTM D698, using a moisture content between optimum and plus/minus 3 percent of optimum. Any subgrade, without stabilization, shall be compacted to a minimum depth of 9 inches. The subgrade shall be brought to the lines and grades required.

The subgrade shall be kept free from all ruts and weak spots. Any ruts and weak spots that develop under construction traffic shall be repaired with suitable material as they develop.

205.3 Quality Assurance. The Testing Laboratory’s representative shall determine the Moisture-Density Relationship in accordance with ASTM D698, on material secured from the roadway or borrow source, for each type of material encountered or used.

The Testing Laboratory’s representative shall determine the in-place density in accordance with ASTM D6938, “Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)” or ASTM D1556, “Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.” The minimum level of testing shall consist of the following:

A. at least one test per station per lane of roadway.

B. a lane is defined as 12’ wide section of pavement regardless of its use.

205.4 Measurement and Payment. The work prescribed under this Item, shall not be paid for directly, but shall be considered as subsidiary work of the Item 110 “Roadway Excavation” and/or Item 130 “Borrow”.

There are no line codes for this Item.

NOTE: This Item requires other Standard Specifications

Item 110 “Roadway Excavation”
Item 130 “Borrow”

END OF ITEM 205
ITEM 220

LIME STABILIZED SUBGRADE

220.1 Description. Mix and compact lime, water and subgrade in the roadway.

220.2 Materials. Furnish uncontaminated lime of uniform quality that meets the requirements of the plans and specifications. Notify the Engineer in writing of the proposed lime source and of any proposed change in lime source. The Contractor shall obtain verification from the Engineer that the specification requirements are met before using the lime source. The Engineer may sample and test lime or lime/subgrade mixture at any time before compaction.

A. Lime. Furnish lime that meets the requirements of TxDOT’s DMS-6350 “Lime and Lime Slurry,” and DMS-6330, “Lime Sources Prequalification of Hydrated Lime and Quicklime.” Use hydrated lime slurry as shown on the plans.

B. Water. Furnish water free of industrial wastes and other objectionable material.

C. Asphalt. When permitted for curing purposes, furnish asphalt or emulsion in accordance with TxDOT’s Item 300, “Asphalts, Oils, and Emulsions,” as shown on the plans or as directed.

D. Mix Design. The Engineer shall determine the target lime content and optimum moisture content in accordance with ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft$^3$ (600 kN-m/m$^3$))” or based upon prior experience with the project materials. The Contractor may propose an alternative mix design developed in accordance with ASTM D698. The Engineer shall use ASTM D698 to verify the Contractor’s proposed mix design before accepting it. The Contractor shall reimburse the County for any and all expenses incurred due to a request by the Contractor to change of mix designs or partial designs, material sources, etc. whether they are approved or not.

220.3 Equipment. Provide machinery, tools, and equipment necessary for proper execution of the work. Provide rollers in accordance with TxDOT’s Item 210 “Rolling.” Provide proof rollers in accordance with TxDOT’s Item 216 “Proof Rolling” when directed.
A. Slurry Equipment. Use slurry tanks equipped with agitation devices to slurry hydrated lime at the jobsite or any other approved location. The Engineer may approve other slurring methods. Provide a pump for agitating the slurry when the distributor truck is not equipped with an agitator. Equip the distributor truck with a sampling device in accordance with Tex-600-J, Part I, when using commercial lime slurry.

B. Pulverization Equipment. Provide pulverization equipment that:

1. cuts and pulverizes material uniformly to the proper depth with cutters that plane to a uniform surface over the entire width of the cut,

2. shows a visible indication of the depth of cut at all times, and

3. mixes the materials uniformly.

220.4 Construction. Construct each layer uniformly, free of loose or segregated areas, and with the required density and moisture content. Provide a smooth surface that conforms to the typical sections, lines, and grades shown on the plans or as directed.

A. Preparation of Subgrade for Treatment. Shape the subgrade in accordance with Item 205 “Subgrade”, and applicable bid items to conform to typical sections shown on the plans and as directed. The Contractor shall pulverize or scarify the existing raw subgrade sufficiently to allow penetration of the lime to the required depth.

B. Pulverization. The Contractor shall pulverize or scarify the existing raw subgrade to allow penetration of the lime to the required depth.

C. Application of Lime. Uniformly apply lime using slurry placement as shown on the plans or as directed. Add lime at the percentage determined in Section 220.2.D, “Mix Design” above. Apply lime only on an area where mixing can be completed during the same working day.

Start lime application only when the air temperature is at least 35°F and rising or is at least 40°F. The temperature shall be taken in the shade and away from artificial heat. Suspend application when the Engineer determines that weather conditions are unsuitable.

Slurry Placement. Provide slurry free of objectionable materials, at or above the approved minimum dry solids content, and with a uniform consistency that shall allow ease of handling and uniform
application. Deliver commercial lime slurry to the jobsite or prepare lime slurry at the jobsite, or other approved location, by using hydrated lime as specified.

Distribute slurry uniformly by making successive passes over a measured section of subgrade until the specified lime content is reached.

D. Mixing. Begin mixing within 6 hours of application of lime. Hydrated lime exposed to the open air for 6 hours or more between application and mixing, or that experiences excessive loss due to washing or blowing, shall not be accepted for payment.

Thoroughly mix the subgrade and lime using approved equipment. Allow the mixture to mellow for 1 to 4 days, as directed. Sprinkle the treated materials during the mixing and mellowing operation, as directed, to achieve adequate hydration and proper moisture content. After mellowing, resume mixing until a homogeneous, friable treated subgrade is obtained.

After mixing, the Engineer shall sample the mixture at roadway moisture and test in accordance with Tex-101-E, Part III to determine compliance with the gradation requirements in Table 1.

| TABLE 1 |
|------------------|------------------|------------------|------------------|------------------|------------------|
| SIEVE SIZE       | TREATED SUBGRADE | SIEVE SIZE       | TREATED SUBGRADE | SIEVE SIZE       | TREATED SUBGRADE |
| 1-3/4 Inch       | 100              | 3/4 Inch         | 85               | No.4             | 60               |

E. Compaction. Compact the treated subgrade using density control. Multiple lifts are permitted when shown on the plans or approved. Bring each layer to the moisture content directed. When necessary, sprinkle the treated subgrade as directed. Determine the moisture content of the treated subgrade at the beginning and during compaction in accordance with ASTM D698.

Begin rolling longitudinally at the sides and proceed toward the center, overlapping on successive trips by at least one-half the width of the roller unit. Offset alternate trips of the roller. Operate rollers at a speed between 2 and 6 MPH, as directed.
Rework, recompact, and refinish treated subgrade that fails to meet or that loses required moisture, density, stability, or finish before the next layer is placed or the project is accepted. Continue work until specification requirements are met. Rework in accordance with Section 220.4.F, “Reworking a Section” below. Perform the work at no additional expense to the County.

The Testing Laboratory shall determine treated subgrade density of completed sections in accordance with ASTM D6938 “Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).” The minimum level of testing shall consist of the following:

1. at least one test per station per lane of roadway.

2. a lane is defined as 12’ wide section of pavement regardless of its use.

Compact to at least 95% of the maximum density as determined in accordance with ASTM D698, unless otherwise shown on the plans.

F. Reworking a Section. When a section of lime treated subgrade is reworked within 72 hours after completion of compaction, rework the section to provide the required density. When a section is reworked more than 72 hours after completion of compaction, add additional lime at 25% of the percentage determined in Section 220.2.D, “Mix Design” at no additional cost to the County. Reworking includes loosening, adding lime or removing unacceptable treated subgrade if necessary, mixing as directed, compacting, and finishing. Determine a new maximum density of the reworked treated subgrade in accordance with ASTM D698, and compact to at least 95% of this density.

G. Finishing. Immediately after completing compaction of the final layer of lime treated subgrade, clip, skin, or tight-blade the surface to a depth of approximately ¼ in. Remove the clipped material and dispose of it at an approved location. Roll the clipped surface immediately with a pneumatic tire roller until a smooth surface is attained. Add small amounts of water as needed during rolling. Shape and maintain the layer and surface in conformity with the typical sections, lines, and grades shown on the plans or as directed. The treated subgrade shall be finished within the tolerances required by TxDOT’s Item 132.3.6.1, “Grade Tolerances.”
H. Curing. Cure for the minimum number of days shown in Table 2 by sprinkling as per TxDOT’s Item 204 “Sprinkling”, or by applying an asphalt material at a rate of 0.05 to 0.20 gal. per square yard as directed. Maintain moisture content during curing. Upon completion of curing, maintain the moisture content in accordance with TxDOT’s Item 132.3.5, “Maintenance of Moisture and Reworking” for treated subgrade prior to placing subsequent courses. Do not allow equipment on the finished layer during curing except as required for sprinkling, unless otherwise approved. Apply seals or additional layers or surface course within 14 calendar days of final compaction.

**TABLE 2**

MINIMUM CURING REQUIREMENTS BEFORE PLACING SUBSEQUENT LAYERS

<table>
<thead>
<tr>
<th>ORIGINAL (UNTREATED) SUBGRADE PI</th>
<th>CURING (DAYS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI ≤ 35</td>
<td>2</td>
</tr>
<tr>
<td>PI &gt; 35</td>
<td>5</td>
</tr>
</tbody>
</table>

1. Subject to the approval of the Engineer. Proof rolling may be required as an indicator of adequate curing.

220.5 Measurement.

A. Lime. When lime is furnished in trucks, the weight of lime shall be determined on certified scales.

When lime is furnished in bags, indicate the manufacturer’s certified weight. Bags varying more than 5% from that weight may be rejected. The average weight of bags in any shipment, as determined by weighing 10 bags taken at random, must be at least the manufacturer’s certified weight.

Hydrated Lime slurry shall be measured as per Item 221 “Hydrated Lime and Lime Slurry”.

B. Lime Treatment. Lime treatment shall be measured by the square yard of surface area at the specified depth. The dimensions for determining the surface area are established by the widths shown on the plans and the lengths measured at placement.

220.6 Payment.
Lime Treatment. Lime treatment shall be paid for at the unit price bid for “Lime Treatment” by the square yard for the depth specified. This price is full compensation for shaping existing material, loosening, mixing, pulverizing, spreading, applying lime, compacting, finishing, curing, blading, shaping and maintaining, replacing, disposing of loosened materials, processing, hauling, preparing secondary subgrade, water, equipment, labor, tools, and incidentals.

Water for sprinkling. Sprinkling and rolling shall not be paid for directly, but shall be subsidiary to this Item, unless otherwise shown on the plans. Amendment of treated subgrade to correct soft spots shall be at the Contractor’s expense.

Asphalt used solely for curing will not be paid for directly, but will be subsidiary to this Item. Asphalt placed for curing and priming will be paid for under Item 310, “Prime Coat/Sealer.”

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 130 “Borrow”
Item 205 “Subgrade”
Item 221 “Hydrated Lime and Lime Slurry”
Item 310 “Prime Coat/Sealer”

END OF ITEM 220
ITEM 221

HYDRATED LIME AND LIME SLURRY

221.1 Description. This Item shall govern for establishing the requirements for hydrated lime and commercial lime slurry of the type and grade considered suitable for use in the treatment of natural or processed materials or mixtures for subgrade, sub-base and base construction.

221.2 Materials. The various types and grades are defined and identified as follows:

A. **Type A.** Hydrated Lime: Shall consist of a dry powder obtained by treating quicklime with enough water to satisfy its chemical affinity for water under the conditions of its hydration. This material is to consist essentially of calcium hydroxide or a mixture of calcium hydroxide and a small allowable percentage of calcium oxide, magnesium oxide and magnesium hydroxide.

   When sampled and tested according to TxDOT’s prescribed Tex-600-J procedures, hydrated lime shall conform to the requirements of TxDOT’s DMS-6350. Hydrated Lime for stabilization purposes shall be applied, as provided in the governing specifications, as a dry powder or mixed with water to form a slurry at the jobsite.

B. **Type B.** Commercial Lime Slurry: Shall be pumpable suspension of solids in water. The water or liquid portion of the slurry shall not contain dissolved material in sufficient quantity or nature that would be injurious for the purpose intended. The solids portion of the mixture, when considered on the basis of "solids content", shall consist principally of hydrated lime of a quality and fineness sufficient to meet TxDOT’s DMS-6350.

221.3 Sampling and Testing. The sampling and testing of lime slurry shall be as determined by Test Procedure Tex-600-J, "Sampling and Testing Lime".

   When Hydrated Lime is used, the quantity of lime will be measured by the ton of 2000 pounds, dry weight.

   When Commercial Lime slurry is used, the quantity of lime shall be calculated from the required minimum percent solids based upon the use of Grade 1, Grade 2, or Grade 3 as follows:
Grade 1: The "Dry Solids Content" shall be at least 31 percent by weight of the slurry and the quantity of lime will be calculated by the ton of 2,000 pounds based on the 31 percent dry weight solids.

Grade 2: The "Dry Solids Content" shall be at least 35 percent by weight of the slurry and the quantity of lime will be calculated by the ton of 2,000 pounds based on the 35 percent dry weight solids.

Grade 3: The "Dry Solids Content" shall be at least 46 percent by weight of the slurry and the quantity of lime will be calculated by the ton of 2,000 pounds based on the 46 percent dry weight solids.

Measurement and Payment. Work performed and materials furnished as prescribed by this Item will be paid for at the unit price bid per ton of 2,000 pounds, dry weight for "Lime", of the type specified, which price shall be full compensation for supplying the lime, for all mixing, spreading, drying, application of the lime, water content of the slurry, for all manipulations required, for all hauling, and freight involved, for all tools, equipment, labor and for all incidentals necessary to satisfactorily complete the work.

There are line code(s), description(s), and unit(s) for this Item.
ITEM 222

PORTLAND CEMENT STABILIZED SUBGRADE

222.1 Description. This Item shall govern for treating the subgrade by the pulverizing, adding portland cement, mixing, wetting and compacting the mixed material to the required density. This Item applies to natural ground, embankment or existing pavement structure and shall be constructed as specified herein and in conformity to the typical sections, lines and grades as shown, on the plans or as established by the Engineer.

Cement treatment shall not be mixed or placed when the air temperature is below 40°F and falling, but may be mixed or placed when the air temperature is above 35°F and is rising, the temperature being taken in the shade and away from artificial heat and with the further provision that cement treatment shall be mixed or placed only when weather conditions, in the opinion of the Engineer, are suitable.

222.2 Materials

A. Soil shall consist of approved material free from vegetation or other objectionable matter encountered in the existing roadbed and other acceptable material used in the preparation of the roadbed in accordance with this Item.

B. Portland cement shall be Type I of a standard brand of cement and shall conform to the requirements of ASTM C150 “Standard Specification for Portland Cement” and DMS-4600.6 A. (as applicable).

The Contractor, at his option, may use bulk cement, provided the apparatus for handling, weighing and spreading the cement is approved by the Engineer. Cement weighing equipment shall meet the requirements of the Item 520 "Weighing and Measuring Equipment”.

C. Water shall be free from substances deleterious to the hardening of the cement treatment and shall meet the requirements of the Item 360 “Concrete Pavement”.

The ratio of cement to soil shall be based on dry weight of the soil/cement mixture and shall be established by the Engineer in the field to provide the desired stability. The cement content in the dry material normally ranges between 6 percent to 10 percent by weight. The percentage of moisture in
the soil, at the time of the cement application shall not exceed the quantity that will permit the uniform and intimate mixture of soil and cement during the dry mixing operations and shall not exceed the specified optimum moisture content for the soil cement mixture, as determined by ASTM D558 “Standard Test Methods for Moisture-Density (Unit Weight) Relations of Soil-Cement Mixtures.”

222.3 Equipment. Equipment necessary for proper construction of the work shall be on the project, in first-class working condition and be approved by the Engineer, both as to type and condition, prior to the start of construction operations. The Contractor shall at all times provide sufficient equipment to enable continuous prosecution of the work.

Portland cement treatment for materials in-place may be constructed with any machine or combination of machines and auxiliary equipment that will produce the results as outlined in this Item.

Mixing may be accomplished by a multiple-pass traveling mixing plant or a single-pass traveling mixing plant.

The equipment provided by the Contractor shall be operated by experienced and capable workmen and shall be that necessary to provide a cement treatment meeting the requirements herein specified.

222.4 Construction Methods. It is the primary requirement of this Item to secure a completed course of treated material containing a uniform portland cement mixture free from loose or segregated areas, of uniform density and moisture content, well bound for its full depth and with a smooth surface suitable for placing subsequent courses. It shall be the responsibility of the Contractor to regulate the sequence of his work, to process a sufficient quantity of material to provide full depth as shown on the plans, to use the proper amount of portland cement, maintain the work and rework the courses as necessary to meet the above requirements.

The portland cement shall be mixed to the full depth shown on the plans and in no case, shall it be less than six (6) inches.

The subgrade shall be firm and able to support, without displacement, the construction equipment at the density hereinafter specified. Soft or yielding subgrade shall be corrected and made stable by scarifying and aeration or adding cement and compacting until it is of uniform stability.

Before other construction operations are begun, the subgrade shall be graded, shaped and compacted, as required, to construct the portland cement treatment for materials in-place in conformance with the lines, grades, thickness and typical cross-section shown on the plans.
Unsuitable material encountered below the top of subgrade elevation, shall be replaced with suitable material from the roadway excavation, or from other suitable material sources per Item 110 “Roadway Excavation”.

The soil shall be so pulverized that, at the completion of moist-mixing 100 percent by dry weight passes a 1 inch sieve, and a minimum of 80 percent passes a No. 4 sieve, exclusive of gravel or stone retained on these sieves. Old bituminous wearing surfaces shall be pulverized so that 100 percent will pass a 1-3/4 inch sieve as per Table 1 below:

TABLE 1

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>BASE</th>
<th>SUBGRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3/4 Inch</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3/4 Inch</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>No. 4</td>
<td>-</td>
<td>60</td>
</tr>
</tbody>
</table>

Portland cement shall be spread uniformly on the soil at the rate specified or as approved by the Engineer. If a bulk cement spread is used, it shall be positioned by string lines or other approved methods during spreading to insure a uniform distribution of cement.

Cement shall be applied only to such an area that all operations can be continuous and completed in daylight and within 5 hours of such application.

The percentage of moisture in the soil at the time of cement application, shall not exceed the quantity that will permit uniform and intimate mixture of the soil and cement during dry mixing operations, and it shall not exceed the specified optimum moisture content for the soil cement mixture.

No equipment, except that used in spreading and mixing, will be allowed to pass over the freshly spread cement, until it is mixed with the soil.

After the cement has been applied, it shall be dry mixed with the soil. Mixing shall continue until the cement has been sufficiently blended with the soil to prevent the formation of cement balls when water is applied. Any mixture of soil and cement that has not been compacted and finished shall not remain undisturbed for more than 30 minutes.

Immediately after dry mixing of soil and cement is complete, water as necessary shall be uniformly applied and incorporated into the mixture.
Pressurized equipment shall provide an adequate supply to insure continuous application of the required amount of water to the sections being processed within 3 hours of the application of the cement. Proper care shall be exercised to insure proper moisture distribution at all times. After the last increment of water has been added, mixing shall continue until a thorough and uniform mix has been obtained.

The material shall be compacted to not less than 95 percent of standard proctor density (ASTM D698 "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft$^3$ (600 kN-m/m$^3$)))). At the start of compaction, the percentage of moisture in the mixture and in the un-pulverized soil lumps, based on dry weights, shall be between optimum and 2 percent above optimum. When the uncompacted soil cement mixture is wetted by rain so that the average moisture content exceeds the tolerance given at the time of final compaction, the entire section shall be reconstructed in accordance with this Item at the sole expense of the Contractor.

The specified optimum moisture content and field density shall be determined from representative samples of the soil, taken in the fields and blended cement in a materials laboratory setting in accordance with ASTM D698.

Prior to the beginning of compaction, the mixture shall be in a loose condition for its full depth. The loose mixture shall then be uniformly compacted to the specified density lines and grades.

After the soil and cement mixture is compacted, water shall be uniformly applied, as needed, and thoroughly mixed. The surface shall then be reshaped to the required lines, grades and cross-section and then lightly scarified to loosen any imprint left by compacting or shaping equipment.

The resulting surface shall be thoroughly rolled with a pneumatic tire roller and "skinned" by a power grader to achieve final grade, removing all loosened soil and cement from the section. The surface shall then be thoroughly compacted with the pneumatic roller, adding small increments of moisture as needed during rolling. If aggregate too large to pass a No. 4 screen is present in the mixture, one complete coverage of the section with the flat wheel roller shall be made immediately after the skinning operation. When directed by the Engineer, surface finishing methods may be varied from this procedure, provided a dense uniform surface, free of surface compaction planes, is produced. The moisture content of the surface material must be maintained at its specified optimum during all finishing operations. Surface compaction and finishing shall proceed in such a manner as to produce, in not more than 2 hours, a smooth, closely
knit surface, free of cracks, ridges or loose material conforming to the crown, grade and line shown on the plans.

222.5 Curing. After the cement treated course has been finished as specified herein, the surface shall be protected against rapid drying by either of the following curing methods for a minimum period of 3 days, or as directed by the Engineer. These methods of curing are:

A. Maintain in a thorough and continuously moist condition by sprinkling.

B. Apply an asphalt membrane to the treated course, immediately after its completion. The asphaltic material shall meet the requirements of Item 300 "Asphalts, Oils, and Emulsions" contained in TxDOT's "Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges," Latest Edition. The quantity and type of asphalt approved for use by the Engineer shall be sufficient to completely cover and seal the total surface of the base and fill all voids. The Contractor shall be responsible for protecting the asphalt membrane from being picked up by the traffic. The asphalt membrane may remain in-place when the proposed surface or base courses are placed. The surface or other base courses may be applied on the finished base as soon after completion as operations will permit.

222.6 Construction Joints. At the end of each day's construction a straight transverse construction joint shall be formed by cutting back into the total width of completed work to form a true two inch depth vertical face free of loose and shattered material.

Construct vertical joints between new cement-treated base and cement-treated base that has been in place 4 hr. or longer. The vertical face may be created by using a header or by cutting back the face to approximately vertical. Place successive base courses using the same methods as the first course. Offset construction joints by at least 6 in.

Cement treatment for large wide areas shall be built in a series of parallel lanes of convenient length and width meeting the approval of the Engineer.

222.7 Traffic. After the 3 day curing period, or as directed by the Engineer, completed sections of cement treated material in-place, may be opened immediately to local traffic and to construction equipment and to all traffic after the curing period, provided the cement treated course has hardened sufficiently to prevent marring or distorting the surface by equipment or traffic.
222.8 Maintenance. The Contractor shall be required to maintain the cement treated course in good condition until the overlying course has been constructed. Maintenance shall include immediate repairs to any defects that may occur. This work shall be done by the Contractor at his own expense and repeated as often as may be necessary to keep the area continuously intact. Faulty work shall be replaced for the full depth of treatment. It is the intent of this Item that the Contractor shall construct the plan depth of cement treatment in one homogeneous mass. The addition of thin stabilized layers will not be permitted in order to provide the minimum specified depth.

222.9 Quality Assurance. The Testing Laboratory’s representative will determine the Moisture-Density Relationships in accordance with ASTM D698 on material secured from the roadway. Samples will be blended with portland cement for each type of material encountered.

The Testing Laboratory’s representative will determine the in-place density in accordance with ASTM D6938 “Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)” or ASTM D1556 “Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.” The minimum level of testing shall consist of the following:

A. at least one test per station per lane of roadway.
B. a lane is defined as 12’ wide section of pavement regardless of its use.

222.10 Measurement. The work performed and the material furnished as prescribed by this Item will be measured as follows:

A. Manipulation of cement during stabilization of the subgrade will be measured by the square yard of surface area of the completed and accepted work in place.
B. Portland cement will be measured by the ton of 2,000 pounds.

222.11 Payment. The work performed and material furnished as prescribed by this Item and measured in accordance with the method indicated in the proposal and in accordance with the applicable provisions of measurement above, will be paid for as follows:

A. "Manipulation of Cement for Stabilized Subgrade" shall be paid for at the contract unit price per square yard.
The unit price bids shall each be full compensation for preparing the subgrade, for furnishing all material, for all freight involved, for weighing the material, for pulverizing, applying cement, water, asphalt membrane, all processing, mixing, spreading, sprinkling, compacting, finishing and curing cement treated soil; and for all manipulations, labor, equipment, fuel, tools, and all incidentals necessary to complete the work.

B. Cement used in stabilized subgrade shall be paid for at the contract unit price per ton for "Cement for Subgrade Stabilization".

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 110 “Roadway Excavation”
Item 360 “Concrete Pavement”
Item 520 “Weighing and Measuring Equipment”

END OF ITEM 222
ITEM 223

LIME-FLY ASH STABILIZED SUBGRADE

223.1 Description. Mix and compact water, lime and fly ash (LFA), and subgrade in the roadway.

223.2 Materials. Furnish uncontaminated material of uniform quality that meet the requirements of the plans and specifications. Notify the Engineer in writing of proposed material sources and of any proposed changes in material sources. The Contractor shall obtain verification from the Engineer that the specification requirements are met before using the sources. The Engineer may sample and test materials at any time before compaction.

A. Lime. Furnish lime that meets the requirements of TxDOT’s DMS-6350, “Lime and Lime Slurry,” and DMS-6330, “Lime Sources Prequalification of Hydrated Lime and Quicklime.” Use hydrated lime or commercial lime slurry as shown on the plans.

B. Fly Ash. Furnish fly ash that meets the requirements of DMS-4615, “Fly Ash for Soil Treatment.” Use Class CS or FS as shown on the plans.

C. Water. Furnish water free of industrial wastes and other objectionable matter.

D. Asphalt. When required by the Engineer for curing purposes, furnish asphalt or emulsion in accordance with TxDOT’s Item 300, “Asphalts, oils, and Emulsions,” as shown on the plans or as directed.

E. Mix Design. Using the material proposed for the project, the Engineer shall verify the target lime-fly ash content and optimum moisture content in accordance with ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3)” or based upon prior experience with the project materials. The Contractor may propose an alternative mix design developed in accordance with ASTM D698. The Engineer shall use ASTM D698 to verify the Contractor’s proposed mix design before accepting it. The Contractor shall reimburse the County for all expenses incurred due to a change of mix designs or partial designs necessitated by changes in the design requested by the Contractor.
223.3 Equipment. Provided machinery, tools, and equipment necessary for proper execution of the work. Provide rollers in accordance with TxDOT Item 210, “Rolling.” Provide proof rollers in accordance with TxDOT Item 216, “Proof Rolling,” when directed.

A. Storage Facility. Store quicklime, dry hydrated lime, and fly ash in closed, weatherproof containers.

B. Slurry Equipment. Use slurry tanks equipped with agitation devices to slurry hydrated lime on the jobsite or other approved location. The Engineer may approve other slurring methods.

Provide a pump for agitating the slurry when the distributor truck is not equipped with an agitator. Equip the distributor truck with a sampling device in accordance with TEX-600-J, Part I, when using commercial lime slurry.

C. Pulverization Equipment. Provide pulverization equipment that:

1. cuts and pulverizes material uniformly to the proper depth with cutters that will plane to a uniform surface over the entire width of the cut,

2. shows a visible indication of the depth of cut at all times, and

3. mixes the materials uniformly.

223.4 Construction. Construct each layer uniformly, free of loose or segregated areas and with the required density and moisture content. Provide a smooth surface that conforms to the typical sections, lines, and grades shown on the plans or as directed.

A. Preparation of Subgrade for Treatment. Shape the subgrade in accordance with Item 205 “Subgrade”, and applicable bid items to conform to typical sections shown on the plans and as directed.

B. Pulverization. Pulverize or scarify existing subgrade after shaping so that 100% passes a 2-1/2” inch sieve. If the subgrade cannot be uniformly processed to the required depth in a single pass, excavate and windrow the material to expose a secondary grade to achieve processing to plan depth.

C. Application and Mixing of LFA. When treating with LFA, apply, mix, and cure lime first unless otherwise directed.
Start treatment operations only when air temperature is at least 35°F and rising or is at least 40°F. The temperature shall be taken in the shade and away from artificial heat. Suspend operations when the Engineer determines that weather conditions are unsuitable.

Minimize dust and scattering by wind. Do not apply lime or fly ash when wind conditions, in the opinion of the Engineer, cause blowing lime or fly ash to become dangerous to traffic or objectionable to adjacent property owners.

During the interval between applications and mixing, sections treated with hydrated lime or fly ash that have been exposed to the open air for a period of 6 hours or more, or that experience excessive loss due to washing or blowing, shall not be accepted for payment.

After mixing and required curing, the Engineer shall sample the mixture at roadway moisture and test in accordance with Tex-101-E, Part III to determine compliance with the gradation requirements in Table 1.

### TABLE 1

**GRADATION REQUIREMENTS (MINIMUM % PASSING)**

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>TREATED SUBGRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3/4 Inch</td>
<td>100</td>
</tr>
<tr>
<td>3/4 Inch</td>
<td>85</td>
</tr>
<tr>
<td>No. 4</td>
<td>60</td>
</tr>
</tbody>
</table>

1. Application of lime. Uniformly apply lime using dry or slurry placement as shown on the plans or as directed. Add lime at the percentage determined in Section 223.2.E, “Mix Design” above. Apply lime only on an area where mixing can be completed during the same working day.

   a. Dry Placement. Before applying lime, bring the prepared subgrade to a moisture content between optimum and 3% above optimum. When necessary, sprinkle as directed. Distribute the required quantity of hydrated lime with approved equipment. Only hydrated lime may be distributed by bag. Do not use a motor grader to spread hydrated lime.
b. Slurry Placement. Provide slurry free of objectionable materials, at or above the approved minimum dry solids content, and with a uniform consistency that will allow ease of handling and uniform application. Deliver commercial lime slurry to the jobsite or prepare lime slurry at the jobsite or other approved location by using hydrated lime as specified.

2. Mixing of Lime. Begin mixing within 6 hours of lime application. Thoroughly mix the subgrade and lime using approved equipment. Allow the mixture to mellow for 1 to 4 days as directed. Sprinkle the treated subgrade during the mixing and mellowing operation, as directed, to achieve adequate hydration and proper moisture content. After mellowing, resume mixing until a homogeneous, friable treated subgrade is obtained.

3. Application of Fly Ash. Uniformly apply fly ash in dry form unless otherwise approved. Apply at the percentage determined in Section 223.2.E, “Mix Design” above. Apply fly ash only on that area where the mixing and compacting operations can be completed during the same working day. Do not use a motor grader to spread fly ash.

For LFA treatment, begin fly ash application within 4 days after the lime mixing operation has been completed unless otherwise approved.

4. Mixing of Fly Ash. Thoroughly dry-mix the material and fly ash using approved equipment until a loose, homogeneous mixture is obtained. Sprinkle as directed, to achieve adequate mixing and hydration moisture. Prevent formation of fly ash balls.

D. Compaction. Compact immediately after mixing in the fly ash. Complete all compaction operations within 6 hours of fly ash application. Determine the moisture content of the mixture at the beginning and during compaction in accordance with ASTM D698. Compact to at least 95% of the maximum density as determined in accordance with ASTM D6938 “Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods” unless otherwise shown on the plans.

Multiple lifts are permitted when shown on the plans or approved by the Engineer. Sprinkle the treated subgrade as directed or aerate to bring each layer to the moisture content directed.
Begin rolling longitudinally at the sides and proceed towards the center, overlapping on successive trips by at least 1/2 the width of the roller unit. Offset alternate trips of the roller.

Operate rollers at a speed between 2 to 6 MPH as directed.

Rework, recompact, and refinish treated subgrade that fails to meet or that loses required moisture, density, stability, or finish before the next course is placed or the project is accepted. Continue work until specification requirements are met. Rework in accordance with Section 223.4.E, “Reworking a Section” below. Perform the work at no additional expense to the County.

The Testing Laboratory shall determine roadway density of completed sections in accordance with ASTM D6938. The minimum level of testing shall consist of the following:

1. at least one test per station per lane of roadway.

2. a lane is defined as 12’ wide section of pavement regardless of its use.

E. Reworking a Section. Reworking includes loosening, adding material or removing unacceptable material if necessary, mixing as directed, compacting, and finishing. When removal is necessary, the Contractor shall replace failing material with other acceptable material from the project site, or replace with Borrow as approved by the Engineer. Add lime and fly ash when reworking LFA-treated sections, at the rate of at least 25% of the percentage determined in Section 223.2.E “Mix Design” as directed. When repulverization of the failing section does not achieve the required density, remove failing material and replace with acceptable treated material.

Determine a new maximum density of the reworked treated subgrade in accordance with ASTM D698, and compact in accordance with Section 223.4.D above.

F. Finishing. Immediately after completing compaction of the final layer, clip, skin, or tight-blade the surface to a depth of approximately 1/4 inch.

Remove clipped material and dispose of it at an approved location. Seal the clipped surface immediately by rolling with a pneumatic tire roller until a smooth surface is attained. Add small increments of water as needed during rolling. Shape and maintain the layer
and surface in conformity with the typical sections, lines, and grades. Complete finishing operations within 2 hours after final compaction.

Finished grade tolerances for subgrade shall be in accordance with TXDOT’s Item 132.6.1, “Grade Tolerances.”

G. Curing. If the plans require a Prime Coat, place the Prime Coat as the curing method (pay item). Otherwise, cure by maintaining in a thorough and continuously moist condition by sprinkling as directed. When directed by the Engineer, cure with an asphalt emulsion applied at a rate of 0.05 to 0.20 gallons per square yard as approved (no pay item). Do not allow equipment on the finished course during curing except as required for sprinkling, unless otherwise approved.

Cure the finished section for 7 days before adding another course or opening to traffic unless otherwise directed. Apply subsequent courses within 14 calendar days of completion of final compaction of the underlying treated course unless otherwise approved.

223.5 Measurement.

A. Lime. Lime shall be measured by the ton as per Item 221 “Hydrated Lime and Lime Slurry” at the unit price bid for “Lime” for one of the following types:

1. Hydrated Lime (Dry),
2. Hydrated Lime (Slurry),
3. Commercial Lime Slurry,
4. Carbide Lime

Commercial Lime Slurry shall be measured by the ton (dry weight) as calculated from the minimum percent dry solids content of the slurry, multiplied by the weight of the slurry in tons delivered.

B. Fly Ash. Fly ash shall be measured by the ton (dry weight). When fly ash is furnished in trucks, the weight of fly ash shall be determined on certified scales.

When fly ash is furnished in bags, each bag must indicate the manufacturer’s certified weight. Bags varying more than 5% from that weight may be rejected. The average weight of bags in any
shipment, as determined by weighing 10 bags taken at random, must be at least the manufacturer’s certified weight.

C. LFA Treatment. LFA treatment shall be measured by the square yard of surface area for the specified depth. The dimensions for determining the surface area are established by the widths shown on the plans and the lengths measured at placement.

223.6 Payment. The work performed as prescribed by this Item and measured in accordance with the provisions of measurement above, shall be paid for at the unit prices bid as follows:

A. Lime. Lime shall be paid as per Item 221 “Hydrated Lime and Lime Slurry” at the unit price bid.

B. Fly Ash. Fly ash shall be paid for under this Item at the unit price bid for “Fly Ash” of the type specified. This price is full compensation for furnishing fly ash.

C. LFA Treatment. LFA treatment shall be paid for under this Item at the unit price bid for “LFA Treated Subgrade,” for the depth specified. No payment shall be made for thickness or width exceeding that shown on the plans. This price is full compensation for shaping existing material, loosening, mixing, pulverizing, spreading, applying lime and fly ash, compacting, finishing, curing including curing materials, water, drying, blading, shaping and maintaining, replacing, disposing of loosened materials, processing, hauling, reworking (if required), preparing secondary subgrade (if required), equipment, labor, tools, and incidentals.

Lime and fly ash used for reworking a section shall be in accordance with Section 223.4.E, “Reworking a Section,” and shall be paid for at the unit prices bid for their respective Items. Placement, mixing, compaction and any other items of work required for subgrade stabilization, will not be paid for directly but considered incidental to this Item.

Sprinkling and rolling shall not be paid for directly but shall be subsidiary to this Item unless otherwise shown on the plans.

Where importation of borrow material is necessary to correct soft spots, payment shall be made as an extra work item under Item 130 “Borrow”.

Asphalt emulsion used solely for curing shall not be paid for directly, but shall be subsidiary to this Item.
Prime Coat placed for curing and priming shall be paid for under Item 310 “Prime Coat/Sealer.”

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 130 “Borrow”
Item 205 “Subgrade”
Item 221 “Hydrated Lime and Lime Slurry”
Item 310 “Prime Coat/Sealer”

END OF ITEM 223
ITEM 224

QUICKLIME (STABILIZATION)

224.1 Description. This Item shall govern for establishing the requirements for quicklime of the type and grade considered suitable for use in the treatment of natural or processed materials or mixtures, for subgrade and subbase construction.

224.2 Materials. Quicklime, for stabilization, shall be Type C Quicklime, Grade DS. Pebble quicklime shall only be used for "dry placing"; slurry placing will not be allowed. Quicklime shall meet the requirements of ASTM C977 "Standard Specification for Quicklime and Hydrated Lime for Soil Stabilization."

When sampled and tested according to prescribed ASTM and TxDOT procedures, quicklime shall conform to the following requirement as to chemical composition:

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>LIMIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unhydrated lime content, percent by weight CaO</td>
<td>Min. 87.0%</td>
</tr>
</tbody>
</table>

The percent by weight of residue retained shall conform to the following requirements:

**WET SIEVE REQUIREMENTS**

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% RESIDUE RETAINED</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 6</td>
<td>*Max. 8.0%</td>
</tr>
<tr>
<td>No. 30</td>
<td>No Requirement</td>
</tr>
</tbody>
</table>

**DRY SIEVE REQUIREMENTS**

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% RETAINED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 inch</td>
<td>0.0%</td>
</tr>
<tr>
<td>3/4 Inch</td>
<td>Max. 10.0%</td>
</tr>
</tbody>
</table>

* The amount of total "active" lime content, as CaO, in the material retained on the No. 6 sieve must not exceed 2.0 percent by weight of the original Type C lime.
CAUTION: Use of quicklime can be dangerous. Users should become informed of the recommended precautions in the handling, storage, and use of quicklime.

224.3 Construction Methods. It is the primary requirement of this Item to secure a completed course of treated material containing a uniform lime soil mixture free from loose or segregated areas, of uniform density and moisture content, well bound for its full depth and with a smooth surface suitable for placing subsequent courses. It shall be the responsibility of the Contractor to regulate the sequence of his work, to use the proper amount of lime, maintain the work, and rework the courses as necessary to meet the above requirements.

The roadbed shall be constructed and shaped to conform to the typical sections, lines, and grades as shown on the drawings or as established by the Engineer. The subgrade shall be firm and able to support, without displacement, the construction equipment at the density herein specified. Any wet or unstable materials below the subgrade shall be corrected, as directed by the Engineer, by scarifying, adding lime, and compacting, or other methods until satisfactory stability is obtained. The cost of the repair of the subgrade and any materials below the subgrade is incidental to this Item.

Lime shall be spread only on that area where the first mixing operations can be completed during the same working day. The application and mixing of lime with the material shall be accomplished by the method of dry placing.

The lime shall be spread by an approved spreader at the rates shown on the Bid Sheet, or as directed by the Engineer.

The lime shall be distributed at a uniform rate and in such a manner as to reduce the scattering of lime by wind to a minimum. Lime shall not be applied when wind conditions, in the opinion of the Engineer, are such that blowing lime becomes objectionable to traffic or adjacent property owners. A motor grader may be used to spread Type C quicklime of Grade DS only.

The material shall be sprinkled until the proper moisture content has been secured.

The material and lime shall be thoroughly mixed by approved road mixers or other approved equipment, and the mixing continued until, in the opinion of the Engineer, a homogeneous friable mixture of material and lime is obtained, such that when all non-slaking aggregates retained on
the 3/4 inch sieve are removed, the remainder of the material shall meet the following requirements when tested in accordance with Tex-101-E, Part III, from samples collected from the roadway.

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>MINIMUM % PASSING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3/4 Inch</td>
<td>100</td>
</tr>
<tr>
<td>3/4 Inch</td>
<td>85</td>
</tr>
</tbody>
</table>

The material and quicklime shall be mixed as thoroughly as possible at the time of the lime application. The material and lime shall be mixed by approved road mixers or other approved equipment and the mixing continued until, in the opinion of the Engineer, a homogeneous friable mixture of material and lime is obtained, free from all clods or lumps. Materials containing plastic clays or other materials which will not readily mix with lime shall be mixed as thoroughly as possible at time of lime application.

Sufficient moisture is to be added during the mixing to hydrate the quicklime, plus the moisture needed for compaction. After mixing and prior to compaction, the mixture of the material, quicklime and water is to be left to cure for two to seven days, as directed by the Engineer. During the curing period, the material shall be kept moist as directed by the Engineer. After the two to seven day curing period, final mixing shall be done as directed by the Engineer.

Compaction shall begin after the two to seven day curing period, as directed by the Engineer. The subgrade shall be stabilized to a minimum depth of 6 inches and compacted to a minimum of 95 percent of standard proctor density (ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³) using a moisture content between optimum and 3 percent above optimum.

Compaction shall begin at the bottom layer and shall continue with successive layers until the entire depth of mixture is uniformly compacted. The material shall be sprinkled, if necessary, and rolled as directed by the Engineer. All irregularities, depressions or weak spots which develop shall be corrected immediately by scarifying the areas affected adding or removing material as required and recompacting by sprinkling and rolling. The surface of the course shall be maintained and cured for a minimum of 3 days, prior to placing a base or surface course or until traffic is allowed to travel thereon.

In addition to the requirements specified for density, the full depth of the material shall be compacted to the extent necessary to remain firm and
stable under construction equipment. After each section is completed, tests as necessary will be ordered. If the material fails to meet the density requirements, it shall be reworked as necessary to meet these requirements. Throughout the entire operation, the shape of the course shall be maintained by blading and the surface upon completion shall be smooth and in conformity with the typical section shown on the plans and to the established lines and grades. Should the material, due to any reason or cause, lose the required stability, density, and finish, before the next course is placed or the work is accepted, it shall be reprocessed and refinshed at the expense of the Contractor.

224.4 Finishing. After the final course of the lime treated subgrade has been compacted, it shall be brought to the required lines and grades in accordance with the typical sections. The completed section shall then be finished by rolling, as directed, with a pneumatic tire or other suitable roller sufficiently light to prevent hairline cracking. The completed section shall be moist or emulsion cured until covered by base material, unless otherwise directed by the Engineer. If the plans provide for the treated material to be sealed or covered by other courses of material, such seal or course shall be applied within 14 days after final mixing and compacting is completed, unless otherwise directed by the Engineer.

224.5 Quality Assurance. The Testing Laboratory’s representative will determine the moisture-density relationships in accordance with ASTM D698 on material secured from the roadway after stabilization with lime, for each type of material encountered.

The Testing Laboratory’s representative will determine the in-place density in accordance with ASTM D6938 “Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods” or D1556 “Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.” The minimum level of testing shall consist of the following:

A. at least one test per station per lane of roadway.

B. a lane is defined as 12’ wide section of pavement regardless of its use.

224.6 Measurement. Manipulation of lime during the stabilization of the subgrade shall be measured by the square yard of subgrade actually stabilized.

The quantity of Type C Quicklime shall be measured by the ton of 2,000 pounds, dry weight, of the quicklime actually delivered on the road, and shall have a weigh ticket from a certified scale.
224.7 Payment. Payment for manipulation of "Quicklime Stabilized Subgrade" shall be made at the contract unit price per square yard of compacted subgrade for the depth specified.

The unit price bid shall be full compensation for loosening, mixing, pulverizing, spreading, drying, application of quicklime and water, compaction, shaping and maintaining; for all manipulations required, for all hauling and freight involved, for all tools, equipment, labor, and all incidentals necessary to complete the work.

Payment for "Quicklime" shall be made at the contract unit price per ton, dry weight of lime used for stabilizing the subgrade, which price shall be full compensation for supplying the lime, for all hauling and freight involved, for all tools, equipment, labor and for all incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 224
ITEM 230

CRUSHED AGGREGATE BASE COURSE

230.1 Description. This Item shall govern for a foundation course for a surface course or for other base courses and shall be composed of crushed aggregate materials; and shall be constructed as herein specified in one or more courses in conformity with the typical sections shown on the plans and to the lines and grades as established by the Engineer.

230.2 Materials. The materials shall be obtained from approved sources, shall be crushed, and shall consist of durable particles of crushed aggregate, mixed with approved binding material. The crushed material shall have a minimum compressive strength of 45 psi at 0 psi lateral pressure and 175 psi at 15 psi lateral pressure using triaxial testing procedures. The crushed aggregate shall meet the following gradation when tested in accordance with ASTM C136 "Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates."

<table>
<thead>
<tr>
<th>Retained on Sieve Conforming to ASTM E11</th>
<th>% Retained, by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3/4 Inch</td>
<td>0</td>
</tr>
<tr>
<td>7/8 Inch</td>
<td>10 – 35</td>
</tr>
<tr>
<td>3/8 Inch</td>
<td>30 – 50</td>
</tr>
<tr>
<td>No. 4</td>
<td>45 – 65</td>
</tr>
<tr>
<td>No. 40</td>
<td>70 – 85</td>
</tr>
</tbody>
</table>

The material passing the No. 40 sieve shall meet the following requirements when tested in accordance with ASTM D4318 “Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.”

A. The liquid limit shall not exceed 35
B. The plasticity index shall not exceed 10

All material retained on the No. 40 sieve shall have a Los Angeles Abrasion percent of wear not exceeding 40 when tested in accordance with ASTM C131 “Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.”
With prior written permission of the Engineer, additives may be used to meet the above requirements.

230.3 Construction Methods. The subgrade shall be prepared in accordance with the pertinent item for subgrade. Immediately before placing the base material, the subgrade shall be checked as to conformity with the grade and section. Any deviation in excess of 1/2 inch in cross-section and in a length of 16 feet measured longitudinally shall be corrected by loosening, adding or removing material, reshaping and compacting by sprinkling and rolling. Sufficient subgrade shall be prepared in advance to insure satisfactory prosecution of the work.

The material for the first course shall be deposited on the subgrade in a lift not to exceed 6 inches in thickness. Material deposited upon the subgrade shall be spread and shaped the same day unless otherwise directed by the Engineer. The material shall be sprinkled, if directed and shall then be bladed, dragged and shaped to the typical sections as shown on the plans. All areas and most of segregated coarse or fine material shall be corrected or removed and replaced with well graded material as directed by the Engineer. If additional binder is considered desirable or necessary after the material is spread and shaped, it shall be furnished and applied in the amount directed by the Engineer. Such binder material shall be carefully and evenly incorporated with the material in-place by scarifying harrowing, brooming or by other approved methods.

The course shall be sprinkled as required and compacted to the extent necessary to provide not less than 95 percent of modified proctor density (ASTM D1557 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft³ (2,700 kN-m/m³))” at a moisture content ranging from optimum to 3 percent above optimum. In addition to the requirements specified for density, the full depth of the flexible base shown on the plans shall be compacted to the extent necessary to remain firm and stable under construction equipment. After each section of flexible base is completed, tests as necessary will be made by the Engineer. If the material fails to meet the density requirements, it shall be reworked as necessary to meet these requirements. Throughout this entire operation the shape of the course shall be maintained by blading, and the surface upon completion shall be smooth and in conformity with the typical sections shown on the plans and to the established lines and grades. In that area on which pavement is to be placed, any deviation in excess of 1/4 inch in cross-section and in length of 16 feet measured longitudinally shall be corrected by loosening, adding or removing material as required, reshaping and recompacting by sprinkling and rolling. Should the base course, due to any reason or cause, lose the required stability, density or finish before the surface is
completed, it shall be recompacted and refinished at the sole expense of the Contractor.

Construction methods for succeeding courses shall be the same as prescribed for the first course. Prior to placing the surfacing on the completed base, the base shall be dry cured to the extent directed by the Engineer.

230.4 Quality Assurance. The Materials Engineer will determine the Moisture-Density Relationship in accordance with ASTM D1557 on material secured from the source of supply, or the Contractor.

The Materials Engineer will determine the in-place density in accordance with ASTM D6938 “Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)” or ASTM D1556 “Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.” The minimum level of testing will consist of at least three tests for each 500 feet per lift per lane of roadway, or 4,000 square feet of completed base.

230.5 Acceptance Requirements. The completed base course shall be checked for determining acceptance as provided herein.

Upon completion of compaction operations, the density of the completed course will be determined in accordance with ASTM D6938 or ASTM D1556. A minimum of one density test will be taken per 1,000 linear feet per roadway. The location of the test will be chosen randomly. If any density test is below requirements, two additional tests will be taken within 5 feet of the failing test location and the average of the three tests will be used as the value for the 1,000 foot location.

The density requirements as based on ASTM D1557, will be 95 percent of the maximum density.

If the density test value per 1,000 foot section is below 95 percent, a price adjustment will be supplied as follows:

<table>
<thead>
<tr>
<th>DENSITY TEST VALUE</th>
<th>% OF CONTRACT UNIT PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>95.0 and above</td>
<td>100</td>
</tr>
<tr>
<td>93.0 to 94.9</td>
<td>90</td>
</tr>
<tr>
<td>90.0 to 92.9</td>
<td>75</td>
</tr>
<tr>
<td>Below 90</td>
<td>50 or remove*</td>
</tr>
</tbody>
</table>
* At the option of the Engineer

The completed base course will not vary from plan thickness in excess of the following tolerances. Base course thickness deficiencies in excess of these tolerances shall be corrected, as specified herein, at the Contractor's expense.

<table>
<thead>
<tr>
<th>UNDERTHICKNESS</th>
<th>OVERTHICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 inch</td>
<td>1-1/2 inches</td>
</tr>
</tbody>
</table>

If an individual test exceeds allowable tolerances, two additional tests will be taken within 5 feet of the failing test location and the average of the three tests (rounded off to the nearest 1/4 inch) will be used as the value for that location. Any failing areas will be isolated for purposes of correction. Base course thickness deficiencies in excess of the foregoing tolerances shall be corrected as follows.

If no grade adjustments are permitted, thickness deficiencies shall be corrected by removing and replacing the full depth of base course in deficient areas with one of the following materials:

A. Item 231 “Cement Stabilized Crushed Aggregate Base Course“

B. Item 250 “Hot Mix Asphaltic Concrete Base Course (Black Base)"

If grade adjustments are permitted, the Contractor shall have the option of correcting thickness deficiencies by furnishing and placing a supplemental layer of asphaltic concrete conforming to Item 250, for the full width of the base course, in lieu of removing and replacing deficient base course. The thickness of the supplemental layer of asphaltic concrete shall be as follows:

<table>
<thead>
<tr>
<th>UNDERTHICKNESS INCHES</th>
<th>MINIMUM THICKNESS OF SUPPLEMENTAL ASPHALTIC CONCRETE INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/4 to 1-1/2</td>
<td>1</td>
</tr>
<tr>
<td>1-3/4 to 2</td>
<td>1-1/2</td>
</tr>
<tr>
<td>2-1/4 to 2-1/2</td>
<td>2</td>
</tr>
<tr>
<td>Over 2-1/2</td>
<td>Remove and replace</td>
</tr>
</tbody>
</table>
230.6 Measurement. Crushed Aggregate Base shall be measured by the square yard of material, furnished and compacted in place and to the thickness specified, or as shown on the plans.

230.7 Payment. Payment for Crushed Aggregate Base, complete and in-place, shall be at the contract unit price per square yard of the specified thickness, which unit price shall include all costs of materials furnished, hauled, dumped, spread, shaped and compacted in maximum 6 inch lifts, including water for sprinkling. If necessary, adjustments will be made in the payment for this Item as outlined in Section 230.5 above.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 231 “Cement Stabilized Crushed Aggregate Base Course”
Item 250 “Hot Mix Asphaltic Concrete Base Course (Black Base)”

END OF ITEM 230
ITEM 231

CEMENT STABILIZED CRUSHED AGGREGATE BASE COURSE

231.1 Description. This Item shall govern for surface courses or for other base courses composed of a mixture of crushed aggregate, portland cement and water and shall be constructed as herein specified and in conformity with the typical cross-sections shown on the plans and to the lines and grades established by the Engineer.

231.2 Materials. Cement shall be Type I of a standard brand of portland cement and shall conform to the requirements of ASTM C150 “Standard Specification for Portland Cement.” Bulk cement or sack cement may be used.

Water shall meet the requirements of ASTM C1602 “Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete.”

The aggregate shall consist of durable particles of crushed aggregate, mixed with approved binding material. The crushed material shall have a minimum compressive strength of 45 psi at 0 psi lateral pressure and 175 psi at 15 psi lateral pressure using triaxial testing procedures.

The crushed aggregate shall meet the following gradation when tested in accordance with ASTM C136 “Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.”

<table>
<thead>
<tr>
<th>RETAINED ON SIEVE CONFORMING TO ASTM E11</th>
<th>% RETAINED, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3/4 Inch</td>
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<td>30 – 50</td>
</tr>
<tr>
<td>No. 4</td>
<td>45 – 65</td>
</tr>
<tr>
<td>No. 40</td>
<td>70 – 85</td>
</tr>
</tbody>
</table>

The material passing the No. 40 sieve shall meet the following requirements, when tested in accordance with ASTM D4318 “Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.”

The liquid limit shall not exceed 35.
The plasticity index shall not exceed 10.
All material retained on the No. 40 sieve shall have a Los Angeles Abrasion percent of wear not exceeding 40 when tested in accordance with ASTM C131 "Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine."

With the approval of the Engineer, additives may be used to meet the above requirements.

Where materials are specified to be measured or proportioned by weight, equipment shall conform to the requirements of the Item 520 "Weighing and Measuring Equipment". Equipment necessary for proper prosecution of the work shall be on the project and approved by the Engineer prior to the beginning of construction operations. All equipment used shall be maintained in a satisfactory working condition. The Contractor shall employ adequate methods in performing the work and shall conduct his operations in a satisfactory and workmanlike manner.

The mix shall be designed with the intention of producing a minimum average compressive strength of 650 psi at seven days, using unconfined compression testing procedures. Cement stabilized specimens shall be prepared, cured and tested as outlined in TxDOT's Test Procedure Tex-120-E. The cement content shall be a minimum of 1-1/2 sacks per ton of mix, as laid.

231.3 Construction Methods. The crushed aggregate and cement shall be dry-mixed in a pug mill of either the batch or continuous flow type. The plant shall be equipped with feeding and metering devices which will add the crushed aggregate, cement and water into the mixer in the specified quantities. The crushed aggregate and cement shall be mixed sufficiently to prevent cement balls from forming when water is added. Mixing shall continue until a uniform and intimate mixture of crushed aggregate cement and water is obtained.

The cement stabilized base shall be placed in uniform layers on the prepared subgrade to produce the depth specified on the plans. The depth of layers shall be as approved by the Engineer. To insure homogeneous distribution of the base material in each layer, the material shall be placed using an approved spreader. The spreading operations shall be done in such a manner as to eliminate nests or pockets of material on non-uniform gradation resulting from segregation in the hauling or dumping operations and in such a manner as to eliminate planes of weakness. Construction joints between new cement stabilized base and cement stabilized base that has been in place four hours or longer shall be approximately vertical. The plane of the joint may be formed by a header which shall be removed immediately prior to placing
the subsequent base or the base placed first may be cut to an approximately vertical edge immediately prior to placing the new base.

Only one longitudinal joint will be permitted where cement stabilized base is placed underneath main lanes and shoulders unless otherwise permitted by the Engineer. This joint shall normally be placed at the centerline of the roadway. Longitudinal joints will not be permitted underneath frontage roads and ramps unless otherwise permitted by the Engineer.

Cement stabilized base shall not be placed when the air temperature is below 40°F. and is falling, but may be placed when the air temperature is above 35°F., and is rising, the temperature being taken in the shade and away from artificial heat and with the further provision that cement stabilized base shall be mixed or placed only when weather conditions, in the opinion of the Engineer, are suitable for such work.

Not more than 60 minutes shall lapse between the start of moist mixing and the start of compaction of the mixture. The layer of portland cement mixture shall be uniform in thickness and surface contour and in such quantity that the completed base will conform to the required grade, cross-section and governing specifications. Dumping of the mixture in piles or windrows upon the subgrade will not be permitted.

The material shall be compacted to not less than 95 percent of modified proctor density (ASTM D1557 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft³ (2,700 kN-m/m³))”) at optimum moisture content. At the start of compaction the percentage of moisture in the mixture, based on oven-dry weights, shall be between optimum and 2 percent above optimum. When the uncompacted mixture is wetted by rain, so that the average moisture content exceeds the tolerance given at the time of final compaction, the entire section shall be reconstructed in accordance with this Item at the sole expense of the Contractor.

Prior to the beginning of compaction, the mixture shall be in loose condition for its full depth. The loose mixture shall then be uniformly compacted to the specified density within 2 hours.

After the mixture is compacted, water shall be uniformly applied as needed and thoroughly mixed in with a spike tooth harrow or equal. The surface shall then be reshaped to the required lines, grades and cross-sections and then lightly scarified to loosen any imprint left by compacting or shaping equipment.
The resulting surface shall be thoroughly rolled with a pneumatic tire roller and "skinned" by a power grader to achieve final grade.

The surface shall then be compacted with the pneumatic tire roller, adding small increments of moisture as needed during rolling. One complete coverage of the section with the flat wheel roller shall be made immediately after the clipping operation. When directed by the Engineer, surface finishing methods may be varied from this procedure, provided a dense uniform surface, free of surface compaction planes is produced. The moisture content of the surface material must be maintained at its specified optimum during all finishing operations. Surface compaction and finishing shall proceed in such a manner as to produce, in not more than two hours, a smooth closely knit surface, free of cracks, ridges or loose material conforming to the crown, grade and line shown on the plans.

After the portland cement treatment for the base has been finished as specified herein, the surface shall be protected against rapid drying by either of the following curing methods for a minimum period of 3 days, or as directed by the Engineer:

A. Maintain a thorough and continuously moist condition by sprinkling.

B. Apply an asphalt membrane on the course, immediately after the surface is completed. The quantity and type of asphalt approved for use by the Engineer shall be sufficient to completely cover and seal the total surface and fill all the voids. The Contractor shall be responsible for protecting the asphalt membrane from being picked up by the traffic. The asphalt membrane may remain in-place when the proposed surface or base courses are placed. The surface or other base courses may be applied on the finished base as soon after completion as operations will permit.

The asphalt shall meet the requirements of Item 300 "Asphalts, Oils and Emulsions" of the Texas Department of Transportation's "Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges".

The cement stabilized base shall be kept free from traffic for a period of 72 hours after completion of compaction.

The Contractor will be required to maintain the cement stabilized base in good condition until the overlaying course has been constructed. Maintenance shall include immediate repair of any defects that may occur. This work shall be done by the Contractor at his own expense and shall be repeated as often as may be
necessary to keep the area continuously intact. Faulty work shall be replaced for the full depth of treatment. It is the intent of this Item that the Contractor shall construct the plan depth of cement treatment in one homogeneous mass. The addition of thin stabilized layers will not be permitted in order to provide the minimum specified depth.

231.4 Quality Assurance. The Testing Laboratory’s representative will determine the Moisture-Density Relationship in accordance with ASTM D1557 on material secured from the source of supply, or the Contractor.

The Testing Laboratory’s representative will mold three samples, each day, or for each 1,000 tons of production for unconfined compressive strength in accordance with Test Procedure Tex-120-E. The compressive strength for that lot of production is the average of the three samples. If the average compressive strength is less than the specified compressive strength, the cement content will be increased to the extent necessary to yield the desired strength.

The Testing Laboratory representative will determine the in-place density with ASTM D6938 “Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)” or ASTM D1556 “Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.” The minimum level of testing will consist of at least three tests for each 1,000 feet per lane of roadway.

231.5 Acceptance Requirements. The acceptance requirements for this Item shall be the same as outlined in Item 230.5, of "Crushed Aggregate Base Course".

231.6 Measurement. "Cement Stabilized Crushed Aggregate Base", will be measured by the square yard of material, furnished and compacted in place and to the thickness specified, or as shown on the plans.

231.7 Payment. The work performed and the material furnished as prescribed by this Item and measured in accordance with the method outlined above, will be paid for at the unit price bid for "Cement Stabilized Crushed Aggregate Base" of the depth specified, or as shown on the plans.

The unit price bid will be full compensation for securing and furnishing all materials; including all royalty and freight involved; for all processing, crushing and loading; for all hauling, delivery, placing, spreading, blading, mixing, stripping, dragging, finishing, curing, asphalt membrane, and maintaining; for all fine grading; for wetting and compaction and all manipulation, labor, tools and incidentals necessary to complete the work.
If necessary, adjustments will be made in the payment for this Item, as outlined in Section 230.5 of these Standard Specifications.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 230 “Crushed Aggregate Base Course”
Item 520 “Weighing and Measuring Equipment”

END OF ITEM 231
ITEM 250

HOT MIX ASPHALTIC CONCRETE BASE COURSE (BLACK BASE)

250.1 Description. This Item shall consist of a base course mixture of compacted mineral aggregate and asphaltic material, constructed on an approved subgrade, in accordance with the plans and specifications and in conformity with the lines and grades.

It is the intent of these specifications that the asphaltic mixtures produced and placed shall meet the requirements of these specifications, for one hundred percent payment. The Contractor shall have the responsibility for the design, production, transportation and laydown of asphaltic concrete mixtures. All phases of this work shall meet the requirements of this Item and be subject to inspection and acceptance by the Engineer.

The Contractor shall exercise quality control over materials and their assembly, design, processing production, hauling, laydown, compaction and all associated equipment. Quality control is defined as the constant monitoring of equipment, materials and processes to ensure that asphaltic concrete mixtures produced and laid are uniform, and are within control limits, and meet all acceptance requirements of this Item and other specification requirements. If these specifications are not being met, and satisfactory control adjustments are not being made, operations shall be discontinued until proper adjustments and uniform operations are established. Control shall be accomplished by a program independent of, but correlated with, the Engineer's quality assurance testing program and shall verify that all requirements of the job mix are being achieved and that necessary adjustments provide specification results.

At all times, when the plant is in operation, the Contractor shall require his supplier to have a level II specialist certified by TxDOT's approved hot mix asphalt certification program and will be available to the plant operator who is capable of designing asphaltic concrete mixes, performing tests and analyses to put the plant into operation and producing a mixture meeting the specifications. The daily operations at the plant will not begin without the presence of the qualified technician, as stated above.

The tests made by the Engineer in his quality assurance testing program shall not relieve the Contractor of his responsibility of quality control.

250.2 Materials. Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications.
A. Mineral Aggregate: The mineral aggregate shall be composed of a coarse aggregate and a fine aggregate and, if required, mineral filler and may include reclaimed asphalt pavement (RAP) that meets the requirements of this Item. The use of RAP may be required on the plans. Samples of coarse aggregate, fine aggregate and mineral filler shall be submitted in minimum 10 pound bags when requested by the Engineer. Unless otherwise required, one or more mineral aggregates containing both coarse and fine aggregate may be used to produce the specified mixture. The documented aggregate test results shall be submitted with the asphalt mix design.

1. Coarse Aggregate: Coarse aggregate stockpiles shall have no more than 20% material passing the No. 8 sieve and shall consist of clean, tough, durable fragments of aggregate and/or mechanically crushed aggregate, reclaimed asphalt pavement (RAP) or a combination thereof, as hereinafter specified, of uniform quality throughout and shall be free from dirt, organic or other injurious matter occurring either freely in the material or as a coating on the aggregate. Samples of each aggregate shall be tested for approval by the Engineer. The coarse aggregate shall have an abrasion of not more than 40% when subjected to the Los Angeles Abrasion Test, test method ASTM C131 “Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.”

<table>
<thead>
<tr>
<th>TEST</th>
<th>REQUIREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasion Loss</td>
<td>Not more than 40%</td>
</tr>
<tr>
<td>Deleterious Material</td>
<td>Less than 1.5%</td>
</tr>
<tr>
<td>Decantation</td>
<td>Less than 1.5%</td>
</tr>
</tbody>
</table>

1. Aggregate contained in RAP will not be required to meet these requirements except as shown on the plans.

2. Reclaimed Asphalt Pavement (RAP). RAP is defined as a salvaged, milled, pulverized, broken or crushed asphaltic pavement. The RAP to be used in the mix shall be crushed or broken to the extent that 100 percent will pass the 2 inch sieve.
The stockpiled RAP shall not be contaminated by dirt or other objectionable materials. Do not use RAP if the decantation value exceeds 5% and the plasticity index is greater than 8. Test the stockpiled RAP for decantation in accordance with Tex-406-A, Part I. Determine the plasticity index in accordance with Tex-106-E if the decantation value exceeds 5%. This requirement applies to stockpiled RAP from which the asphalt has not been removed by extraction.

Only RAP from designated sources will be allowed in mixes using more than 25 percent RAP, unless otherwise shown on the plans.

3. Fine Aggregate: Fine aggregates consist of manufactured sands, screenings, and field sands. At most 15 percent of the total aggregate may be field sand or other uncrushed fine aggregate. The fine aggregate shall be that part of the aggregate passing the No. 8 sieve and shall consist of sand and fine aggregate particles from the coarse aggregate material sources or a combination thereof. Sand shall be composed of durable particles free from injurious foreign matter. Screening shall be of the same or similar materials as specified for coarse aggregates. Fine aggregate from each source shall be non-plastic.

<table>
<thead>
<tr>
<th>TEST</th>
<th>REQUIREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasticity Index</td>
<td>Not more than 6%</td>
</tr>
<tr>
<td>Sand Equivalent Value</td>
<td>Not less than 45</td>
</tr>
</tbody>
</table>

4. Mineral Filler: Mineral filler, when required, shall consist of thoroughly dried stone dust, slate dust, portland cement, lime, fly ash or other mineral dust approved by the Engineer. The mineral filler shall be free from foreign matter. Fines collected by bag house or other air cleaning or dust collecting equipment may be permitted as mineral filler in amounts up to two percent of the asphaltic mixture, provided that the portion passing the No. 200 master gradation limit is not exceeded. When these fines are permitted in the asphaltic mixture, they shall be introduced in the same manner prescribed for other mineral fillers.
When mineral filler is permitted by the Engineer, it shall be controlled by a measuring device acceptable to the Engineer.

A hopper or other acceptable storage system shall be required to maintain a constant supply of mineral filler to the measuring device.

Mineral filler shall meet the following gradations, when tested in accordance with TxDOT’s Test Procedure Tex-200-F.

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% PASSING, BY WEIGHT OR VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 8</td>
<td>100</td>
</tr>
<tr>
<td>No. 200, not less than</td>
<td>55</td>
</tr>
</tbody>
</table>

B. Bituminous Material:

Asphalt Binder: Unless otherwise shown on the plans, the asphalt binder shall be PG 64-22, Performance Grade, asphalt binder in accordance with TxDOT’s Item 300, Section 300.2.10, “Performance Graded Binders”, of the Texas Department of Transportation’s, “Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges”, Latest Edition.

C. Tack Coat. Furnish CSS-1H, SS-1H, or a PG binder with a minimum high-temperature grade of PG 58 for tack coat binder in accordance with TxDOT’s Item 300, “Asphalts, Oils, and Emulsions.” Specialized or preferred tack coat materials may be allowed or required when shown on the plans. Do not dilute emulsified asphalts at the terminal, in the field, or at any other location before use.

The Engineer will obtain at least one sample of the tack coat binder per project in accordance with Tex-500-C, Part III, and test it to verify compliance with Item 300, “Asphalts, Oils, and Emulsions.” The Engineer will obtain the sample from the asphalt distributor immediately before use.

D. Additives: Additives to facilitate mixing and/or improving the quality of the asphaltic mixture shall be used when noted on the plans or in the specifications. It may be used with written permission of the Engineer. If lime or a liquid antistripping agent is used, then add in accordance with, Item 301 “Asphalt Antistripping Agent”, in the
250.3 Mixtures.

A. General: The paving mixture shall consist of a uniform mixture of:

1. coarse aggregate,
2. fine aggregate,
3. asphaltic material binder.

If required, the paving mixture may also include any or all of the following:

1. RAP,
2. mineral fillers,
3. additives.

B. The supplier of the black base shall submit a proposed mixture design report, which conforms to all the requirements of this Item, for verification by the Engineer. Include the following items in the mixture design report:

1. The combined aggregate gradation, source, specific gravity, and percent of each material used.
2. Plotted job-mix gradation on a gradation chart with sieve sizes raised from 0.45 power. This plot must show that the proposed gradation of the job-mix formula is within the limits of master gradation.
3. Results of all applicable tests.
4. Signature of the Level II person or persons who performed the design.
5. Date the mixture design was performed, and a unique identification number for the mixture design.

Approval of the proposed design, by the County, will require that the supplier maintain the source and quality of aggregates
proposed throughout production and changes which require modification of the proposed mix design shall require the written approval of the Engineer. The supplier of the black base shall follow the established job mix formula both as to asphalt content and gradation.

The grading of each constituent shall be such as to produce, when properly proportioned, a mixture conforming to the following limitations for grading for the type specified. The exact proportions of each constituent producing the total aggregate within these limits shall meet the following requirements:

**TABLE 1**

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% PASSING, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2 Inch</td>
<td>100</td>
</tr>
<tr>
<td>1 Inch</td>
<td>90 – 100</td>
</tr>
<tr>
<td>3/8 Inch</td>
<td>45 – 70</td>
</tr>
<tr>
<td>No. 4</td>
<td>30 – 55</td>
</tr>
<tr>
<td>No. 40</td>
<td>15 – 30</td>
</tr>
</tbody>
</table>

**TABLE 2**

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% PASSING, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2 Inch</td>
<td>100¹</td>
</tr>
<tr>
<td>1 Inch</td>
<td>98 – 100</td>
</tr>
<tr>
<td>3/4 Inch</td>
<td>84 – 98</td>
</tr>
<tr>
<td>3/8 Inch</td>
<td>60 – 80</td>
</tr>
<tr>
<td>No.4</td>
<td>40 – 60</td>
</tr>
<tr>
<td>No. 8</td>
<td>29 – 43</td>
</tr>
<tr>
<td>No. 30</td>
<td>13 – 28</td>
</tr>
<tr>
<td>No. 50</td>
<td>6 – 20</td>
</tr>
<tr>
<td>No. 200</td>
<td>2 – 7</td>
</tr>
</tbody>
</table>
1. Defined as maximum sieve size. No tolerance allowed.

Testing for gradation shall be in accordance with TxDOT’s Test Procedure Tex-200-F, Latest Edition.

The gradation of the material produced shall not vary from the designated grading limits for any sieve size by more than plus/minus 5 percent by weight, based on total mixture, for sieve sizes greater than or equal to the No. 8 and plus/minus 3 percent for sieve sizes less than the No. 8. The average asphalt content shall not vary from the optimum asphalt content tolerance determined from the approved job mix design, by more than plus/minus 0.3 percent.

Laboratory density and stability of the mixture when designed and tested, during production, in accordance with these Standard Specifications and the test procedures outlined in the Latest Edition of Texas Department of Transportation’s “Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges” shall meet the following physical properties:

<table>
<thead>
<tr>
<th>LAB DENSITY, PERCENT</th>
<th>HVEEM STABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>94%</td>
<td>98%</td>
</tr>
</tbody>
</table>

Stability and density tests are intended for control tests. If the laboratory stability and/or density of the mixture produced has a value lower than that specified and in the opinion of the Engineer is not due to a change in source or quality of materials, production may proceed with consequent changes in the mix until the laboratory stability and density equals or exceeds the specified values. If, in the opinion of the Engineer, there is a change in the source, types, or quality of material from that used in the design mixture, production will be discontinued until a new design mixture is determined by trial mixes and the Contractor shall pay all costs of redesigning the mix. The Contractor may submit a new mixture-design at any time during the project. The compacted thickness of the mixture or mixtures used shall be as specified by the plans or specifications. The specific test method to be used in this specification is listed in Section 250.4. The supplier’s daily QA/QC test results shall be forwarded to Harris County’s Material Engineer, on a daily basis.
C. Extraction or Ignition Test: The percentage of asphalt binder in any mixture shall not vary from the proportion established by the job mix formula.

When required by the Engineer, samples of the hot mixture may be taken at the plant or from the trucks or from the finished pavement. The location of sampling of the mixture shall be in accordance with ASTM D979 “Standard Practice for Sampling Bituminous Paving Mixtures.” When tested in accordance with ASTM D2172 “Standard Test Methods for Quantitative Extraction of Asphalt Binder from Asphalt Mixtures,” or TxDOT’s: Tex-236-F and Tex-200-F, the average of the results of the aggregate gradations and asphalt content shall not vary from the values established in the job mix formula. Provide the Engineer with split samples of the mixtures and blank sample used to determine the ignition oven correction factors. TxDOT’s Test Procedure, Tex-236-F should be used to determine the aggregate and asphalt correction factors from ignition oven.

The mix shall be designed in accordance with Texas Department of Transportation’s Test Procedure Tex-204-F "Design of Bituminous Mixtures" to conform with the requirements of this Item, with the exception that the laboratory density will be determined as a percentage of the mixture theoretical maximum density. The theoretical maximum specific gravity shall be determined in accordance with Texas Department of Transportation’s Test Procedure Tex-227-F "Theoretical Maximum Specific Gravity of Bituminous Mixtures" on trial samples at each asphalt content. The optimum asphalt binder content will correspond to 96 percent laboratory density provided the mixture satisfies the minimum Hveem stability of 35 percent.

D. Stock Pile Gradations: Once a job mix design has been established in accordance with the Latest Edition of Texas Department of Transportation’s Test Procedure Tex-204-F "Design of Bituminous Mixtures", the coarse aggregate delivered to the stockpiles shall not vary on any grading size fraction by more than plus or minus 8 percentage points from the percentage found in the samples submitted by the Contractor and upon which the job mix design was based. The intent of this requirement is to insure consistency and uniformity of the asphaltic mixture produced in the drum mix plant. Should the gradation of coarse aggregates in the stockpiles vary by more than the allowed tolerance, the Engineer may stop the production and may require that new aggregate be furnished to the stockpiles that meet the gradations of the aggregates submitted for the design mix formula.
E. Tolerances: If the paving mixture produced varies from the job-mix formula gradation and/or asphaltic material content by more than the tolerances and restrictions, proper changes shall be made until the mixture meets the requirements, as directed by the Engineer.

250.4 Test Methods.

Testing of Materials: The Engineer will perform random tests to determine if the materials and construction procedures produce a product which meets the contract documents. The specific test methods for material analysis are outlined in the following Tables.

A. Testing of mineral aggregates shall be in accordance with the following ASTM standard laboratory test procedures:

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling Aggregates</td>
<td>ASTM D75 &quot;Standard Practice for Sampling Aggregates&quot;</td>
</tr>
<tr>
<td>Sieve Analysis</td>
<td>TxDOT's Test Procedure Tex-200-F &quot;Sieve Analysis of Fine and Coarse Aggregates&quot;</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>ASTM C127 &quot;Standard Test Method for Relative Density (Specific Gravity), and Absorption of Coarse Aggregate&quot;</td>
</tr>
<tr>
<td></td>
<td>ASTM C128 “Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate”</td>
</tr>
</tbody>
</table>
### Property Test Method

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Equivalent</td>
<td>ASTM D2419 “Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate” or TxDOT’s Test Procedure Tex-203-F “Sand Equivalent Test”</td>
</tr>
<tr>
<td>Deleterious Materials</td>
<td>TxDOT’s Test Procedure Tex-217-F “Determining Deleterious Material and Decantation Test for Coarse Aggregates” Part I</td>
</tr>
<tr>
<td>Decantation</td>
<td>TxDOT’s Test Procedure Tex-217-F “Determining Deleterious Material and Decantation Test for Coarse Aggregates” Part II</td>
</tr>
</tbody>
</table>

### B. Performance Graded Binders, PG binders must be smooth and homogeneous material which will not foam when heated to 350˚F and meet the requirements of Section 300.2.10 “Performance Graded Binders” of TxDOT Specification Item 300, Latest Edition.

Testing of bituminous mixtures shall be in accordance with the following standard laboratory test procedures:

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling Bituminous Mixtures</td>
<td>TxDOT’s Test Procedure Tex-222-F &quot;Sampling Bituminous Mixtures” or ASTM D979 “Standard Practice for Sampling Bituminous Paving Mixtures”</td>
</tr>
<tr>
<td>PROPERTY</td>
<td>TEST METHOD</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Molding of Specimens</td>
<td>TxDOT's Test Procedure Tex-206-F &quot;Compacting Specimens Using the Texas Gyratory Compactor (TGC)&quot;</td>
</tr>
<tr>
<td>Height of Specimens</td>
<td>ASTM D3549 &quot;Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens&quot;</td>
</tr>
<tr>
<td>Bulk Density of Specimens</td>
<td>TxDOT's Test Procedure Tex-207-F &quot;Determining Density of Compacted Bituminous Mixtures&quot;</td>
</tr>
<tr>
<td>HVEEM Stability</td>
<td>TxDOT's Test Procedure Tex-208-F &quot;Test for Stabilometer Value of Bituminous Mixtures&quot;</td>
</tr>
<tr>
<td>Maximum Theoretical Density</td>
<td>TxDOT's Test Procedure Tex-227-F &quot;Theoretical Maximum Specific Gravity of Bituminous Mixtures&quot;</td>
</tr>
<tr>
<td>Method of Mix Design</td>
<td>TxDOT's Test Procedure Tex-204-F &quot;Design of Bituminous Mixtures&quot;</td>
</tr>
<tr>
<td>Extraction</td>
<td>TxDOT's Test Procedure Tex-210-F, &quot;Determining Asphalt Content of Bituminous Mixtures&quot; or TxDOT's Test Procedure Tex-236-F &quot;Determining Asphalt Content from Asphalt Paving Mixtures by the Ignition Method&quot;</td>
</tr>
</tbody>
</table>
250.5 Equipment. Provide equipment to produce, haul, place, and compact asphalt pavement, that complies with requirements of the Latest Edition of Item 320 “Equipment for Asphalt Concrete Pavement” and in the Texas Department of Transportation’s “Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges” (hereinafter referred to simply as “TxDOT’s Specifications”).

The Engineer, or his authorized representative, shall have access at any time to all parts of the paving plant.

250.6 Heating and Discharge of Materials.

A. Heating of Materials: Do not heat the asphalt binder above the temperatures specified in Item 300 “Asphalts, Oils, and Emulsions”, of TxDOT’s Specifications, Latest Edition; or outside the manufacturer’s recommended values. On a daily basis, provide the engineer with records of asphalt binder and hot-mix asphalt discharge temperatures in accordance with Item 320, “Equipment for Asphalt Concrete Pavement”, of TxDOT’s Specifications, Latest Edition.

B. Mixing and Discharge of Materials: Notify the Engineer of the target discharge temperature and produce the mixture within 25°F of the target. Monitor the temperature of the material in the truck before shipping to ensure that it does not exceed 350°F. Harris County will not pay for or allow placement of any mixture produced at more than 350°F.

Control the mixing time and temperature so that substantially all moisture is removed from the mixture before discharging from the plant. If requested, determine the moisture content by oven drying in accordance with TxDOT’s Test Procedure, Tex-212-F, Part II, and verify that the mixture contains no more than 0.2 percent of moisture by weight. Obtain the sample immediately after
discharging the mixture into the truck, and perform the test promptly.

250.7 Asphalt Mixing Plants. Mixing plants may be either the weigh batch type, or the drum mix type. Both types of plants shall be equipped with satisfactory conveyors, power units, aggregate handling equipment, bins and dust collectors, etc. and comply with the requirements of the Latest Edition of TxDOT’s, Specification Item 320 “Equipment for Asphalt Concrete Pavement”.

250.8 Spreading and Finishing Machine. The spreading and finishing machine shall conform to the requirements of the Latest Edition of TxDOT’s Specification, Item 320 “Equipment for Asphalt Concrete Pavement”, and as specified herein:

The spreading and finishing machine shall be of a type approved by the Engineer and shall be capable of producing a surface that will meet the requirements of the typical cross-section and the surface test, when required by the Engineer, and when the mixture is dumped directly into the finishing machine shall have adequate power to propel the delivery vehicles in a satisfactory manner. The finishing machine shall be equipped with a flexible spring and/or hydraulic type hitch sufficient in design and capacity to maintain contact between the rear wheel of the hauling equipment and the pusher rollers of the finishing machine while the mixture is being unloaded. The paver shall have a receiving hopper of sufficient capacity for a uniform spreading operation.

The hopper shall be equipped with a distribution system to place the mixture uniformly in front of the screed. The screed or strike-off assembly shall produce a surface of the required evenness and texture without tearing, shoving, gouging or displacing the mixture.

The use of any vehicle which requires dumping directly into the finishing machine and which the finishing machine cannot push or propel in such a manner as to obtain the desired lines and grades without resorting to hand finishing will not be allowed. Unless waived by the Engineer, automatic screed controls will be required for asphaltic concrete spreading and finishing machines.

Asphaltic-concrete spreading and finishing machines shall be equipped with an approved automatic dual longitudinal screed control system and a transverse screed control system. The longitudinal controls shall be capable of operating from any longitudinal grade reference including a stringline, 40 foot ski, mobile stringline or matching shoe. The asphaltic concrete spreading and finishing machine shall be equipped with a screed heater and vibrator.
The Contractor shall furnish all equipment required for grade reference. It shall be maintained in good operating condition by personnel trained in the use of this type of equipment. The equipment shall be capable of constructing a finished surface within specified tolerances.

The automatic grade control device shall produce a finished surface meeting the requirements of the surface test on the items of work for which a spreading and finishing machine is required. Skin-patching will not be permitted unless approved by the Engineer and any section of pavement not meeting the minimum tolerance shall be corrected at the Contractor's expense.

The spreader shall be capable of spreading and finishing courses of bituminous plant mix material in lanes not less than 10 feet in width and shall be capable of operating at forward speeds consistent with the satisfactory laying of the mixture.

The asphaltic mixture, when placed with a spreading and finishing machine, shall not be placed unless the air temperature is at least 40°F and rising. The air temperature shall be taken in the shade away from artificial heat. Asphalt shall not be placed when the temperature of the surface on which the mat is to be placed is below 60°F.

It is further provided that the asphaltic mixture shall be placed only when the humidity, general weather conditions and temperature and moisture condition of the base, in the opinion of the Engineer, are suitable.

250.9 Transporting Asphaltic Concrete. The asphaltic concrete mixture, heated and prepared as specified, shall be hauled to the work site in tight vehicles previously cleaned of all foreign material.

The dispatching of the vehicles shall be arranged so that all material delivered may be placed and all rolling shall be completed during daylight hours. Cover each truck load of mixture with waterproof tarpaulins. The inside of the trucks body may be given a light coating of, lime slurry or other approved release agent to prevent the mixture from adhering to the body. A hole for inserting a thermometer shall be installed in the truck body. Truck beds shall be clean before they are loaded with asphalt. If, in the opinion of the Engineer, the truck bed is damaged, it shall be removed from the project.

250.10 Lay-Down Operations.

A. Minimum Mixture Placement Temperatures. Use Table below for suggested minimum mixture placement temperatures.
SUGGESTED MINIMUM MIXTURE PLACEMENT TEMPERATURE

<table>
<thead>
<tr>
<th>HIGH-TEMPERATURE BINDER GRADE</th>
<th>MINIMUM PLACEMENT TEMPERATURE (Before Entering Paver)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 64 or lower</td>
<td>260°F</td>
</tr>
<tr>
<td>PG 70</td>
<td>270°F</td>
</tr>
<tr>
<td>PG 76</td>
<td>280°F</td>
</tr>
<tr>
<td>PG 82 or higher</td>
<td>290°F</td>
</tr>
</tbody>
</table>

B. Windrow Operations. When hot mix is placed in windrows, operate windrow pickup equipment so that substantially all the mixture deposited on the roadbed is picked up and loaded into the paver.

C. Placing. The Contractor shall have the option of placing material in either one or more lifts, in order to maintain uniform compaction. Lifts shall not exceed 4 inches in thickness. Tack Coat shall be required between lifts. Tack Coat shall conform to Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”, Section 340.10.

The asphaltic mixture shall be placed and spread on the approved prepared surface with the specified spreading and finishing machine, in such a manner that when properly compacted the finished pavement will be smooth, of the required density and will meet the requirements of the typical cross-sections and the surface tests. During the application of asphaltic material, care shall be taken to prevent splattering of adjacent pavement, curb and gutter and structures.

When the asphaltic mixture is placed in a narrow strip along the edge of an existing pavement, or used to level up small areas of an existing pavement, or placed in small irregular areas where the use of a finishing machine is not practical, the finishing machine may be eliminated, provided a satisfactory surface can be obtained by other approved methods.

Adjacent to flush curbs, gutters, liners and structures, the surfaces shall be finished uniformly high so that when compacted it will be slightly above the edge of the gutter and flush to the structure.

250.11 Compaction. The pavement shall be compacted thoroughly and uniformly with the necessary rollers to obtain the density, stability and cross-section
of the finished paving mixture meeting the requirements of the plans and specifications.

Rolling equipment shall consist of pneumatic tire and steel wheel rollers. Breakdown rolling shall be accomplished immediately after placing, using steel wheel rollers. Vibratory rollers will not be permitted unless prior approval is obtained from the Engineer and unless the equipment is operated by personnel who are properly certified to operate this equipment.

All equipment shall be in good mechanical condition, properly adjusted and free from wear that would impair the quality of the work. Necessary precautions shall be taken to prevent the dropping of gasoline, oil, grease or other foreign matter on the pavement, by the compaction, or any equipment.

Pneumatic tire rollers shall have tires of equal size and diameter capable of exerting an average contact pressure varying from 40 to 90 psi, by adjusting ballast and/or tire pressure. All tires shall have equal pressure. The wheels will be placed so that one pass will accomplish one complete coverage equal to the width of the roller with a minimum of 1/4 inch overlap. The wheels shall not wobble. The operating weight and tire pressure shall be as such as to provide the required density. The rollers shall be in the best mechanical condition. Pneumatic tire rollers shall be equipped with water systems and fiber mats.

Steel wheel rollers shall be a three wheel two-axle tandem (bull wheel) or three-axle tandem roller weighing not less than 8 tons and developing compression in the rear wheels of not less than 250 pounds per inch of roller width. The rollers shall have power units and be equipped with scrapers to keep the wheels clean and with the means of keeping the wheels wet, to prevent mixes from sticking to the rollers.

Vibratory rollers shall have a minimum of one vibratory drum weighing no less than 8 tons. The vibratory roller shall be capable of obtaining frequency and amplitude combinations that will produce an impact spacing smaller than the thickness of the mat, or a minimum of 8 to 10 blows per foot.

All rolling with any type of roller shall be done as directed by the Engineer. Breakdown (initial pass) rolling shall be conducted with a steel wheel roller or vibratory roller, intermediate rolling shall be conducted with a steel-wheel roller or pneumatic-tired roller and finished rolling shall be conducted with a steel wheel roller or pneumatic-tired roller unless directed otherwise by the Engineer. When rolling with vibratory steel
wheel rollers, the manufacturer's recommendation shall be followed, unless otherwise directed by the Engineer.

The specific rollers used in sequence to obtain the required compaction shall be approved by the Engineer. The ambient temperature, humidity, wind velocity, temperature of existing surface, mat thickness, and temperature of paving mixture shall be considered by the Engineer in determining the type and amount of rollers needed to achieve the required compaction. Approval of the Engineer will not relieve the Contractor of his responsibility to produce the required density.

Rolling pattern shall be established daily and verified as outlined in Test Procedure Tex-207-F, Part IV and III respectively, to achieve the required air void content. The daily established rolling pattern used is subject to approval by the Engineer. The daily established rolling pattern shall be followed unless changes in the mixture or placement conditions occur which affect compaction. A new rolling pattern will be established at this time. If required, test strips approximately 300-500 feet in length shall be established to determine proper rolling patterns. A maximum of two strips will be allowed. If the required rolling patterns cannot be determined that will give the required density with two strips, the first two strips will be removed, before the third strip is constructed.

The mixture shall be placed at a temperature of between 260°F and 325°F. Rolling shall begin as soon as the paving mixture will not be displaced laterally by the weight of the roller. When rolling with the steel-wheel, pneumatic-tired roller or vibratory roller, longitudinal joints shall be rolled initially, however rolling shall begin at the low side of the pavement and proceed toward the higher side of the pavement, overlapping on successive trips by at least half the width of the rear wheel unless otherwise directed by the Engineer. Alternate trips of the roller shall be a minimum of six inches difference in length. The motion of the roller shall be slow enough at all times to avoid displacement of the mixture. To prevent adhesion of the surface mixture to the roller, the rollers shall be kept thoroughly moistened with water, but an excess of water will not be permitted. The roller shall not be allowed to stand on pavement which has not been fully compacted. If any displacement occurs, it shall be repaired at once by the use of rakes, and fresh mixture where required, any repair is subject to the Engineer's approval.

The maximum roller speed for any compaction equipment shall comply with the following table unless directed otherwise by the Engineer. The speed of the roller shall, at all times, be slow enough to avoid displacement of the hot mixture and shall not be greater than the speed indicated below.
MAXIMUM ROLLING SPEEDS
TYPE OF ROLLING

<table>
<thead>
<tr>
<th>COMPACTOR</th>
<th>BREAKDOWN (miles/hr)</th>
<th>INTERMEDIATE (miles/hr)</th>
<th>FINISH (miles/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Wheel Roller</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Pneumatic-tire Roller</td>
<td>-</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Vibratory Roller</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Rolling shall be continued until required compaction can be obtained and all roller marks are eliminated. Complete all compaction operations before the pavement temperature drops below 160°F unless otherwise allowed. The Engineer may allow compaction with a light finish roller operated in static mode for pavement temperatures below 160°F.

Rolling with a trench type roller will be required on widening areas in trenches and other limited areas where satisfactory compaction cannot be obtained with the rollers specified or approved.

The roller must not stand on the compacted pavement which has not cooled to normal atmospheric temperature. To prevent adhesion of the paving mixtures to the rollers, the wheels shall be kept properly moistened with water; however, excess water will not be permitted.

If, in the opinion of the Engineer, the asphaltic concrete surface course is not being properly compacted, specimens shall be taken to determine the density of the asphaltic concrete at various locations.

Density of the completed asphaltic concrete shall be uniform over the entire roadway area. The Engineer may have the material (part or all) removed and replaced on areas where density is found not to be that specified, when tested. The entire cost of removing and replacing material from areas because of unacceptable density variations shall be borne by the Contractor and at no cost to the County.

Hand Tamping: The edges of the pavement along curbs, headers and similar structures, and all places not accessible to the roller, or in such positions as will not allow thorough compaction with the rollers, shall be thoroughly compacted with lightly oiled tamps.

Compaction Criteria. In place compaction methods used to obtain the required density necessary to gain the Engineer’s approval shall be divided into Type A or Type B construction.
Type A construction shall represent asphalt being laid over New Construction, that is, all phases of construction beginning at the sub-base level and ending with the asphalt surface mix shall be New Construction.

Type B construction shall represent asphalt being laid over in-situ material or base repair, that is, all asphalt overlay, level-up, base repair, cold in-placed recycled asphalt or hot in-placed recycled asphalt. For all base repairs used to construct an asphalt overlay and level-up the gradation of composite aggregate shall be as shown in Table 1. However, all base repairs used to construct hot in-placed recycled asphalt, the gradation of the composite aggregate shall be as shown in Table 2.

Type A:

In place compaction control is required of all paving mixtures. Asphaltic concrete shall be placed and compacted to obtain from 3 to 8 percent air voids. Do not increase the asphalt content of the mixture to reduce pavement air voids. In no case shall the compacted roadway specimen have air voids in excess of 8 percent. The Contractor shall establish a rolling pattern as outlined in Test Procedure Tex-207-F, Part IV, to achieve the required air void content. The Contractor shall confirm compaction as outlined in Test Procedure Tex-207-F, Part III, through nuclear density testing supplied by the laboratory retained by Harris County. The target density can be established daily and verified with a nuclear density gauge as outlined in Tex-207-F, Part IV and III, respectively. It is recommended that the Thin Lift Asphalt Gauge be used, however other nuclear equipment may be used with prior approval of the Engineer as long as proper correlation is performed and correlation proof is maintained and kept with the gauge at all times. The Contractor shall understand that all nuclear density testing is performed only as an aid to construction, and the Engineer’s approval will not relieve the Contractor of his responsibility to produce the required density. Acceptance of the asphalt by Harris County shall be by the acceptable core density and other methods of determining in-place density, which correlate satisfactorily with results obtained from roadway specimens, may also be used when approved by the Engineer. Correlation of average nuclear gauge readings to core density results shall be performed after each day’s production, as outlined herein after. The Laboratory Technician shall continue to check and verify the rolling pattern by use of nuclear equipment every 100 feet, at a minimum and mark core locations every 500 feet, at center of alternate lane. For Parking Lots, every 1,100 square yards, take 4 nuclear gauge readings at each marked core location. Cores shall be taken the same day, or no later than the beginning of the next day. Core locations must be back filled and compacted with similar pavement material. The in-place density and air void shall be measured in accordance with Test
Procedures Tex-207-F and Tex-227-F. Correlation of average nuclear gauge density reading to core density results shall be established for the cores taken daily and forwarded to Harris County on a daily basis. This process will continue for each day’s placement, until the Engineer determines that a good bias has been established for that nuclear gauge. Then the same nuclear gauge should be utilized to establish and verify the in-place densities afterward. The specific rolling pattern used is subject to approval by the Engineer. The daily established rolling pattern shall be followed unless changes in the mixture or placement conditions occur which affect compaction. A new rolling pattern will be established at this time. If required, test strips approximately 300-500 feet in length shall be established to determine proper rolling patterns. A maximum of two strips will be allowed. If the required rolling patterns cannot be determined that will give the required density, with two strips, then the first two strips will be removed, before the third strip is constructed.

Type B:

The Contractor shall establish a rolling pattern as outlined in Test Procedure Tex-207-F, Part IV, to achieve an acceptable density. The Contractor shall confirm compaction as outlined in Test Procedure Tex-207-F, Part III, through nuclear density testing supplied by the Laboratory retained by Harris County. The target density shall be established and controlled with a nuclear gauge as outlined in Tex-207-F, Part IV and III respectively. It is recommended that the Thin Lift Asphalt Gauge be used, however other nuclear equipment may be used with prior approval of the Engineer. The Laboratory Technician shall continue to check and verify the rolling pattern by use of nuclear equipment, at a minimum of every 100 feet per lane. Acceptance of the asphalt by Harris County shall be upon receiving final reports from the Material Engineer verifying Mix Design and Conformance to the Rolling Pattern. Cores shall not be taken for densities unless otherwise directed by the Engineer. Cores will be used to verify depth as required. The daily established rolling pattern used is subject to approval by the Engineer. The daily established rolling pattern shall be followed unless changes in the mixture or placement conditions occur which affect compaction. A new rolling pattern will be established at this time.

250.13 Construction Joints. Placing of the surface course shall be as nearly continuous as possible, and the roller shall pass over the unprotected end of the freshly laid mixture only when the laying of the course is discontinued for such length of time as to permit the mixture to become chilled. In all such cases, when the work is resumed, the material laid shall be cut back so as to produce a slightly beveled edge for the full thickness of the course.
The old material which has been cut away shall be removed from the work site, and the new mix laid against the fresh cut.

When the work is resumed, the materials laid shall be cut back to a point where material is full depth, which will be removed altogether with the surplus material, and the fresh mix laid against the joint thus formed.

Hot smoothing irons may be used for sealing joints, but in such cases extreme care shall be exercised to avoid burning the surface. Any unevenness indicated by a 10 foot straight edge laid perpendicular to the joint, immediately after final rolling, shall be corrected at that time.

250.14 Irregularities. Immediately take corrective action if surface irregularities, including but not limited to segregation, rutting, raveling, flushing, fat spots, mat slippage, color, texture, roller marks, tears, gouges, streaks, or uncoated aggregate particles, are detected. The Engineer may suspend production or placement operations until the problem is corrected. At the expense of the Contractor and to the satisfaction of Engineer, remove and replace any mixture that does not bond to the existing pavement or that has other surface irregularities identified above.

250.15 Surface Requirements. The final surface of the pavement after compaction shall be smooth and true to the established line and grade and typical cross-sections shown on the plans and, when tested with a standard 10 foot or 16 foot straightedge laid parallel to the centerline of the roadway, shall have no deviation in excess of 1/8 inch per foot for a 16 foot straightedge or 1/16 inch per foot for a 10 foot straightedge from the nearest point of contact and the maximum ordinate measured from the face of the straightedge shall not exceed 1/4 inch at any point. Any areas of the surface not meeting these requirements shall be immediately corrected as directed. Tests shall be made at transverse construction joints out at randomly selected locations.

250.16 Opening to Traffic. Allow the compacted pavement to cool before opening to traffic unless directed by the Engineer. If the surface ravels or deteriorates in any manner, it will be the Contractor's responsibility to correct this condition at his expense.

250.17 Measuring Devices. All templates, straight edges, and measuring devices necessary for the proper construction and checking of the work shall be furnished, operated and maintained by the Contractor at his entire expense.

250.18 Quality Assurance. The County will engage a Testing Firm to provide quality assurance services for Hot Mix Asphaltic Concrete (Black Base).
The Testing Firm will sample and test stockpiles for gradation, in accordance with TxDOT’s Test Procedure Tex-200-F and deleterious materials and decantation in accordance with TxDOT’s Test Procedure Tex-217-F (Parts I and II) for each 3,000 tons production. The abrasion loss of the material shall be determined in accordance with ASTM C131, for each 4,000 tons of production.

Asphalt binder will not be sampled and tested, provided that the supplier will provide copies of test results for PG-grade binder used for the project. Undocumented asphalt binder will require sampling and testing in accordance with ASTM D3381 “Standard Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction” and AASHTO Method T-102 or Tex-540-C and shall meet the requirements of, “Performance Graded Binder”, Item 300 of TxDOT’s Specifications, Latest Edition. The Contractor will be responsible for the cost of these tests. The Engineer may verify the quality of the asphalt binder at any time, by sampling and testing, in accordance with the aforementioned methods.

The mixture shall be sampled, for each 400 (cumulative) tons of production and the following tests will be made for each sample of the mixture.

<table>
<thead>
<tr>
<th>TEST</th>
<th>DESIGNATION</th>
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<tbody>
<tr>
<td>Laboratory Density</td>
<td>Tex-207-F</td>
</tr>
<tr>
<td>Maximum Theoretical Density</td>
<td>Tex-227-F</td>
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<tr>
<td>Hveem Stability</td>
<td>Tex-227-F</td>
</tr>
<tr>
<td>Extraction and Gradation</td>
<td>Tex-210-F or Tex-236-F</td>
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</tbody>
</table>

Based on daily and total production, Harris County may waive the sampling and laboratory testing.

Type A:

Following compaction of the mixture in the pavement, the Laboratory representative shall sample the pavement by cutting cores and determining the in-place density in accordance with TxDOT’s Procedure Tex-207-F, and air voids as outlined in Section 250.12 of this Item. Additional samples and/or tests will be taken to provide quality assurance only when approved by the Engineer.

Type B:

Construction shall be acceptable by Harris County upon receiving final reports from the Materials Engineer verifying Mix Design and conformance to the rolling pattern.
250.19 Truck Scales. A set of standard platform truck scales will be placed at the plant and shall be provided with a suitable weigh office adjacent to the scales for the use of the trucks weigher. Scales which are not accurate to within 4 pounds per 1,000 pounds total load shall not be used. Scales shall meet the requirements of the Item 520 “Weighing and Measuring Equipment”.

250.20 Measurement. Hot mix asphaltic concrete base course, as specified by this Item, shall be measured by the ton of 2,000 pounds. Measurement by weight shall be made on truck scales as previously specified. Records shall be kept on the tare weight, total weight and net weight of asphaltic concrete for each load of same. A day ticket shall accompany each load to the job site, indicating the net weight, gross weight, tare weight, and road name. The asphaltic material for tack coat will be measured at the point of delivery on the road in gallons at the applied temperature. The quantity to be paid for shall be the number of gallons used, as directed, for the tack coat.

250.21 Payment shall be made as follows:

A. Where the bid sheet specifies FOB the job site, the asphaltic concrete shall be transported to the job site in Harris County specified on the bid sheet, and unloaded at the location indicated.

B. Where the bid sheet specifies FOB the plant, the material shall be loaded on Harris County vehicles.

C. The "Hot Mix Asphaltic Concrete Base Course" furnished and placed as prescribed by this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Hot Mix Asphaltic Concrete Base Course", which price shall be full compensation for furnishing all materials, for all freight involved, for all heating, mixing, hauling, cleaning the subgrade, placing asphaltic concrete mixture, rolling and finishing; for all manipulations, labor, tools, equipment and incidentals necessary to complete the work.

D. The work performed and materials furnished for "Tack Coat" and measured as provided for under measurement will be paid for at the contract unit price bid for "Tack Coat" as provided in Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”, of the type specified, which price shall be full compensation for cleaning the area or subgrade; for furnishing, heating, hauling and distributing the asphaltic material as specified; for all freight involved; for all manipulation,
labor, tools, equipment and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 340 “Hot Mix-Hot Laid Asphalitic Concrete”
Item 520 “Weighing and Measuring Equipment”

END OF ITEM 250
ITEM 251

BASE REPAIR WITH HOT MIX ASPHALTIC CONCRETE BASE COURSE

251.1 Description. This Item shall govern for scarifying, loading and disposing of existing asphaltic surface and base materials and the furnishing and placing of hot mix asphaltic concrete base (black base), on the approved subgrade.

251.2 Materials. Black base shall be in accordance with Item 250 "Hot Mix Asphaltic Concrete Base Course (Black Base)".

The asphaltic material shall conform to Item 300 "Asphalts, Oils, and Emulsions" of the Texas Department of Transportation Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges, Latest Edition.

251.3 Construction Methods. The existing asphaltic surface and flexible base material shall be removed for its full depth and to the dimensions and at the locations directed by the Engineer. The surface and base material shall be removed in such a manner as not to disturb the underlying subgrade.

Unless otherwise directed by the Engineer, the Contractor shall not consider pitted (small surface failures) areas as base repair. These areas shall be cleaned out and leveled up with the level-up course. This work is considered subsidiary to this Item and shall not be paid for separately.

Base repair shall consist of saw-cutting or other approved cutting method, scarifying and disposing of asphalt surface and base material to a depth equal to the bottom of existing base but not less than eight inches (8"). The areas of repair shall be cut in square or rectangular shape with faces free of loose material. One pair of faces shall be at right angles to the alignment of the proposed roadway. Repair areas shall extend at least 12 inches horizontally, into the existing base and/or subgrade.

The black base shall be placed and compacted in lifts not to exceed four (4) inches.

During the time period from April 15th to October 16th, of each year, the asphaltic material used for tack coat shall be either SS-1, anionic slow setting emulsion or CSS-1, cationic slow setting emulsion. During the remainder of the year, the asphaltic material shall be RC-250, rapid curing cutback asphalt.
Tack coat shall be applied to the vertical faces at the rate of 0.10 gallons per square yard, or as directed by the Engineer.

251.4 Measurement. Base repair with hot mix asphaltic concrete base material (black base), as specified by this Item, shall be measured by the ton of 2,000 pounds. Measurement by weight shall be made on truck scales as specified in Item 250 “Hot Mix Asphaltic Concrete Base Course (Black Base)”. Records shall be kept on the tare weight, total weight and net weight of asphaltic concrete. The asphaltic material for tack coat shall not be measured and paid for, but shall be considered subsidiary to the bid item for black base.

251.5 Payment. Base repair with hot mix asphaltic concrete base material, furnished and placed, and measured as provided above, shall be paid for at the unit price bid per ton. This price shall be full compensation for tack coat, saw-cutting or other approved cutting method, scarifying, removing, disposing of pavement materials, preparation of subgrade, furnishing all materials, placing asphaltic concrete mixture, compaction and finishing and for all manipulations, labor, tools, equipment and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 250 "Hot Mix Asphaltic Concrete Base Course (Black Base)"

END OF ITEM 251
ITEM 252

IN-PLACE FULL DEPTH COLD FLEXIBLE PAVEMENT RECYCLING

252.1 Description. This Item shall govern for a stabilized base course composed of a mixture of the existing bituminous concrete pavement, the existing base course material, any required new material and an admixture. The manufacture of the stabilized base course shall be done by in-place pulverizing and blending of the existing pavement and base materials and the introduction of additives, if called for. Additives may be in the liquid or dry form.

252.2 Materials. The additive shall be of the type called for on the drawings or in the proposal.

Asphalt emulsions and cutback asphalts, when used, shall meet the requirements of the TxDOT “Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges” Item 300 "Asphalts, Oils and Emulsions”, Latest Edition (hereinafter called simply “TxDOT Item 300”).

Portland cement shall be in accordance with Item 222 "Portland Cement Stabilized Subgrade". Lime shall be in accordance with Item 221 "Hydrated Lime and Lime Slurry", or Item 224 "Quicklime (Stabilization)". Fly ash shall be in accordance with Item 223 "Lime-Fly Ash or Fly Ash Stabilized Subgrade".

Water shall meet the requirements of ASTM C94 “Standard Specification for Ready-Mixed Concrete”.

When new materials are added, black base shall meet the requirements of Item 250 "Hot Mix Asphaltic Concrete Base Course (Black Base)" and granular materials shall meet the requirements of Item 230 "Crushed Aggregate Base Course".

252.3 Equipment. The Contractor shall furnish a self-propelled machine capable of pulverizing the existing materials to minimum depth of 10 inches, in one pass.

The equipment shall be of sufficient size, equipped with uniform blades and be capable of obtaining a uniform blend of existing and added materials. The equipment shall be capable of producing the gradation indicated herein, or additional screening and crushing will be required. The equipment must also be capable of mixing the pulverized material
and additive to a homogeneous mixture. The method of depositing the mixed material shall be such that segregation does not occur. The mixing equipment used shall be a Bomag MPH 100 Recycler, or equipment that is approved as equal.

When liquid additives are used, the mixing equipment shall be equipped with a positive displacement pump, capable of accurately metering the required quantity of liquid additive. The pump shall be equipped with a positive interlock system which will permit addition of the additive only when the pulverized material is present in the mixing chamber and will automatically shut off when the material is not in the mixing chamber. Each mixing machine shall be equipped with a meter capable of registering the rate of flow and total delivery of the liquid additive introduced into the mixture.

252.4 Application and Mixing of Liquid Additives. Liquid additives shall be uniformly distributed and mixed with the pulverized material and any existing underlying material, or new imported material, as specified. The machine used for injecting the liquid additive shall have a variable speed pump with a control system as specified above.

The mixing machine shall be equipped with a foot per minute instrument that is integral to the variable speed pump controller ensuring that additive can be added only when the machine is moving.

The totalizer shall be such that the amount of liquid used during any given period can be read directly. The application rate of the liquid additive shall be expressed in terms of gallons per square yard. This rate shall be based on the percent by weight of the total mixture, as determined by the Engineer.

252.5 Construction. When new base material is required, it shall be spread on the existing pavement section before the recycling process is begun. The type of equipment used, shall be capable of being adjusted so that an application rate, of the new material, of ± 5 percent is provided.

When exposed during the mixing process, the subgrade shall be firm and able to support, without displacement, the construction equipment used. Soft or yielding areas shall be corrected and made stable by scarifying and aeration, or the introduction of additives, and compacting until it is of uniform stability. The cost of repair of the subgrade is incidental to this item.

Where excessive surface deformation is evident, or when elevation or profile changes are required, pulverization should take place prior to the introduction of additives. Pulverization should also be the first step when
aeration is necessary, or when the moisture content must be increased or decreased.
The existing pavement, base material and new material shall be pulverized and blended so that the entire mass of material shall be uniformly graded.

A. Granular Base

The bituminous surface, any new material, except additive, and the existing granular base material shall be pulverized and mixed initially by the mixing equipment. If sufficient moisture is absent for proper mixing, water in the amount specified by the Engineer, shall be introduced using the mixing equipment. Graders may be used in the mixing operation, after the material has been given a preliminary pulverizing with the mixing equipment.

The mixing and aeration shall proceed from one side of the work area to the other (windrowed) using a motor grader, until the mixture has a uniform appearance, free from "flat" spots and excess moisture. Aeration of the mixture shall continue in this manner, until the mixture is dried to a moisture content acceptable to the Engineer.

After the mixture has been thoroughly mixed and aerated, it shall be spread and shaped with the grader. Spreading will be performed to provide a uniform layer of loose material. The pulverized material shall then be lightly compacted with a roller.

If required by the Engineer, the pulverized material and water shall be allowed to set-up for about 48 hours, or for the time directed by the Engineer. As part of the spreading operation, the mixture will be shaped so that when compacted, it will be in close conformity with the lines, grades, and cross-sections established by the Engineer.

After the curing period, the pulverized material shall be mixed with the kind and amount of additive indicated by the Engineer. The existing bituminous pavement, new material, if required, existing base material and additive shall be pulverized and blended until the new additive(s) is uniformly dispersed throughout the material. The introduction of the additive shall be done with the mixing equipment, as outlined above.

When tested in accordance with ASTM C136 “Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates” the pulverized mixture shall meet the following gradation:
Prior to the beginning of compaction, the mixture shall be in a loose condition for its full depth. The loose mixture shall then be uniformly compacted to the specified density, lines and grades.

Compaction shall begin immediately after final mixing. The mixture shall be compacted using vibratory rollers. After this initial compaction, final compaction and finishing shall take place with a smooth drum or pneumatic tired roller. The mixture shall be compacted to 95 percent of Standard Proctor Density (ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lb/ft³)” at ± 2 percent of the optimum moisture content.

After the material is compacted, water shall be uniformly applied to the surface, as needed. The surface shall then be reshaped to the required lines, grades and cross-sections and then lightly scarified to loosen any imprint left by compacting and reshaping equipment.

The resulting surface shall be thoroughly rolled with a pneumatic tired roller and "skinned" by a power grader to achieve final grade, removing all loosened material from the surface. The surface shall then be compacted with the pneumatic roller, adding small increments of moisture, as needed, during rolling. If material larger than a No. 4 screen is present in the mixture, one complete coverage of the surface, with the flat wheel roller shall be made immediately after the skinning operation.

After the surface of the recycled base has been finished as specified herein, it shall be protected against rapid drying by applying an asphaltic membrane to the recycled surface immediately after its completion. The material for the asphaltic membrane shall be EAP&T (Emulsified Asphalt Prime and Tack), CSS-1, or SS-1 (Asphalt Emulsion), per TxDOT Item 300, as approved by the Engineer. The amount of asphaltic material (refer to plans) shall be sufficient to completely cover and seal the total

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<tr>
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<td>0</td>
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<td>0 – 5</td>
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<tr>
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<tr>
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<tr>
<td>No. 200</td>
<td>Greater than 95</td>
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surface and fill all voids. The Contractor shall use this method for curing the recycled base and it shall be his responsibility to protect the asphalt membrane from being picked up by the traffic.

The asphalt membrane may remain in place when the proposed surface is placed. The surface course may be applied as soon after completion as operations will permit.

At the end of each day's construction, a straight transverse construction joint shall be formed by cutting back into the total width of completed work to form a true two inch depth vertical face free of loose and shattered material.

After the 3 day curing period, or as directed by the Engineer, completed sections may be opened immediately to local traffic and to construction equipment, during the curing period, provided the material has hardened sufficiently to prevent marring or distorting the surface by the equipment or traffic.

When a surface course is required, it shall be applied at the required thickness in accordance with Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”. Prior to placement of surface course, the recycled base shall be proof rolled to locate soft or yielding areas, the soft or yielding areas shall be corrected in accordance with Section 252.7 or as directed by the Engineer. Proof rolling equipment shall meet the requirements of TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges” Item 216 “Proof Rolling”, Latest Edition. A tack coat shall be applied in accordance with Item 340.11.

B. Black Base

When new black base is required, it shall be spread on the existing pavement section before the recycling process is begun, in accordance with Section 252.5.

When exposed during the mixing process, the subgrade shall be firm and able to support, without displacement, the construction equipment used. Soft or yielding subgrade shall be corrected in accordance with Section 252.5.

Pulverization shall take place prior to the introduction of additives. The existing pavement, base material and new material, except additives, shall be pulverized and blended so that the entire mass of material will be uniformly graded.
The bituminous surface and black base shall be mixed initially by the pulverizing equipment. If excess moisture is present, the material shall be worked until it is at the moisture content specified by the Engineer. Graders may be used in the mixing operation after the material has been given a preliminary mixing with the pulverizing machine.

The mixing and aeration shall proceed from one side of the work area to the other (windrowed) until the mixture has a uniform appearance, free from "fat" spots and excess moisture. Aeration of the mixture shall continue in this manner until the mixture is dried to a moisture content acceptable to the Engineer.

After the mixture has been thoroughly mixed and aerated, it shall be spread and shaped with a grader. Spreading will be performed to provide a uniform layer of loose material.

After spreading, the pulverized material shall be mixed with the kind and amount of additive indicated by the Engineer. The existing bituminous pavement, new material if required, existing base material and additive, probably an emulsion, shall be blended until the new additive(s) is uniformly dispersed throughout the material. The introduction of the additive shall be done with the mixing equipment.

When tested in accordance with ASTM C136 “Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates”, the pulverized material shall meet the following gradation:

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</table>

After the introduction of the additive(s), and the mixture has been thoroughly mixed and aerated, it shall be spread with a grader and any excess moisture, from the emulsion, shall be removed. If required, aeration of the mixture shall continue until the mixture is dried to a moisture content acceptable to the Engineer.
After the mixture has been thoroughly mixed and aerated, it shall be spread and shaped with a grader. Spreading will be performed to provide a uniform layer of loose material. The pulverized material shall be lightly compacted with a roller and then allowed to set-up for about 48 hours, or for the time directed by the Engineer.

After the curing period, the pulverized material shall be re-mixed with the mixing equipment.

Prior to the beginning of compaction, the mixture shall be in a loose condition to its full depth. The loose mixture shall then be uniformly compacted to the specified density, lines and grades.

Compaction shall begin immediately after final mixing. The mixture shall be compacted in one lift using vibratory rollers. After initial compaction, final compaction and finishing shall take place with a smooth drum or pneumatic tired roller. The mixture shall be compacted to 95 percent of Standard Proctor Density (ASTM D698).

After the material is compacted, a tack coat, if required, shall be applied in accordance with Item 340.11.

Where a surface course is required, it shall be applied at the required thickness in accordance with Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”.

At the end of each day's construction, a straight transverse construction joint shall be formed by cutting back into the total width of completed work to form a true two inch depth vertical face, free of loose and shattered material.

252.6 Traffic. After the curing period, or as directed by the Engineer, completed sections of recycled base may be opened immediately to local traffic and to all traffic, provided it has hardened sufficiently to prevent marring or distorting of the surface by equipment or traffic.

252.7 Maintenance. The Contractor shall be required, within the limits of his contract, to maintain the recycled base course in good condition until all work has been completed and accepted. Maintenance shall include immediate repairs to any defects that may occur. This work shall be done by the Contractor at his own expense and may be repeated as often as may be necessary to keep the area continuously intact. Faulty work shall be replaced for the full depth of treatment. It is the intent of this Item that the Contractor constructs the plan depth of recycled base in one
homogeneous mass. The addition of thin layers in order to provide the minimum specified depth will not be permitted.

252.8 Quality Assurance. The Testing Laboratory’s representative will determine the in-place density in accordance with ASTM D6938 “Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods” and D 1556, “Standard Test Methods for Density and Unit Weight of Soil in Place by Sand-Cone Method”. The minimum level of testing will consist of at least two tests using the nuclear density gauge and one test using the Sand Cone Method, for each 1,000 feet per lane of roadway or 4,000 square feet of base material.

252.9 Measurement. Cold in-place recycling shall be measured by the square yard. The additive of the type specified by the Engineer shall be measured by the ton or gallon.

252.10 Payment. The basis of payment for Full Depth Cold Flexible Pavement Recycling shall be by the unit price bid per square yard, which price shall be full compensation for all cutting back shoulders, stripping and scarifying, if necessary, pulverizing and blending, the addition of any admixture, remixing, compaction and curing, including the removal and disposal of all excess material, including all labor, tools and equipment necessary to do the work.

Liquid additives shall be paid for by the unit price bid per gallon for the material. Dry additives shall be paid for by the unit price bid, per ton, for the material. Asphalt membrane shall be paid for by the unit price bid per gallon, per Item 310 “Prime Coat” and Item 323 “Emulsified Asphalt Treatment”.

When it is necessary to add additional materials, granular materials shall be paid for under Item 230 “Crushed Aggregate Base Course” and “Black Base” shall be paid for under Item 250 ”Hot Mix Asphaltic Concrete Base Course (Black Base)”.

The surface course, including any necessary tack, shall be paid for under Item 340 ”Hot Mix-Hot Laid Asphaltic Concrete”.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 221 “Hydrated Lime and Lime Slurry”
Item 222 “Portland Cement Stabilized Subgrade”
Item 223 “Lime Fly Ash or Fly Ash Stabilized Subgrade”
Item 224 “Quicklime (Stabilization)”
Item 230 “Crushed Aggregate Base Course”
Item 250 “Hot Mix Asphaltic Concrete Base Course (Black Base)”
Item 310 “Prime Coat/Sealer”
Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”

END OF ITEM 252
300 ITEMS

- 309 – Milling Existing Pavement
- 310 – Prime Coat/Sealer
- 320 – Single Course Surface Treatment
- 322 – Two Course Surface Treatment
- 323 – Emulsified Asphalt Treatment
- 324 – Seal Coat
- 340 – Hot Mix-Hot Laid Asphaltic Concrete
- 341 – Hot In-Place Asphalt Recycling
- 360 – Concrete Pavement
- 361 – Full Depth Repair of Concrete Pavement
ITEM 309

MILLING EXISTING PAVEMENT

309.1 Description. This Item shall govern for milling existing asphalt surfacing and base course material to the lines and grades as shown on the drawings or established, by the Engineer.

309.2 Construction Methods. The existing asphalt surfacing and base course material at points shown on the drawings or designated by the Engineer shall be milled off to the depth and width shown by the lines and grades on the drawings or established by the Engineer. The existing material to be removed shall be milled by means of rotary cutting blades, until it is broken into particles small enough to be easily removed. Prior to and after the milling process, all dirt and foreign material shall be removed from the pavement surface by power brooming or other approved methods.

309.3 Measurement. This Item will be measured by the square yard of old pavement in its original position for the nominal depth indicated.

309.4 Payment. The work performed as prescribed for this Item, measured as provided under “Measurement” will be paid for at the unit price for “Milling Existing Pavement”, which price shall be full compensation for furnishing all labor, tools, equipment, supplies and incidentals necessary to satisfactorily complete the work; including salvaging, transporting, and delivering the material, as required.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 309
ITEM 310

PRIME COAT/SEALER

310.1 Description. This Item shall govern the application of asphaltic material on the completed subgrade, base course or other designated area in accordance with these Standard Specifications.

310.2 Materials. Use material of the type and grade shown on the plans in accordance with Item 300 "Asphalts, Oils, and Emulsions" of the Texas Department of Transportation's "Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges", Latest Edition. The asphaltic material shall be tested in accordance with ASTM D2027 "Standard Specification for Cutback Asphalt (Medium-Curing Type)."

If the asphaltic material selected for prime coat is MC-30, it shall be applied at the rate of 0.25 - 0.35 gallons per square yard.

310.3 Construction Methods. Apply the prime coat when the air temperature is at least 60°F or above 50°F and rising. Measure the air temperature in the shade away from artificial heat. The Engineer will determine when weather conditions are suitable for application.

When, in the opinion of the Engineer, the subgrade or base is satisfactory to receive the prime coat, the surface shall be cleaned by sweeping or other approved methods. The surface shall be lightly sprinkled just prior to application of the asphaltic material, if the Engineer deems it necessary. The asphaltic material shall be applied on the clean surface by an approved type of self-propelled distributor that distributes the material in the quantity specified, evenly and smoothly under pressure necessary for proper distribution. The Contractor shall provide all necessary facilities for:

A. determining the temperature of the asphaltic material in all of the heating equipment and in the distributor,

B. determining the application rate and for securing uniformity at the junction of two distributor loads.

The distributor shall have been recently calibrated and the Engineer shall be furnished an accurate and satisfactory record of such calibration. If, after beginning the work, the yield on the asphaltic material appears to be in error, the distributor shall be recalibrated in a manner satisfactory to the Engineer before proceeding with the work.
All storage tanks, piping, retorts, booster tanks and distributors used in storing or handling asphalt shall be kept clean and in good operating conditions at all times and shall be operated in such manner that there will be no contamination of the asphaltic material with foreign material. It shall be the responsibility for the Contractor to provide and maintain in good working order, a recording thermometer at the storage heating unit at all times. Prime coat shall be applied within the recommended temperature range as designated in Table 19 of TxDOT's Item 300, and at a rate designated in the bid item description.

310.4 Measurement. The asphaltic material for prime coat will be measured at the point of delivery on the road, in gallons, at the applied temperature. The method of measurement shall be strapping before and after application. “Strapping” a distributor is a method of measuring the amount of asphalt that is in a distributor with a strapping stick that is supplied by the manufacturer and calibrated to a specific unit.

310.5 Payment. The work performed and materials furnished as prescribed by this Item and measured as provided under “Measurement” will be paid for at the unit price bid for prime coat, which price shall be full compensation for cleaning the surface to be coated, and for furnishing, heating, hauling and distributing the asphalt as specified; for all freight involved; and for all manipulation, labor, tools, equipment and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 310
ITEM 320

SINGLE COURSE SURFACE TREATMENT

320.1 Description. This Item shall govern for a wearing surface composed of a single application of asphaltic material, covered with aggregate, constructed on a prepared base course or surface in accordance with these Standard Specifications.

320.2 Materials. Asphaltic material shall conform to the requirements of Item 300 "Asphalts, Oils, and Emulsions" of the Texas Department of Transportation's "Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges", Latest Edition. The asphaltic material shall be Grade CRS-1P or CRS-2P. Both CRS-1P and CRS-2P are rapid setting cationic emulsions for use in placing surface treatments, when the air temperature is 60°F and rising. The emulsion shall break and cure in a reasonable amount of time when the aggregate is applied, regardless of sunlight or humidity conditions. The emulsion supplier shall furnish samples of the base asphalt and polymer used in making the finished emulsion, to be tested in accordance with TxDOT's Item 300.2.4, Table 10.

The aggregate shall be washed crushed limestone and shall consist of angular fragments of rock (excluding schist, shale or slate), of uniform quality throughout, with not more than 5 percent of soft friable material and not more than 5 percent of flat or elongated pieces, the width of which is less than half the length, and with a percent of wear not more than 35 when tested in accordance with the Los Angeles Abrasion Test (ASTM C131 “Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine”). Pre-coated aggregate shall be aggregate of the type and grade specified, coated with 0.5 to 1.5 percent by weight of residual bitumen from a pre-coating material. The limestone rock asphalt shall be fluxed with 0.5 to 1.5 percent by weight of fluxing material.

When tested by TxDOT Test Procedure Tex-200-F, Part 1, the aggregate shall meet the gradation requirements specified below:

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% RETAINED, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/8 Inch</td>
<td>0</td>
</tr>
<tr>
<td>3/4 Inch</td>
<td>0 - 2</td>
</tr>
<tr>
<td>SIEVE SIZE</td>
<td>% RETAINED, BY WEIGHT</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>5/8 Inch</td>
<td>20 – 40</td>
</tr>
<tr>
<td>1/2 Inch</td>
<td>80 - 100</td>
</tr>
<tr>
<td>3/8 Inch</td>
<td>95 - 100</td>
</tr>
<tr>
<td>No. 8</td>
<td>99 – 100</td>
</tr>
</tbody>
</table>

320.3 Construction Methods. All holes, ruts, depressions or other defects in the surface shall be repaired by cleaning out defective areas by scarifying, or acceptable hand methods, and (after being filled with new material of the same character as contained in the road surface, or other materials approved by the Engineer) shall be compacted by rolling or tamping so that a smooth, hard, well cemented surface, conforming to the lines, grade and typical cross-section shown on the plans is secured. After the required repairs have been made in an acceptable manner and the patches allowed to set-up under traffic and are properly bonded, the surface of the roadway shall be swept clean from dirt, dust and other deleterious matter by means of a mechanical rotary street sweeper, hand brooms or compressed air. All cakes of dust or clay and all foreign matter shall be removed and the surface thoroughly cleaned before any bituminous material is applied and until the embedded aggregate is cleaned, but not discharged or loosened. If found necessary by the Engineer, the surface may be lightly sprinkled just prior to application of the bitumen.

Single course surface treatment shall not be applied when the air temperature is below 60°F and falling, but it may be applied when the air temperature is above 50°F and rising. Air temperature shall be taken in the shade and away from artificial heat. Single course surface treatment shall not be applied when the temperature of the roadway surface is below 60°F. Asphaltic material shall not be placed when general weather conditions, in the opinion of the Engineer, are not suitable.

CRS-1P or CRS-2P bituminous material shall be applied on the clean surface at the rate of approximately 0.35 gallons per square yard and covered with the aggregate at the rate of one cubic yard (loose measure) to each 95 square yards of surface area.

The entire surface shall be thoroughly rolled with a self-propelled roller giving a compression of not less than 200 pounds per inch of roller width. The roller used shall be as specified by the Engineer.

The Contractor shall repair all fatty spots with additional cover material and all lean mixtures by additional asphalt to the extent that a uniform
dense treatment is finally obtained. Should depressions or uneveness or irregular spots develop in the surface, they shall be remedied and the surface brought to true grade and cross-section. Brooming and rolling shall be repeated on two successive work days, after application of aggregate.

320.4 Measurement. Asphaltic material will be measured at the point of application, on the road, in gallons at the application temperature. The quantity to be paid for shall be the number of gallons used, as directed, in the accepted surface treatment.

Aggregate shall be measured by the ton of 2,000 pounds, dry weight, actually used in the work. The dry weight shall be determined by deducting the weight of the moisture from the weight of the material.

320.5 Payment. The work performed and the materials furnished as prescribed by this Item and measured as provided under “Measurement” will be paid for at the unit prices bid for "Asphalt" and "Aggregate" which price shall be full compensation for cleaning and sprinkling the base; for furnishing, preparing, hauling and placing all materials; for all freight involved; and for all manipulations, labor, tools, equipment and incidentals necessary to do the work, including rolling.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 320
ITEM 322

TWO COURSE SURFACE TREATMENT

322.1 Description. This Item shall govern for a wearing surface composed of two applications of asphaltic material, each covered with aggregate, constructed on a prepared base course or surface in accordance with these Standard Specifications.

322.2 Materials. Asphaltic material shall conform to the requirements of Item 300 "Asphalts, Oils, and Emulsions" of the Texas Department of Transportation’s "Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges", Latest Edition. The CRS-1P or CRS-2P are rapid setting cationic emulsions for use in placing surface treatments, when the air temperature is 60°F and rising. The emulsion shall break and cure in a reasonable amount of time when the aggregate is applied, regardless of sunlight or humidity conditions. The emulsion supplier shall furnish the Engineer samples of the base asphalt and polymer used in making the finished emulsion to be tested in accordance with TxDOT’s Item 300.2.4, Table 10.

The aggregate shall be washed crushed limestone and shall consist of angular fragments of rocks (excluding schist, shale or slate), of uniform quality throughout, with not more than 5 percent of soft friable material and not more than 5 percent of flat or elongated pieces, the width of which is less than half the length, and with a percent of wear of not more than 35, when tested in accordance with the Los Angeles Abrasion Test, ASTM C131 “Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.” Pre-coated aggregate shall be aggregate of the type and grade specified, coated with 0.5 to 1.5 percent by weight of residual bitumen from a pre-coating material. The limestone rock asphalt shall be fluxed with 0.5 to 1.5 percent by weight of fluxing material.

When tested by TxDOT Test Procedure Tex-200-F, Part 1, the aggregate shall meet the gradation requirements specified below:

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% RETAINED, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/8 Inch</td>
<td>0 - 2</td>
</tr>
<tr>
<td>1/2 Inch</td>
<td>20 – 40</td>
</tr>
<tr>
<td>3/8 Inch</td>
<td>80 – 100</td>
</tr>
</tbody>
</table>
SIEVE SIZE | % RETAINED, BY WEIGHT
---|---
1/4 Inch | 95 – 100
No. 8 | 99 – 100

APPLICATION NO. 2

SIEVE SIZE | % RETAINED, BY WEIGHT
---|---
5/8 Inch | 0
1/2 Inch | 0 – 2
3/8 Inch | 20 – 35
1/4 Inch | 95 – 100
No. 8 | 99 – 100

322.3 Construction Methods. Two course surface treatment shall be applied when the air temperature is above 50°F and is rising. Do not apply surface treatment when the air temperature is 60°F and falling. Air temperature shall be taken in the shade and away from artificial heat. Two course surface treatment shall not be applied when the roadway surface is below 60°F. Asphaltic material shall not be placed when general weather conditions, in the opinion of the Engineer, are not suitable.

All holes, ruts, depressions or other defects in the surface shall be repaired by cleaning out defective areas by scarifying or acceptable hand methods and after being filled with new material of the same character as contained in the road surface, or other materials approved by the Engineer and shall be compacted by rolling or tamping so that a smooth, hard, well cemented surface, conforming to the lines, grade and typical cross-section shown on the plans is secured. After the required repairs have been made in an acceptable manner and the patches allowed to set-up under traffic and are properly bonded, the surface of the roadway shall be swept clean from dirt, dust and other deleterious matter by means of a mechanical rotary street sweeper, hand brooms or compressed air. All cakes of dust or clay and all foreign matter shall be removed and the surface thoroughly cleaned before any bituminous material is applied and until the top embedded aggregate is cleaned, but not dislodged or loosened. If found necessary by the Engineer, the surface may be lightly sprinkled just prior to the application of the bitumen.

Bituminous material shall be applied on the clean surface at the rate of 0.30 gallons per square yard and covered with the No. 1 aggregate at the
rate of one cubic yard (loose measure) to each 95 square yards of surface area. The work shall then be rolled and a second application of 0.30 gallons of asphaltic material per square yard shall be made. The bituminous material application rate may be varied by the Engineer. The No. 2 aggregate shall be applied at the rate of one cubic yard (loose measure) to each 80 square yards of surface area.

The entire surface shall be thoroughly rolled with a self-propelled roller giving a compression of not less than 200 pounds per inch of roller width.

The aggregate shall be evenly and accurately distributed to the end that an even and smooth surface shall be obtained. After the work has been completed as specified above, there should be a slight excess of the No. 2 stone over the surface. The Contractor shall repair all fatty spots with additional cover material and all lean mixtures by additional asphalt, to the extent that a uniform dense treatment is finally obtained. Should depressions or uneveness or irregular spots develop in the surface, they shall be remedied and the surface brought to true grade and cross-section.

Brooming and Rolling shall be repeated on two successive work days.

322.4 Measurement. Asphaltic material will be measured at the point of application, on the road, in gallons at the application temperature. The quantity to be paid for shall be the number of gallons used, as directed, in the accepted surface treatment.

Aggregate shall be measured by the ton of 2,000 pounds, dry weight, actually used in the work. The dry weight shall be determined by deducting the weight of the moisture from the weight of the material.

322.5 Payment. The work performed and the materials furnished as prescribed by this Item and measured as provided under measurement will be paid for at the unit prices bid for "Asphalt" and "Aggregate", which prices shall be full compensation for cleaning and sprinkling the base; for furnishing, preparing, hauling, and placing all materials; for all freight involved; and for all manipulations, labor, tools and equipment and incidentals necessary to complete the work, including rolling.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 322
ITEM 323

EMULSIFIED ASPHALT TREATMENT

323.1 Description. This Item shall govern for one or more applications of mixture of emulsified asphalt of the type specified and water to be used as earthwork seal or surface seal. This mixture may be applied to the base course, subgrade, shoulders or pavement surface at the locations and to the extent shown on the plans.


The asphalt emulsion shall be heated to a temperature of 110° - 160° F., before it is mixed with water. The asphalt, emulsifier and water mixture shall be applied at a rate which will give a residual asphalt coverage of 0.25 gallons per square yard.

The water shall meet the requirements of the Item 360 "Concrete Pavement".

323.3 Construction Methods. The emulsified asphalt and water mixture shall be applied by a self-propelled sprinkler, so operated as to uniformly distribute the mixture in the quantity determined by the Engineer.

The emulsion and water may be mixed in the sprinkler tank. The Contractor shall make suitable provisions for agitating the two materials sufficiently to produce a uniform blend. The sprinkler truck shall have been recently calibrated, and the Engineer shall be furnished an accurate and satisfactory record of such calibration. After beginning the work, should the yield of the emulsion applied appear to be in error, the distributor shall be calibrated in a manner satisfactory to the Engineer, before proceeding with the work.

Where indicated on the plans, emulsified asphalt treatment shall be mixed with the base or sub-base material. The emulsified asphalt and water mixture shall be applied and incorporated into the top portion of the sub-base or base course layers to the depth and width shown on the plans or as directed by the Engineer.
The percentage of emulsified asphalt in the mixture, shall be regulated to insure that the specified amount of emulsified asphalt is incorporated into the material, while maintaining the proper moisture content.

The treated material shall be mixed by blading or other approved methods; then shaped and compacted by rolling, as required by the pertinent specification for the particular course, to the lines, grades and typical sections shown on the plans. The surface shall be maintained with light applications of emulsified asphalt and water, or raw water, as directed by the Engineer, during the curing of the course.

323.4 Measurement. Emulsified asphalt will be measured by the gallon of emulsified asphalt used, in the asphalt and water mixture.

323.5 Payment. The work performed and the emulsified asphalt furnished as prescribed by this Item and measured as provided under measurement will be paid for at the unit price bid for "Emulsified Asphalt"; which price shall be full compensation for furnishing all required materials, including mixing water for application; for all freight involved; for all hauling, mixing and distributing the mixture as specified; and for all manipulation, labor, tools, equipment and incidentals necessary to complete the work.

Where asphalt emulsion is used in lieu of water curing, it shall not be paid for directly, but shall be incidental to that part of the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 360 "Concrete Pavement"

END OF ITEM 323
ITEM 324

SEAL COAT

324.1 Description. This Item shall govern for a surface treatment composed of a single application of asphalt, covered with aggregate, for the sealing of existing pavements.

324.2 Materials. The asphaltic material used shall be AC-10 or as recommended by the design engineer, and shall meet the requirements of Item 300 "Asphalts, Oils, and Emulsions", of the Texas Department of Transportation’s "Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges", Latest Edition. The material shall be applied at an approximate rate of 0.35 gallons per square yard. Aggregate shall meet the requirements of the Item 320 “Single Course Surface Treatment”.

324.3 Construction Methods. The area to be treated shall be cleaned of dirt, dust or other deleterious matter by sweeping or other approved methods. If found necessary by the Engineer, the surface shall be lightly sprinkled, just prior to the application of asphaltic material. Asphaltic material shall be applied on the cleaned surface by an approved type of self-propelled pressure distributor so operated as to distribute the material in the quantity specified evenly and smoothly, under a pressure necessary for proper distribution.

Seal coats shall not be applied when the air temperature is below 50°F, and is falling, but may be applied when the air temperature is above 40°F, and is rising; the air temperature being taken in the shade and away from artificial heat. Seal coats shall not be applied when the temperature of the roadway surface is below 60°F. Asphaltic material shall not be placed when general weather conditions in the opinion of the Engineer, are not suitable.

The Contractor shall provide all necessary facilities for determining the temperature of the asphaltic material in all of the heating equipment and in the distributor, for determining the rate at which it is applied, and for securing uniformity at the junction of two distributor loads. The distributor shall have been recently calibrated and the Engineer shall be furnished an accurate and satisfactory record of such calibration.
After beginning the work, should the yield on asphaltic material appear to be in error, the distributor shall be calibrated in a manner satisfactory to the Engineer before proceeding with the work.

Asphaltic material may be applied for the full width of the seal coat in one application. Asphaltic material shall not be applied until immediate covering with the aggregate is assured.

Aggregate shall be immediately and uniformly applied and spread by an approved self-propelled continuous feed aggregate spreader, unless otherwise shown on the plans or authorized by the Engineer in writing. The aggregate shall be applied at the rate directed by the Engineer.

The entire surface shall be broomed, bladed, or raked, as required by the Engineer and shall be thoroughly rolled with the type or types of rollers specified.

Brooming and Rolling shall be repeated on two successive work days.

The Contractor shall be responsible for the maintenance of the surface until the work is accepted by the Engineer. All holes or failures in the seal coat surface shall be repaired by use of additional asphalt and aggregate and all fat or bleeding surfaces shall be covered with approved cover material in such a manner that the asphaltic material will not adhere to or be picked up on the wheels of vehicles.

Temporary stockpiling of aggregates on roadway will be permitted provided the stockpiles are spaced not less than 1,000 feet apart and are so placed that they neither obstruct traffic nor interfere with roadway drainage. The Contractor shall be responsible for the proper preparation of all stockpile areas before aggregates are placed thereon, including leveling and cleaning of debris necessary for protection of the aggregate to prevent any contamination thereof.

All storage tanks, piping, retorts, booster tanks and distributors used in storing or handling asphaltic material shall be kept clean and in good operation condition at all times and they shall be operated in such manner that there will be no contamination of the asphalt with foreign material. It shall be the responsibility of the Contractor to provide and maintain in good working order a recording thermometer at the storage heating unit at all times.

The Contractor shall load, haul, distribute and apply the stockpiled aggregate and clean up all stockpiles.
Item 324
Page -3-

324.4 Measurement. Asphaltic material will be measured at the point of application on the road, in gallons at the applied temperature. The quantity to be paid for shall be the number of gallons used, as directed, in the accepted seal coat.

 Aggregate shall be measured by the ton of 2,000 pounds, dry weight.

324.5 Payment. The work performed and the materials furnished as prescribed by this Item and measured as provided for under measurement will be paid for at the unit price bid for asphalt and the unit price bid for aggregate, of the type and grade specified, which price shall be full compensation for cleaning and sprinkling the existing surface; for furnishing, preparing, hauling and placing all materials; for all freight involved and for all manipulation, labor, tools, equipment and incidentals necessary to complete the work, including rolling.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 320 “Single Course Surface Treatment”

END OF ITEM 324
ITEM 340

HOT MIX-HOT LAID ASPHALTIC CONCRETE

340.1 Description. This Item shall govern for a leveling up course, a surface course, or any combination of these courses, each to be composed of a compacted mixture of mineral aggregate and asphaltic material. The pavement shall be constructed on the previously approved subgrade, base, existing wearing surface or in the case of a bridge, on the prepared slab or as otherwise specified herein and in accordance with the details shown on the drawings.

It is the intent of these Standard Specifications that the asphaltic mixtures produced and placed shall meet the requirements of these specifications for one hundred percent payment. The Contractor shall have the responsibility for the design, production, transportation and laydown of asphaltic concrete mixtures. All phases of this work shall meet the requirements of this Item and be subject to inspection and acceptance by the Engineer.

The Contractor shall exercise quality control over materials and their assembly, design, processing, production, hauling, laydown and all associated equipment. Quality control is defined as the consistent monitoring of equipment, materials and processes to ensure that asphaltic concrete mixtures produced and laid are uniform, are within control limits and meet all acceptance requirements of this Item and other specification requirements. If these Standard Specifications are not being met, and satisfactory control adjustments are not being made, operations shall be discontinued until proper adjustments and uniform operations are established. Control shall be accomplished by a program independent of, but correlated with the Engineer's quality assurance testing program and shall verify that all requirements of the job mix are being achieved and that necessary adjustments provide specification results.

At all times, when the plant is in operation, the Contractor shall require his supplier to have a level II specialist certified by TxDOT, in their approved hot mix asphalt certification program or his designated representative, available to the plant operator who is capable of designing asphaltic concrete mixes, performing tests and analysis to put the plant into operation and producing a mixture meeting the specifications. The daily operations at the plant shall not begin without the certified technician present.
The tests made by the Engineer in his quality assurance testing program shall not relieve the Contractor of his responsibility of quality control and he should conduct such tests as are necessary to design, control and place mixtures within the limits of this Item.

340.2 Materials. Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications. Notify the Engineer before changing any material source or formulation. When the Contractor makes a source or formulation change, a Mix-Design using the new material satisfying the requirements of this Item must be submitted for review and approval prior to production. The Engineer may sample and test project materials at any time during the project to verify compliance.

A. Mineral Aggregate: The mineral aggregate shall be composed of a coarse aggregate and a fine aggregate and, if required, mineral filler and may include reclaimed asphalt pavement (RAP) that meets the requirements of this Item. The use of RAP may be required on the plans. RAP use will be allowed in all mixtures except as specifically excluded herein or on the plans. Samples of coarse aggregate, fine aggregate, and mineral filler, shall be submitted in minimum 10 pound bags, when requested by the Engineer. Unless otherwise required, one or more mineral aggregates containing both coarse and fine aggregate may be used to produce the specified mixture. The documented aggregate quality test results stated herein after shall be submitted with the Mix-Design.

1. Coarse Aggregate: Coarse aggregate stockpiles must have no more than 20% material passing the No. 8 sieve and shall consist of clean, tough, durable fragments of aggregate and/or mechanically crushed aggregate, reclaimed asphalt pavement (RAP) or, a combination thereof, as hereinafter specified, of uniform quality throughout and shall be free from dirt, organic or other injurious matter occurring either freely in the material or as a coating on the aggregate. Coarse aggregate from each source of supply shall meet the physical requirements outlined herein. The coarse aggregate shall meet the grading requirements herein. The aggregate contained in RAP shall not be required to meet these requirements except as shown on the plans. The polish value of RAP aggregate shall not be used in any determination of polish value specification compliance.
PHYSICAL REQUIREMENTS FOR COARSE
AGGREGATE

<table>
<thead>
<tr>
<th>TEST</th>
<th>REQUIREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasion Loss</td>
<td>Not more than 40%</td>
</tr>
<tr>
<td>Deleterious Material</td>
<td>Less than 1.5%</td>
</tr>
<tr>
<td>Decantation</td>
<td>Less than 1.5%</td>
</tr>
</tbody>
</table>

1. Aggregate contained in RAP will not be required to meet these requirements except as shown on the plans.

When tested by Test Procedure Tex-200-F it shall meet the following requirements:

GRADATION REQUIREMENTS FOR COARSE
AGGREGATE

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% PASSING, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 Inch</td>
<td>100</td>
</tr>
<tr>
<td>No. 8</td>
<td>Not more than 20</td>
</tr>
</tbody>
</table>

2. Reclaimed Asphalt Pavement (RAP). RAP is defined as a salvaged, milled, pulverized, broken or crushed asphaltic pavement. The RAP to be used in the mix shall be crushed or broken to the extent that 100 percent will pass the 2 inch sieve.

The stockpiled RAP shall not be contaminated by dirt or other objectionable materials. Unless otherwise shown on the plans, stockpiled, crushed RAP must have either a decantation of no more than 5 percent or a plasticity index of no more than 8, when tested in accordance with Test Procedure Tex-406-A, Part I, or Test Procedure Tex-106-E, respectively. This requirement applies to stockpiled RAP from which the asphalt has not been removed by extraction.

RAP sources that are designated on the plans will be available for use by the Contractor. Only RAP from designated sources will be allowed in mixes using more than 10 percent RAP, unless otherwise shown on the plans. When RAP sources are designated, either in stockpile or existing pavements, the approximate gradation, asphalt content, and asphalt cement properties of this material shall be shown on the plans.
Only RAP from Harris County or other designated sources may be used in surface courses.

RAP designated for use in surface courses shall not exceed 15 per cent by weight.

3. Fine Aggregate: Fine aggregates consist of manufactured sands, screenings, and field sands. Fine aggregate stockpiles must meet the gradation requirements herein after specified. Supply fine aggregates that are free from organic impurities. The fine aggregate should be tested in accordance with Tex-408-A to verify the material is free from organic impurities. At most 15% of the total aggregate may be field sand or other uncrushed fine aggregate. With the exception of field sand, use fine aggregate from coarse aggregate sources that meet the requirements herein after specified or otherwise approved.

Fine aggregate from each source shall satisfy the requirements outlined herein. The fine aggregate shall meet the grading herein.

PHYSICAL REQUIREMENTS OF FINE AGGREGATE

<table>
<thead>
<tr>
<th>TEST</th>
<th>REQUIREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasticity Index</td>
<td>Not more than 6%</td>
</tr>
<tr>
<td>Sand Equivalent Value</td>
<td>Not less than 45%</td>
</tr>
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</table>

When tested by Test Procedure Tex-200-F it shall meet the following requirements:

GRADATION REQUIREMENTS FOR FINE AGGREGATE

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% PASSING, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 Inch</td>
<td>100</td>
</tr>
<tr>
<td>No. 8</td>
<td>70 – 100</td>
</tr>
<tr>
<td>No. 200</td>
<td>0 – 30</td>
</tr>
</tbody>
</table>

4. Mineral Filler: Mineral filler, when required, shall consist of thoroughly dried stone dust, slate dust, portland cement, lime, fly ash or other mineral dust approved by the Engineer. The mineral filler shall be free from foreign matter. Fines collected by bag house or other air cleaning
or dust collecting equipment may be permitted as mineral filler in amounts up to two percent of the asphaltic mixture, provided that the portion passing the No. 200 master gradation limit is not exceeded. When these fines are permitted in the asphaltic mixture, they shall be introduced in the same manner prescribed for other mineral fillers.

When mineral filler is permitted by the Engineer, it shall be controlled by a measuring device acceptable to the Engineer.

A hopper or other acceptable storage system shall be required to maintain a constant supply of mineral filler to the measuring device. Mineral filler shall meet the following gradations when tested in accordance with TxDOT’s Test Procedure Tex-200-F.

**GRADATION REQUIREMENTS FOR MINERAL FILL**

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% PASSING, BY WEIGHT OR VOLUME</th>
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</thead>
<tbody>
<tr>
<td>No. 8</td>
<td>100</td>
</tr>
<tr>
<td>No. 200</td>
<td>55 – 100</td>
</tr>
</tbody>
</table>

B. Bituminous Material:

1. **Asphalt Binder:** Unless otherwise shown on the plans, the asphalt binder shall be PG 64-22, Performance Grade. The performance graded (PG) asphalt binder specified herein or on the plans shall conform to the requirements of TxDOT’s Item 300 "Asphalts, Oils and Emulsions", as published by the Texas Department of Transportation's "Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges", Latest Edition (hereinafter referred to simply as “TxDOT’s Specifications”) Section 300.2.J, “Performance Graded Binder”.

   The material shall be homogeneous, shall be free from water, shall not foam when heated to 350°F., and shall meet the following requirements:

2. **Additives:** Additives to facilitate mixing and/or improve the quality of the asphaltic mixture shall be used when noted on the plans or specifications or may be used upon written permission by the Engineer. If lime or a liquid antistripping

agent is used, add in accordance with the Latest Edition of TxDOT’s Specification Item 301 “Asphalt Antistripping Agents”.

340.3 Mixtures.

A. General: The paving mixture shall consist of a uniform mixture of coarse aggregate, fine aggregate, mineral filler, if required, and asphalt binder. The supplier of the asphaltic material shall submit a proposed mixture design report, which conforms to all the requirements of this Item, for verification by the Engineer. Include the following items in the mixture design report:

1. The combined aggregate gradation, source, specific gravity, and percent of each material used.

2. Plotted Job-mix gradation, on a gradation chart with sieve sizes raised to 0.45 power. This plot must show that the gradation of the proposed job-mix formula is within the limits of master gradation.

3. Results of all applicable tests.

4. Signature of the Level II Specialist who performed the design.

5. Date the mixture design was performed, with a unique identification number for the mixture design.

Approval of the proposed design, by the County, will require that the supplier maintain the source and quality of aggregates proposed throughout production and changes which require modification of the proposed mix design will be subject to the approval of the Engineer. The supplier of the asphaltic concrete shall follow the established job mix formula both as to asphalt content and gradation.

Extraction and Ignition Test: The percentage of asphalt binder in any mixture shall not vary from the proportion established by the job mixture design.

When required by the Engineer, samples of the hot mixture may be taken at the plant, or from the trucks, or from the finished pavement. The location of the sampling of the mixture shall be in accordance with ASTM D979 “Standard Practice for Sampling Bituminous Paving Mixtures.” When tested in accordance with
ASTM D2172 “Standard Test Methods for Quantitative Extraction of Asphalt Binder from Asphalt Mixtures” or TxDOT’s Test Procedure Tex-236-F and Tex-200-F, the average of the results of the aggregate gradations and asphalt content shall not vary from the values established in the job mix formula, by allowable tolerance established herein.

Provide the Engineer with split samples of the mixtures and blank samples used to determine the Ignition Oven correction factors. TxDOT’s Test Procedure Tex-236-F should be used to determine the aggregate and asphalt correction factors

The mix shall be designed in accordance with the Latest Edition of Texas Department of Transportation Test Procedure Tex-204-F "Design of Bituminous Mixtures" to conform with the requirement herein, with the exception that the laboratory density will be determined as a percentage of the mixture Theoretical Maximum Density. The Theoretical Maximum Specific Gravity shall be determined in accordance with Texas Department of Transportation Test Procedure Tex-227-F "Theoretical Maximum Specific Gravity of Bituminous Mixtures" on trial samples at each asphalt content. The optimum asphalt binder content will correspond to 96.5 percent laboratory density provided the mixture satisfies the minimum Hveem Stability of 40 percent.

The average asphalt content shall not vary by more than plus or minus 0.3 percent by weight (based on total mixture), from the optimum asphalt binder content determined by the approved job mix formula. However, in no case shall the asphalt binder be less than 4.7 percent of the mixture by weight.

B. Stockpile Gradations: Once a job mix design has been established in accordance with the Latest Edition of Texas Department of Transportation’s Test Procedure Tex-204-F "Design of Bituminous Mixtures", the coarse aggregate delivered to the stockpiles shall not vary on any grading size fraction by more than plus or minus 8 percentage points from the percentage found in the samples submitted by the Contractor and upon which the job mix design was based. The intent of this requirement is to insure consistency and uniformity of the asphaltic mixture produced in the drum mix plant. Should the gradation of coarse aggregates in the stockpiles vary by more than the allowed tolerance, the Engineer may stop the production and may require that new aggregate be furnished to the stockpiles that meet the gradations of the aggregates submitted for the design mix formula.
C. The grading of each constituent shall be such as to produce, when properly proportioned, a mixture conforming to the master limitations listed herein. The exact proportions of each constituent shall produce the total aggregate blend within these limits.

**FINE GRADED (TYPE D) SURFACE COURSE PAVING MIXTURE MASTER GRADING LIMITS**

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% PASSING, BY WEIGHT OR VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4 Inch</td>
<td>100</td>
</tr>
<tr>
<td>1/2 Inch</td>
<td>98 – 100</td>
</tr>
<tr>
<td>3/8 Inch</td>
<td>85 – 100</td>
</tr>
<tr>
<td>No. 4</td>
<td>50 – 70</td>
</tr>
<tr>
<td>No. 8</td>
<td>35 – 46</td>
</tr>
<tr>
<td>No. 30</td>
<td>15 – 29</td>
</tr>
<tr>
<td>No. 50</td>
<td>7 – 20</td>
</tr>
<tr>
<td>No. 200</td>
<td>2 – 7</td>
</tr>
</tbody>
</table>

D. Tolerances: The aggregate portion of the paving mixture produced shall not vary from the design gradation by more than the tolerances allowed herein. The material is further restricted to conform to the limitations of the master grading for the type specified. The asphaltic material portion of the paving mixture shall not vary from the design amount by more than the allowed tolerance and is also restricted to conform to the master limits. The test method for determining the aggregate gradation and asphalt content of the mixture is listed in Section 340.4.

**TABLE 1**

**OPERATIONAL TOLERANCES**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>TEST METHOD</th>
<th>ALLOWABLE DIFFERENCE BETWEEN TRIAL BATCH AND JMF1 TARGET</th>
<th>ALLOWABLE DIFFERENCE FROM CURRENT JMF TARGET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual % retained for #8 sieve and larger</td>
<td>Tex-200-F or Tex-236-F</td>
<td>Must be within master grading limits in Table 8</td>
<td>±5.0(^1,2)</td>
</tr>
<tr>
<td>DESCRIPTION</td>
<td>TEST METHOD</td>
<td>ALLOWABLE DIFFERENCE BETWEEN TRIAL BATCH AND JMF1 TARGET</td>
<td>ALLOWABLE DIFFERENCE FROM CURRENT JMF TARGET</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
<td>--------------------------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Individual % retained for sieves smaller than #8 and larger than #200</td>
<td></td>
<td>±3.0&lt;sup&gt;1,2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>% passing the #200 sieve</td>
<td></td>
<td>±2.0&lt;sup&gt;1,2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Asphalt binder content, %</td>
<td>Tex-236-F</td>
<td>±0.5</td>
<td>±0.3&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

1. When within these tolerances, mixture production gradations may fall outside the master grading limits; however, the % passing the #200 will be considered out of tolerance when outside the master grading limits.

2. Only applies to mixture produced for Lot 1 and higher.

If the paving mixture produced varies from the job-mix formula gradation and/or asphaltic material content by more than the tolerances and restrictions, proper changes shall be made until the type mixture meets the requirements, as directed by the Engineer.

Laboratory density and stability of the mixture when designed and tested during production, in accordance with these Standard Specifications and the test methods outlined in Section 340.4 shall meet the following physical properties.

<table>
<thead>
<tr>
<th>LABORATORY DENSITY, PERCENT</th>
<th>HVEEM STABILITY, PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>94</td>
<td>98</td>
</tr>
</tbody>
</table>

Stability and density tests are intended for control tests. If the laboratory stability and/or density of the mixture produced has a value lower than that specified and in the opinion of the Engineer is not due to a change in source or quality of materials, production may proceed with consequent changes in the mix until the laboratory stability and density equals or exceeds the specified values. If, in the opinion of the Engineer, there is a change in the source, type or quality of material from that used in the design mixture, production shall be discontinued until a new design...
mixture is determined by trial mixes and the Contractor shall pay all costs of redesigning the mix. The Contractor may submit a new mixture design at anytime during the project. The compacted thickness of the mixture or mixtures used shall be as specified by the plans or specifications. The specific test method for determining laboratory density, HVEEM Stability and compacted thickness is listed in Section 340.4. The Supplier’s daily QA/QC test results shall be forwarded to Harris County’s Materials Engineer on a daily basis.

340.4 Test Methods.

Testing of Materials: The Testing Laboratory’s representative shall perform random tests to determine if the materials and construction procedures produce a product which meets the contract documents. The specific test methods for material analysis are outlined in the following Tables. Testing procedures are ASTM Standards unless otherwise noted.

A. Testing of mineral aggregates shall be in accordance with the following standard laboratory test procedures:

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling Aggregate</td>
<td>ASTM D75 &quot;Sampling Aggregates&quot;</td>
</tr>
<tr>
<td>Sieve Analysis</td>
<td>TxDOT Test Procedure Tex-200-F &quot;Sieve Analysis of Fine and Coarse Aggregates&quot;</td>
</tr>
<tr>
<td>Abrasion Resistance</td>
<td>C131 &quot;Resistance to Degradation of Small Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine&quot;</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>C127 &quot;Specific Gravity and Absorption of Coarse Aggregate&quot; C128 &quot;Specific Gravity and Absorption of Fine Aggregate&quot;</td>
</tr>
</tbody>
</table>
B. Performance Graded Binders. PG binders must be smooth and homogeneous material which will not foam when heated to 350°F and meet the requirements of TxDOT’s Specification Item 300, Latest Edition.

Testing of asphalt binder shall be in accordance with the following standard laboratory test procedures:

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity, 140°F</td>
<td>D2171 &quot;Test Method for Viscosity of Asphalts By Vacuum Capillary Viscometer&quot;</td>
</tr>
<tr>
<td>Viscosity, 135°C</td>
<td>D4402 &quot;Standard Test Method for Viscosity Determination&quot;</td>
</tr>
<tr>
<td>Penetration, 77°F</td>
<td>D5 &quot;Test Method of Penetration of Bituminous Materials&quot;</td>
</tr>
<tr>
<td>Flash Point</td>
<td>D92 &quot;Test Method for Flash and Fire Points by Cleveland Open Cup&quot;</td>
</tr>
</tbody>
</table>
C. Testing of bituminous mixtures shall be in accordance with the following standard laboratory test procedures:

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ductility</td>
<td>D113 &quot;Test Method for Ductility of Bituminous Materials&quot;</td>
</tr>
<tr>
<td>Spot Test</td>
<td>AASHTO T-102 &quot;Spot Test of Asphaltic Materials&quot;</td>
</tr>
<tr>
<td>Sampling Bituminous Mixtures</td>
<td>TxDOT Test Procedure Tex-222-F &quot;Sampling Bituminous Mixtures&quot; or ASTM D979</td>
</tr>
<tr>
<td>Molding of Specimens</td>
<td>TxDOT Test Procedure Tex-206-F &quot;Compacting Specimens Using the Texas Gyratory Compactor (TGC)&quot;</td>
</tr>
<tr>
<td>Height of Specimens</td>
<td>D3549 &quot;Test Method for Thickness or Height of Compacted Bituminous Paving Mixtures Specimens&quot;</td>
</tr>
<tr>
<td>Bulk Density of</td>
<td>TxDOT Test Procedure Specimens Tex-207-F &quot;Determining Density of Compacted Bituminous Mixtures&quot;</td>
</tr>
<tr>
<td>HVEEM Stability</td>
<td>TxDOT Test Procedure Tex-208-F &quot;Test for Stabilometer Value of Bituminous Mixtures&quot;</td>
</tr>
</tbody>
</table>
### Property | Test Method
--- | ---
Maximum Theoretical Density | TxDOT Test Procedure Tex-227-F "Theoretical Maximum Specific Gravity of Bituminous Mixtures"
Method of Mix Design | TxDOT Test Procedure Tex-204-F "Design of Bituminous Mixtures"
Extraction | TxDOT Test Procedure Tex-210-F “Determining Asphalt Content of Bituminous Mixtures by Extraction”, or Tex-236-F “Determining Asphalt Content from Asphalt Paving Mixtures by the Ignition Method”
Gradation | Tex-200-F “Sieve Analysis of Fine and Coarse Aggregate”

**340.5 Equipment.** Provide equipment to produce, haul, place, and compact that complies with the requirements of the Latest Edition of TxDOT’s Specification Item 320 “Equipment for Asphalt Concrete Pavement”, and herein after specified.

**340.6 Heating and Discharge of Materials.**

A. **Heating of Materials.** Do not heat the asphalt binder above the temperatures specified in TxDOT’s Specification Item 300 “Asphalts, Oils, and Emulsions”, Latest Edition; or outside the manufacturer’s recommended values. On a daily basis, provide the Engineer with the records of asphalt binder and hot-mix asphalt discharge temperatures in accordance with Item 320 “Equipment for Asphalt Concrete Pavement”, of TxDOT’s Specifications, Latest Edition.

B. **Mixing and Discharge of Materials.** Notify the Engineer of the target discharge temperature and produce the mixture within 25°F of the target. Monitor the temperature of the material in the truck before shipping to ensure that it does not exceed 350°F and is not lower than 215°F. Harris County will not pay for or allow placement of any mixture produced above 350°F.
Control the mixing time and temperature so that substantially all moisture is removed from the mixture before discharging from the plant. The Engineer may determine the moisture content by oven-drying in accordance with Tex-212-F, Part II, and verify that the mixture contains no more than 0.2% of moisture by weight. The Engineer shall obtain the sample immediately after discharging the mixture into the truck, and perform the test promptly.

340.7 Asphalt Mixing Plants. Mixing plants may be either the weigh batch type, or the drum mix type. Both types of plants shall be equipped with satisfactory conveyors, power units, aggregate handling equipment, bins and dust collectors, etc. and comply with the requirements of the Latest Edition of TxDOT's Specification Item 320 “Equipment for Asphalt Concrete Pavement”.

340.8 Spreading and Finishing Machine. The spreading and finishing machine shall conform to the requirements of the Latest Edition of TxDOT’s Specification, Item 320 “Equipment for Asphalt Concrete Pavement”, and as specified herein:

The spreading and finishing machine shall be of a type approved by the Engineer and shall be capable of producing a surface that will meet the requirements of the typical cross-section and the surface test, when required by the Engineer, and when the mixture is dumped directly into the finishing machine shall have adequate power to propel the delivery vehicles in a satisfactory manner. The finishing machine shall be equipped with a flexible spring and/or hydraulic type hitch sufficient in design and capacity to maintain contact between the rear wheel of the hauling equipment and the pusher rollers of the finishing machine while the mixture is being unloaded. The paver shall have a receiving hopper of sufficient capacity for a uniform spreading operation, equipped with a vibrating screed and heater.

The hopper shall be equipped with a distribution system to place the mixture uniformly in front of the screed.

The screed or strike-off assembly shall produce a surface of the required evenness and texture without tearing, shoving, gouging or displacing the mixture.

The use of any vehicle which required dumping directly into the finishing machine and which the finishing machine cannot push or propel in such a manner as to obtain the desired lines and grades without restoring to hand finishing will not be allowed. Unless waived by the Engineer,
automatic screed controls shall be required for asphaltic concrete spreading and finishing machines.

Asphaltic-concrete spreading and finishing machines shall be equipped with an approved automatic dual longitudinal screed control system and a transverse screed control system. The longitudinal controls shall be capable of operating from any longitudinal grade reference including a stringline, 40 foot ski, mobile stringline or matching shoe. The asphaltic concrete spreading and finishing machine shall be equipped with a screed heater and vibrator.

The Contractor shall furnish all equipment required for grade reference. It shall be maintained in good operating condition by personnel trained in the use of this type of equipment. The equipment shall be capable of constructing a finished surface within specified tolerances.

The automatic grade control device shall produce a finished surface meeting the requirements of the surface test on the items of work for which a spreading and finishing machine is required. Skin-patching will not be permitted unless approved by the Engineer and any section of pavement not meeting the minimum tolerance shall be corrected at the Contractor's expense.

The spreader shall be capable of spreading and finishing courses of bituminous plant mix material in lanes not less than 10 feet in width and shall be capable of operating at forward speeds consistent with the satisfactory laying of the mixture.

The asphaltic mixture, when placed with a spreading and finishing machine, shall not be placed unless the air temperature is 40°F and rising, or 50°F and dropping. The air temperature shall be taken in the shade away from artificial heat. Asphalt shall not be placed when the temperature of the surface on which the mat is to be placed is below 60°F.

It is further provided that the asphaltic mixture shall be placed only when the humidity, general weather conditions and temperature and moisture condition of the base, in the opinion of the Engineer, are suitable.

The Engineer can reject individual truckloads of hot-mix. When a load of hot-mix is rejected for reasons other than temperature, contamination, or excessive uncoated particles, the Contractor may request that the rejected load be tested. Make this request within 4 hr. of rejection. The Engineer will sample and test the mixture. If test results are within the operational tolerances shown in Table 1 above, payment will be made for
the load. If test results are not within operational tolerances, no payment will be made for the load.

340.9 Transporting Asphaltic Concrete. The asphaltic concrete mixture, heated and prepared as specified, shall be hauled to the work site in tight vehicles previously cleaned of all foreign material.

The dispatching of the vehicles shall be arranged so that all material delivered may be placed and all rolling shall be completed during daylight hours. Cover each load of mixture with waterproof tarpaulins. The inside of the trucks body may be given a light coating of, lime slurry or other approved release agent necessary to prevent the mixture from adhering to the body. A hole for inserting a thermometer shall be installed in the truck body. Truck beds shall be clean of debris or material that is damaging to the asphalt being hauled before they are loaded with asphalt. If, in the opinion of the Engineer, the truck bed is damaged, it shall be removed from the project.

340.10 Tack Coat. Unless otherwise shown on the plans or approved, furnish CSS-1H, SS-1H, or a PG binder with a minimum high temperature grade of PG-58 for tack coat binder in accordance with the Latest Edition of TxDOT's Specification Item 300 “Asphalts, Oils, and Emulsions”.


Do not dilute emulsified asphalts at the terminal, in the field, or at any other location before use. If required, verify that emulsified asphalt proposed for use meets the minimum residual asphalt percentage specified in the Latest Edition of TxDOT’s Specification, Item 300 “Asphalts, Oils, and Emulsions”. The diluted emulsion shall be applied at an approximate rate of 0.05 to 0.15 gal./sq. yd., evenly and smoothly under a pressure necessary for proper distribution. No more shall be placed than can be covered in one day.

Before the asphaltic surface course is laid, the surface of the base, or the surface of the concrete bridge, as the case may be, shall be thoroughly broomed to the satisfaction of the Engineer. When an application of tack coat is required, the base shall be coated with an application of diluted emulsion or, as directed, with an approved distributor and at the application rate indicated by the Design Engineer.

Tack coat shall not be applied when the air temperature is below 50°F. and falling, but may be applied when the air temperature is above 50°F.
and rising. Tack coat shall not be placed when the temperature of the surface on which the asphalt is to be placed is below 60°F.

340.11 Lay Down Operations.

A. Minimum Mixture Placement Temperatures. Use Table below for suggested minimum mixture placement temperatures.

B. Windrow Operations. When hot mix is placed in windrows, operate windrow pickup equipment so that substantially all the mixture deposited on the roadbed is picked up and loaded into the paver.

### SUGGESTED MINIMUM MIXTURE PLACEMENT TEMPERATURE

<table>
<thead>
<tr>
<th>HIGH TEMPERATURE BINDER GRADE</th>
<th>MINIMUM PLACEMENT TEMPERATURE (Before Entering Paver)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 64 or lower</td>
<td>260°F</td>
</tr>
<tr>
<td>PG 70</td>
<td>270°F</td>
</tr>
<tr>
<td>PG 76</td>
<td>280°F</td>
</tr>
<tr>
<td>PG 82 or higher</td>
<td>290°F</td>
</tr>
</tbody>
</table>

340.12 Placing. The asphaltic mixture shall be dumped and spread on the approved prepared surface with the specified spreading and finishing machine, in such a manner that when properly compacted the finished pavement will be smooth, of the required density and will meet the requirements of the typical cross-sections and the surface tests. During the application of asphaltic material, care shall be taken to prevent splattering of adjacent pavement, curb and gutter and structures.

When the asphaltic mixture is placed in a narrow strip along the edge of an existing pavement, or used to level up small areas of an existing pavement, or placed in small irregular areas where the use of a finishing machine is not practical, the finishing machine may be eliminated, provided a satisfactory surface can be obtained by other approved methods.

Adjacent to flush curbs, gutters, liners and structures, the surfaces shall be finished uniformly high so that when compacted it will be slightly above the edge of the gutter and flush to the structure.

340.13 Compacting. The pavement shall be compacted thoroughly and uniformly with the necessary rollers to obtain the density, stability and
cross-section of the finished paving mixture meeting the requirements of the plans and specifications.

Rolling equipment shall consist of pneumatic tire and steel wheel rollers. Breakdown rolling shall be accomplished immediately after placing, using steel wheel rollers.

All equipment shall be in good mechanical condition, properly adjusted and free from wear that would impair the quality of the work. Necessary precautions shall be taken to prevent the dropping of gasoline, oil, grease or other foreign matter on the pavement, by the compaction, or any equipment.

Pneumatic tire rollers shall have tires of equal size and diameter capable of exerting an average contact pressure varying from 40 to 90 psi, by adjusting ballast and/or tire pressure. All tires shall have equal pressure. The wheels shall be placed so that one pass will accomplish one complete coverage equal to the width of the roller with a minimum of 1/4 inch overlap. The wheels shall not wobble. The operating weight and tire pressure shall be as such as to provide the required density. The rollers shall be in the best mechanical condition. Pneumatic tire rollers shall be equipped with water systems and fiber mats. The Contractor shall provide a second steel wheel roll for wipe of pneumatic tire roller marks on all overlay projects.

The rollers shall have power units and be equipped with scrapers to keep the wheels clean and with the means of keeping the wheels wet, to prevent mixes from sticking to the rollers.

Vibratory rollers shall have a minimum of one vibratory drum weighing no less than 8 tons. The vibratory roller shall be capable of obtaining frequency and amplitude combinations that will produce an impact spacing smaller than the thickness of the mat, or a minimum of 8 to 10 blows per foot.

All rolling with any type of roller shall be done as directed by the Engineer. Breakdown (initial pass) rolling shall be conducted with a steel wheel roller or vibratory roller, intermediate rolling shall be conducted with a steel wheel roller or pneumatic tire roller and finished rolling shall be conducted with a steel wheel roller unless directed otherwise by the Engineer. When rolling with vibratory steel wheel rollers, the manufacturer’s recommendation shall be followed, unless otherwise directed by the Engineer.

The specific rollers used in sequence to obtain the required compaction shall be approved by the Engineer. The ambient temperature, humidity,
wind velocity, temperature of existing surface, mat thickness, and temperature of paving mixture shall be considered by the Engineer in determining the type and amount of rollers needed to achieve the required compaction. Approval of the Engineer will not relieve the Contractor of his responsibility to produce the required density.

Rolling pattern shall be established daily and verified as outlined in Test Procedure Tex-207-F, Part IV and III, respectively, to achieve the required air void content. The daily established rolling pattern used is subject to approval by the Engineer. The daily established rolling pattern shall be followed unless changes in the mixture or placement conditions occur which affect compaction. A new rolling pattern shall be established at this time. If required, test strips approximately 300-500 feet in length shall be established to determine proper rolling patterns. A maximum of two strips will be allowed. If the required rolling patterns cannot be determined that will give the required density with two strips, the first two strips will be removed, before the third strip is constructed.

The mixture shall be placed at a temperature of between 260°F and 325°F.

Rolling shall begin as soon as the paving mixture will not be displaced laterally by the weight of the roller. When rolling with the steel-wheel, pneumatic tire roller or vibratory roller, longitudinal joints shall be rolled initially, however rolling shall begin at the low side of the pavement and proceed toward the higher side of the pavement, overlapping on successive trips by at least half the width of the rear wheel unless otherwise directed by the Engineer. Alternate trips of the roller shall be a minimum of six inches difference in length. The motion of the roller shall be slow enough at all times to avoid displacement of the mixture. To prevent adhesion of the surface mixture to the roller, the wheel shall be kept thoroughly moistened with water, but an excess of water will not be permitted. The roller shall not be allowed to stand on pavement which has not been fully compacted. If any displacement occurs, it shall be repaired at once by the use of rakes, and fresh mixture where required, any repair is subject to the Engineer's approval.

The maximum roller speed for any compaction equipment shall comply with the following table unless directed otherwise by the Engineer. The speed of the roller shall, at all times, be slow enough to avoid displacement of the hot mixture and shall not be greater than the speed indicated below.
MAXIMUM ROLLING SPEEDS
TYPE OF ROLLING

<table>
<thead>
<tr>
<th>CAMPACTOR</th>
<th>BREAKDOWN (miles/hr)</th>
<th>INTERMEDIATE (miles/hr)</th>
<th>FINISH (miles/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Wheel Roller</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Pneumatic Tire Roller</td>
<td>-</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Vibratory Roller</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Rolling shall be continued until the specified compaction can be obtained and all roller marks are eliminated. Complete all compaction operations before the pavement temperature drops below 160°F unless otherwise allowed. The Engineer may allow compaction with a light finish roller operated in static mode for pavement temperatures below 160°F.

Rolling with a trench type roller or other approved method, will be required on widening areas in trenches and other limited areas where satisfactory compaction cannot be obtained with the rollers specified or approved.

The roller must not stand on the compacted pavement which has not cooled to normal atmospheric temperature.

To prevent adhesion of the paving mixtures to the rollers, the wheels shall be kept properly moistened with water, however, excess water will not be permitted.

If, in the opinion of the Engineer, the asphaltic concrete surface course is not being properly compacted, specimens shall be taken to determine the density of the asphaltic concrete at various locations.

Density of the completed asphaltic concrete shall be uniform over the entire roadway area. The Engineer may have the material (part or all) removed and replaced on areas where density is found not to be that specified, when tested. The entire cost of removing and replacing material from areas because of unacceptable density variations shall be borne by the Contractor and at no cost to the County.

The Contractor shall have the option of placing material in either one or more lifts, in order to maintain uniform compaction. Lifts shall not exceed 2 inches in thickness.
Hand Tamping: The edges of the pavement along curbs, headers and similar structures, and all places not accessible to the roller, or in such positions that do not allow thorough compaction with the rollers, shall be thoroughly compacted with lightly oiled tamps.

340.14 Compaction Criteria. In place compaction methods used to obtain the required density necessary to achieve Engineer's approval shall be divided into Type A or Type B construction.

Type A construction shall represent asphalt being laid over New Construction, that is, all phases of construction beginning at the sub-base level and ending with the asphalt surface mix shall be new construction.

Type B construction shall represent asphalt being laid over in-situ material, that is, all Asphalt Overlays, Hot In-Place Recycled Asphalts, or other similar construction that places a surface asphalt on top of an existing roadway.

Type A:

In place compaction control is required of all paving mixtures. Asphaltic concrete shall be placed and compacted to obtain from 3 to 8 percent air voids. Do not increase the asphalt content of the Mixture to reduce pavement air voids. In no case shall the compacted roadway specimens have air voids in excess of 8 percent.

The Contractor shall establish a rolling pattern as outlined in Test Procedure Tex-207-F, Part IV, to achieve the required air void content. The Contractor shall confirm compaction as outlined in Test Procedure Tex-207-F, Part III, through nuclear density testing supplied by the laboratory retained by Harris County. The target density can be established daily and verified with a nuclear density gauge as outlined in Tex-207, IV and III respectively. It is recommended that the Thin Lift Asphalt Gauge be used, however other nuclear equipment may be used with prior approval of the Engineer as long as proper correlation is performed and correlation proof is maintained and kept with the gauge at all times. Correlation of average nuclear gauge readings to core density results shall be performed after each day's production as outlined herein after. The Laboratory Technician shall continue to check and verify the rolling pattern by use of nuclear equipment at minimum every 100 feet and mark core locations every 500 feet, at center of alternate lane. The Contractor shall understand that all nuclear density testing is performed only as an aid to construction, and the Engineer's approval will not relieve the Contractor of his responsibility to produce the required density. Acceptance of the asphalt by Harris County shall be by the acceptable
core density. Other Methods of determining in-place density which correlate satisfactorily with results obtained from roadway specimens may also be used when approved by the Engineer. For Parking Lots, every 1100 square yards, take 4 nuclear gauge readings, at each marked core location. Cores shall be taken the same day or no later than the beginning of the next day, as the asphalt is laid. Core locations must be back filled and compacted with similar pavement material. The in-place density and air void shall be measured in accordance with Test Procedures Tex-207-F and Tex-227-F. Correlation of average nuclear gauge density reading to core density results shall be established for the cores taken daily and forwarded to Harris County on the daily basis. This process shall continue for each day’s placement until the engineer determines that a good bias has been established for that nuclear gauge. Then the same nuclear gauge should be utilized to establish and verify the in-place densities, afterwards. The specific rolling pattern used is subject to approval by the Engineer. The daily established rolling pattern shall be followed unless changes in the mixture or placement conditions occur which affect compaction. A new rolling pattern shall be established at this time. If required, test strips approximately 300-500 feet in length shall be established to determine proper rolling patterns. A maximum of two strips will be allowed. If the required rolling patterns cannot be determined that will give the required density with two strips, the first two strips shall be removed, before the third strip is constructed.

Type B:

The Contractor shall establish a rolling pattern as outlined in Test Procedure Tex-207-F, Part IV, to achieve an acceptable density. The Contractor shall confirm compaction as outlined in Test Procedure Tex-207-F, Part III, through nuclear density testing supplied by the Laboratory retained by Harris County. The target density shall be established and controlled with a nuclear gauge as outlined in Tex-207-F, Part IV and III respectively. It is recommended that the Thin Lift Asphalt Gauge be used, however other nuclear equipment may be used with prior approval of the Engineer. The Laboratory Technician shall continue to check and verify the rolling pattern by use of nuclear equipment at minimum every 100 feet per lane. Acceptance of the asphalt by Harris County shall be upon receiving final reports from the Material Engineer verifying Mix Design and Conformance to the Rolling Pattern. Cores shall not be taken for densities unless otherwise directed by the Engineer. Cores will be used to verify depth as required. The daily established rolling pattern used is subject to approval by the Engineer. The daily established rolling pattern shall be followed unless changes in the mixture or placement conditions occur which affect compaction. A new rolling pattern shall be established at this time.
340.15 Construction Joints. Placing of the surface course shall be as nearly continuous as possible, and the roller shall pass over the unprotected end of the freshly laid mixture only when the laying of the course is discontinued for such length of time as to permit the mixture to become chilled. In all such cases, when the work is resumed, the material laid shall be cut back so as to produce a slightly beveled edge for the full thickness of the course.

The old material which has been cut away shall be removed from the work site, and the new mix laid against the fresh cut.

A 10 foot straight edge shall be used immediately after final rolling and any unevenness shall be corrected at that time.

Hot smoothing irons may be used for sealing joints, but in such cases extreme care shall be exercised to avoid burning the surface.

Irregularities. Immediately take corrective action if surface irregularities, including but not limited to segregation, rutting, raveling, flushing, fat spots, mat slippage, color, texture, roller marks, tears, gouges, streaks, or uncoated aggregate particles, are detected. The Engineer may suspend production or placement operations until the problem is corrected.

At the expense of the Contractor and to the satisfaction of the Engineer, remove and replace any mixture that does not bond to the existing pavement or that has other surface irregularities identified above.

340.16 Surface Requirements. The final surface of the pavement after compression shall be smooth and true to the established line and grade and typical cross-sections shown on the plans and, when tested with a standard 10 foot or 16 foot straightedge laid parallel to the centerline of the roadway, shall have no deviation in excess of 1/8 inch per foot for a 16 foot straight edge or 1/16 inch per foot for a 10 foot straight edge from the nearest point of contact and the maximum ordinate measured from the face of the straightedge shall not exceed 1/4 inch at any point. Any areas of the surface not meeting these requirements shall be immediately corrected as directed. Tests shall be made at transverse construction joints out at randomly selected locations. Any unevenness indicated by a 10 foot straight edge laid perpendicular to the job, immediately after final rolling, shall be corrected at that time.

340.17 Opening to Traffic. Allow the compacted pavement to cool before opening to traffic unless otherwise directed by the Engineer. If the surface ravels or deteriorates in any manner, it will be the Contractor's responsibility to correct this condition at his expense.
340.18 Measuring Devices. All templates, straight edges, and other measuring devices necessary for the proper construction and checking of the work shall be furnished, operated and maintained by the Contractor at his entire expense.

340.19 Quality Assurance. The County will engage a Testing Firm to provide quality assurance services for the Hot Mix Hot Laid Asphaltic Concrete. The Testing Firm will sample and test stockpiles for gradation in accordance with TxDOT’s Test Procedure Tex-200-F and deleterious materials and decantation in accordance with TxDOT’s Test Procedure Tex-217-F (Parts I and II) for each 3,000 tons of production. The abrasion loss of the material shall be determined in accordance with ASTM C131 “Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine”, for each 4,000 tons of production.

Asphalt binder will not be sampled and tested, provided that the supplier will provide copies of test results for PG grade binder used for the project. Undocumented asphalt binder will require sampling and testing in accordance with AASHTO Method T-102 “Standard Method of Test for Spot Test of Asphaltic Materials” or TxDOT’s Test Procedure Tex-540-C and shall meet the requirements of the Latest Edition, of TxDOT’s Specification Item 300. The Contractor will be responsible for the cost of these tests. The Engineer may verify the quality of the asphalt binder at any time, by sampling and testing in accordance with the aforementioned methods.

The mixture shall be sampled, for each 400 (cumulative) tons of production and the following tests will be performed on each sample of the mixture.

<table>
<thead>
<tr>
<th>TEST</th>
<th>DESIGNATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory Density</td>
<td>Tex-207-F</td>
</tr>
<tr>
<td>Maximum Theoretical Density</td>
<td>Tex-227-F</td>
</tr>
<tr>
<td>Hveem Stability</td>
<td>Tex-208-F</td>
</tr>
<tr>
<td>Extraction and Gradation</td>
<td>Tex-210-F or Tex-236-F</td>
</tr>
</tbody>
</table>

Based on daily and total production Harris County may waive the sampling and laboratory testing.

Following compaction of the mixture in the pavement, the Laboratory will sample the pavement represented by Type A Construction by cutting cores and determining the in-place density and air voids as outlined in accordance with TxDOT's Test Procedure Tex-207-F and in Section
340.14 of this Item. Additional samples and/or tests shall be taken to provide quality assurance only when approved by the Engineer.

Type B construction shall be acceptable by Harris County upon receiving final reports from the Engineer verifying Mix Design and conformance to the rolling pattern.

340.20 Truck Scales. A set of standard platform truck scales will be placed at the plant and shall be provided with a suitable weigh office adjacent to the scales for the use of the truck weighers. Scales which are not accurate to within 4 pounds per one thousand (1,000) pounds total load shall not be used. Dray tickets shall accompany each load indicating the tare load, gross load, net load, and road name of asphaltic concrete. The Engineer shall have access to the weigh office as well as all other parts of the mixing plant. Scales shall meet the requirements of the Item 520 "Weighing and Measuring Equipment".

340.21 Measurement. Hot mix-hot laid asphaltic concrete surfacing of the types specified to the thickness shown on the plans will be measured by the ton of 2,000 pounds. Measurement by weight shall be made on truck scales as previously specified. Dray tickets shall be kept on the tare load, total load, net load, and road name of asphaltic concrete for each load of same. Cut back asphalt used in the tack coat or prime coat will be measured by the gallon of material actually used for this purpose and shall be based on measurement at the point of delivery and at the applied temperature.

340.22 Payment. Payment shall be made as follows:

A. Where the bid sheet specifies FOB the job site, the asphaltic concrete shall be transported to the job site in Harris County specified on the bid sheet, and unloaded at the location indicated.

B. Where the bid sheet specifies FOB the plant, the material shall be loaded on Harris County vehicles.

C. The "Hot Mix-Hot Laid Asphaltic Concrete Surfacing" furnished and placed as prescribed by this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Hot Mix-Hot Laid Asphaltic Concrete Surfacing", which price shall be full compensation for furnishing all materials, for all freight involved, for all heating, mixing, hauling, cleaning the base, placing asphaltic concrete mixture, rolling and finishing; for all manipulations, labor, tools, equipment and incidentals necessary to complete the work.
The “Hot Mix-Hot Laid Asphaltic Concrete Surfacing” material, furnished and placed, as used for partial level-up (low areas) on some roads and feathering intersections and driveways on all roads to be resurfaced, shall be paid for by a separate bid item, as variable material thickness is required for these transitional surface applications of HMHL, asphaltic concrete.

Hot Mix-Hot Laid Asphaltic Concrete Surfacing will be paid by the ton in four separate bid items, and/or as additionally described, as follows:

1. Hot Mix Hot Laid Asphaltic Concrete Surfacing, furnished and placed (specify thickness);

2. Asphaltic Concrete Surfacing for feathering driveways;

3. Asphaltic Concrete Surfacing for feathering intersections; and

4. Asphaltic Concrete Surfacing for level up course (specify thickness).

D. All work and materials incidental to the above application of the tack coats or prime coats performed and measured as prescribed above will be paid for at the contract unit price bid per gallon for tack coat or prime coat, which price shall be full compensation for the preparation of existing base course or pavement, furnishing all materials, all hauling, heating, manipulations and for all labor, tools, equipment and incidentals necessary to satisfactorily apply the tack coat or prime coat.

Records shall be kept of the tare weight and net weight of asphaltic concrete, for each load of same.

Cutback or emulsified asphalt used as the tack coat will be measured by the gallon of material actually used on the street for this purpose and shall be based on measurement taken at the point of delivery on the street and at the applied temperature.

All work and materials incidental to the application of the tack coat performed and measured as prescribed above will be paid for at the contract unit price bid per gallon for tack coat or prime coat, which price shall be full compensation for the preparation of existing base course or pavement, furnishing all materials, all hauling, heating, manipulation and for all labor, tools, equipment
and incidentals necessary to satisfactorily apply the tack coat or prime coat.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 520 "Weighing and Measuring Equipment"

END OF ITEM 340
ITEM 341

HOT IN-PLACE ASPHALT RECYCLING

341.1 Description. This Item shall govern for the process of asphalt surface rehabilitation consisting of repaving the existing asphaltic pavement in a simultaneous multi-step process of heating, scarifying, applying an asphalt rejuvenator, and relaying the old asphaltic surface, and then placing an overlay of new asphaltic concrete over the recycled asphalt pavement. The total thickness of the asphaltic pavement shall be as shown on the construction drawings.

341.2 Materials.

A. The new asphaltic concrete material shall be in accordance with Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”. It shall be the Contractor's responsibility to supply the newly added asphaltic concrete. The temperature of the new asphaltic concrete shall be in accordance with Item 340, when delivered to the jobsite.

B. The asphalt rejuvenator shall be AES-300RP, Polymer Modified High-Float Emulsion, or equivalent, and shall meet the requirements of Item 300 “Asphalts, Oils, and Emulsions” of the Texas Department of Transportation’s Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges, Latest Edition.

341.3 Equipment. The machine that heats, scarifies, rejuvenates, and mixes must also lay the recycled asphalt material, as well as the new material. Recycled asphaltic material must be laid within 30 seconds after scarification begins to ensure a hot monolithic bond with the scarified pavement surface.

A. Heater, Scarifier, Repaver Unit: This machine shall be a self-contained machine specifically designed to re-process upper layers of existing asphaltic pavements. This machine shall be as approved by the Engineer with due consideration being given to proven past performance of the unit for similar work. The heater-scarifier-repaver unit shall consist of at least the following:

1. A heating mechanism capable of heating the asphaltic concrete pavement surface to a temperature high enough to allow for full depth of required scarification of the material without breaking aggregate particles; without charring the pavement; and without producing undesirable pollutants.
The heating mechanism shall be so equipped that heat application shall be under an enclosed or shielded hood to prevent damage to outlying grass, shrubs, or trees. In the event of burning of the asphalt or excessive production of pollutants, the Engineer may require that operation be discontinued. Operations may not be resumed until adjustments have been made to the satisfaction of the Engineer.

2. Scarifying sections shall be equipped with separate automatic height adjustments in order to clear utility manholes and/or other obstructions in the pavement surface. These sections shall be able to penetrate the surface a minimum of 1 inch. The machine must have sufficient power to push scarifiers through the high spots and create a leveled surface conforming to the desired finished profile of the pavement. The machine must be able to scarify pavement sections in depths up to one inch in height.

3. A leveling unit capable of gathering the heated and scarified material into a windrow or otherwise leveling the material in a manner acceptable to the Engineer, and then distributing the material over the width being processed so as to produce a uniform cross-section.

4. A system for adding and blending recycling asphalt rejuvenator, to be applied at a rate determined by laboratory analysis based on laboratory tests on pavement samples. The application rate will be synchronized with the machine speed to provide uniform application and maintain a tolerance of less than 5 percent from the rate determined by laboratory analysis. This rate may be adjusted in the field with the concurrence of the Engineer.

5. A spreading and finishing mechanism capable of producing a surface that will meet the requirements of the typical cross-section, shown by the enclosed drawing and any required surface tests. Automatic screed control, if required, shall meet the requirements of Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”.

B. Rollers: Rollers shall be in accordance with Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”.

341.4 Construction Methods.
A. The pavement surface to be heater scarified shall be cleaned of all deleterious material by blading, brooming or other approved methods, prior to beginning the heater-scarification operation. It shall be the responsibility of the Contractor to protect the adjacent landscape from heat damage. This protection may consist of individual shielding and/or water spray or other methods approved by the Engineer.

B. The existing asphaltic pavement shall be evenly heated, scarified, mixed and re-laid to the minimum depth shown on the construction drawings, by a continuously moving heater-scarifier-repaver unit. It shall be controlled to assure uniform heat penetration without causing differential burning of the surface. Charring of the asphalt will not be permitted. Under no circumstances shall the scarifying penetrate into the existing flexible base course.

C. The heated material shall have a temperature in a range between 225° F. and 265° F. as measured immediately behind the heater-scarifier. The Contractor will regulate the temperature within these limitations, and the mixture shall not vary from this selected temperature more than 25° F. Temperature measurement methods shall be in accordance with Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”.

D. Rejuvenator shall be applied during the mixing operation. The rate of application for the rejuvenator shall be provided according to the geotechnical lab results based on existing road surface material tests.

E. The new asphaltic concrete shall be placed (laid) over the in-place hot scarified material. The in-place material shall have a residual temperature of at least 190° F. Again temperature measurement methods shall be in accordance with Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”.

F. New asphaltic concrete pavement overlay shall be placed over the hot re-laid recycled asphaltic material. The hot re-laid asphaltic concrete shall have a temperature of at least 190° F. when the new asphaltic material is placed over it.

G. Hot mix asphaltic concrete shall be placed and spread using a vibratory screed, and, unless otherwise directed by the Engineer, an automatic longitudinal screed control system shall be required.
H. To the varying properties of the existing asphalt pavement, the following adjustments shall be made, as required, as directed by the Engineer.

1. Depth of scarification may be varied.

2. Rate of asphalt rejuvenator may be varied as necessary to maintain a uniform mixture. A laboratory will have determined the recommended rate of rejuvenator application prior to the execution of the project.

3. The amount of new asphaltic material required may be adjusted as necessary to maintain the total design depth of recycled material and new asphaltic concrete pavement.

341.5 Sampling. Minimum of one sample of the hot in place recycled material shall be taken per day.

341.6 General Requirements. The work under this Item will not be allowed when the air temperature is not in accordance with Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”.

341.7 Quality Assurance. The rolling pattern shall be established daily/road as outlined in TxDOT’s Test Procedure Tex-207-F, Part IV, and densities and compaction verified as outlined in Test Procedure Tex-207-F, Part III, at minimum for every 100 feet.

The new Hot Mix-Hot Laid Asphaltic Concrete mixture overlay shall be sampled and tested as per requirements of Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”.

The recycled material shall be sampled at a frequency of one sample for every 3,500 square yards of recycled area or minimum of one sample per day for a recycled area of greater than 700 square yards, and the following tests should be performed on the recycled material:

<table>
<thead>
<tr>
<th>TEST</th>
<th>DESIGNATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction</td>
<td>Tex-210-F or Tex-236-F</td>
</tr>
<tr>
<td>Gradation</td>
<td>Tex-200-F</td>
</tr>
<tr>
<td>Abson Recovery</td>
<td>Tex-211-F</td>
</tr>
<tr>
<td>Penetration</td>
<td>ASTM D5</td>
</tr>
<tr>
<td>Viscosity</td>
<td>ASTM D2170</td>
</tr>
</tbody>
</table>
341.8 Measurements. The asphalt recycling process as described above will be measured by the square yard of material, in place.

The new Hot Mix-Hot Laid Asphaltic Concrete overlay material, meeting the requirements of Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”, shall be paid for by the ton of material, in place.

The rejuvenating agent shall be paid for by the gallon of material, blended with the existing asphaltic material.

341.9 Payment. The work performed and the materials furnished as prescribed by this Item and measured as outlined above, shall be paid for as follows:

The recycling work shall be paid for by the square yard, which price shall be full compensation for all surface cleaning, heating and scarifying, and relaying the blended asphaltic concrete mixture as well as rolling and finishing, for all manipulations, labor, tools, equipment and incidentals necessary to complete the work.

Payment for new asphaltic concrete shall be by the ton of material furnished, delivered and in place for "Hot Mix-Hot Laid Asphaltic Concrete" which price shall be full compensation for furnishing all material, for all freight involved, for all heating, mixing, hauling, placing asphaltic concrete mixture, rolling and finishing, for all manipulations, labor, tools, equipment and incidentals necessary to complete the work.

Payment for the rejuvenating agent shall be by the gallon. The unit price quoted for this Item shall be full compensation for furnishing, delivering and properly mixing the rejuvenating agents in the recycling process and for all manipulations, labor, tools, equipment and incidentals necessary to complete the work.

Payment for the test that determines the rate of application for the rejuvenator shall be paid for per each test. The Contractor shall hire a geotechnical lab to provide these tests as soon as bid award notification is made so the rate of application for the rejuvenator shall be available at the Pre-Construction Meeting.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 340 “Hot Mix-Hot Laid Asphaltic Concrete”

END OF ITEM 341
ITEM 360

CONCRETE PAVEMENT

360.1 Description. This Item shall govern for a pavement of portland cement concrete with reinforcement. The pavement shall be as shown on the drawings, and may or may not include monolithic curbs. The pavement includes any driveways that are included in the project bid.

The pavement shall be constructed as herein specified on the prepared subgrade or other base course in conformity with the thickness and typical cross-sections shown on the drawings, and to the lines and grades established by the Engineer. All materials shall be provided from an approved Texas Department of Transportation (TxDOT) supplier and it shall be the responsibility of the Contractor to provide certification that such approval has been met. In addition, other tests or approvals may be required at the discretion of the Engineer.

360.2 Materials. Harris County’s standard mix design shall contain minimum 5-1/2 sacks (94 pounds per sack) of cementitious material (including fly ash as necessary) per cubic yard and achieve a minimum compressive strength of 3,000 psi at 28 days.

The use of fly ash is acceptable and when used, the mix design shall contain 5-1/2 sacks of cementitious material per cubic yard with a fly ash content of not more than 25 percent by weight, and will achieve a minimum compressive strength of 3,000 psi at 28 days. It is recommended that the percent of fly ash by weight be reduced to a maximum of 20 percent during cold weather concreting (average ambient temperature, over a 24 hour period after placement, less than 50° F). Fly ash shall be Class C or Class F, conforming to the requirements of ASTM C618 “Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.” Fly ash shall have a minimum combined Oxide content of 50 percent for Class C or 70 percent for Class F. Do not use Class C fly ash in sulfate-resistant (Type II cement) concrete.

“High Early Strength Concrete” shall contain 7 sacks of portland cement (only) per cubic yard and may be produced from either Type I, Type II, or Type III portland cement with other chemical admixtures.

Concrete Components:

Concrete shall be composed of portland cement, fly ash (if required), water, chemical admixtures and coarse and fine aggregates, as outlined below:
A. Portland cement shall meet the requirements of ASTM C150 "Standard Specification for Portland Cement." Unless otherwise permitted or required, cement shall be Type I, Type II, or Type III.

B. Fly Ash for concrete pavement (if applicable) shall meet the requirements of TxDOT's DMS-4610, "Fly Ash." Fly ash is not allowed for use in High Early Strength Concrete.

C. Mixing water for concrete shall conform to the requirements of ASTM C1602 "Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete."

D. Chemical admixtures shall conform to the following specifications:

1. Air-entraining admixtures shall conform to the requirements of ASTM C260 "Standard Specification for Air-Entraining Admixtures for Concrete"

2. Chemical admixtures shall conform to the requirements of ASTM C494 "Standard Specification for Chemical Admixtures for Concrete."

E. Aggregates shall conform to ASTM C33 "Standard Specification for Concrete Aggregates."

Coarse aggregate shall consist of durable particles of gravel, crushed stone, or combinations thereof, free from frozen material or injurious amounts of salt, alkali, vegetative matter, or other objectionable material either free or as an adherent coating, and its quality shall be reasonably uniform throughout. It shall contain no more than 0.25 percent by weight of clay lumps and not more than 1.0 percent by weight of laminated and/or friable particles. When tested by ASTM C136 “Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates” and C117 “Standard Test Method for Minerals Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing”, it shall meet the following grading requirements:

TABLE 1

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% RETAINED, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3/4 Inch</td>
<td>0</td>
</tr>
<tr>
<td>1-1/2 Inch</td>
<td>0 – 5</td>
</tr>
</tbody>
</table>
The loss by decantation shall be a maximum of 1 percent.

F. Fine aggregate shall consist of clean, hard, durable and uncoated particles of natural or manufactured sand or a combination thereof, with or without mineral filler. It shall be free from frozen material, or injurious amounts of salt, alkali, vegetative matter or other objectionable material and it shall not contain more than 0.5 percent, by weight, of clay lumps. When subjected to the color test for organic impurities, ASTM C40 “Standard Test Method for Organic Impurities in Fine Aggregates for Concrete”, the fine aggregate shall show a color not darker than the standard.

Unless otherwise specified, fine aggregate shall meet the following grading requirements:

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% RETAINED, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 Inch</td>
<td>70 – 90</td>
</tr>
<tr>
<td>No. 4</td>
<td>95 – 100</td>
</tr>
<tr>
<td>No. 8</td>
<td>0 – 20</td>
</tr>
<tr>
<td>No. 16</td>
<td>15 – 50</td>
</tr>
<tr>
<td>No. 30</td>
<td>35 – 75</td>
</tr>
<tr>
<td>No. 50</td>
<td>65 – 90</td>
</tr>
<tr>
<td>No. 100</td>
<td>90 – 100</td>
</tr>
<tr>
<td>No. 200</td>
<td>97 – 100</td>
</tr>
</tbody>
</table>

Fine aggregate shall be subjected to ASTM D2419 “Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate”. The sand equivalent shall be not less than 80.

Mineral filler shall consist of stone dust, clean crushed sand or other approved inert material.

Reinforcing Steel:
Unless otherwise designated on the drawings, or herein, all bar reinforcement shall be deformed and shall conform to ASTM A615 "Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement", Grade 60, open hearth, basic oxygen or electric furnace new billet steel. The use of Grade 40 is permissible for bars that must be bent. The use of prefabricated deformed steel bar mats, conforming to ASTM A184 "Standard Specification for Welded Deformed Steel Bar Mats for Concrete Reinforcement", is not permitted.

Tie bars (including L-bars) shall be the same spacing and diameter as the transverse or longitudinal bars (as the case may be), and shall be tied to the transverse or longitudinal reinforcing steel being used in the pavement. Tie bars shall be a minimum of 30 inches in length. Type III adhesives meeting the requirements of TxDOT Material Specification DMS-6100 "Epoxies and Adhesives" shall be used for installing drilled-in reinforcing steel and dowels, into the existing concrete pavements.

Expansion Joints:

Boards for expansion joint filler shall be 3/4 inch finished thickness. The material for the boards shall consist of "All Heart Merchantable Redwood" or composite material as approved by the Engineer. The joint filler shall meet the testing requirements of ASTM D545 "Standard Test Methods for Preformed Expansion Joint Fillers for Concrete Construction (Non-extruding and Resilient Types)."

If the joint filler used is a bituminous composite, it shall meet the requirements of ASTM D1751 "Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types)."

Joint sealant shall meet the requirements of ASTM D6690 "Standard Specification for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements", Type II or III. Joint sealant for expansion joints shall be installed 1/4 inch below the top of pavement elevation. Prefabricated expansion joints may be used with approval by the Engineer.

Load transmission devices shall consist of an 18 inch smooth dowel placed as shown on the Standard Civil Drawing. The dowel size varies with pavement thickness as shown on the Concrete Pavement Details of the Harris County Standard Civil Drawings. Dowels may be sheared or saw cut to the desired length.

Storage of Materials. Cement shall be stored in well ventilated weathertight buildings, bins, or silos which shall exclude moisture and contaminants.
Aggregate stockpiles shall be arranged and used in such a manner as to avoid contamination, with other materials or with other sizes of like aggregates. To ensure that this condition is met, any test for determining conformance to requirements for cleanliness and grading shall be performed on samples secured in accordance with ASTM D75 “Standard Practice for Sampling Aggregates.” Frozen or partially frozen aggregates shall not be used. Unless otherwise authorized by the Engineer, all aggregate shall be stockpiled at least 24 hours prior to use, to reduce free moisture content.

Chemical admixtures shall be stored in such a manner as to avoid contamination, evaporation, or damage. For those used in the form of suspensions or non-stable solutions, agitating equipment shall be provided to assure thorough distribution of the ingredients. Liquid admixtures shall be protected from freezing and from temperature changes which would adversely affect their characteristics.

360.4 Proportioning of Concrete. Concrete for all parts of the work shall be of the specified quality, capable of being placed without excessive segregation and, when hardened, shall develop all characteristics required by this Item and the contract documents.

The specified compressive strength of the concrete, for each portion of the structure, shall be as designated in the contract documents. Strength requirements shall be based on the 28 day and 7 day compressive strength, respectively.

360.5 Concrete Classification. Concrete shall be classified as shown in Table 3 of Item 421 “Structural Concrete”.

360.6 Selection of Proportions. Proportions of materials for concrete shall be established to provide:

A. Workability and consistency to permit concrete to be worked readily into forms and around reinforcement under conditions of placement to be employed without segregation or excessive bleeding.

B. Strength requirements in accordance with Table 3 of Item 421.

C. Resistance to special exposure as required by the Engineer and as specified in the contract documents or in Special Provisions.

Unless otherwise permitted, the concrete mix design shall be proportioned to provide a slump between 1 and 6 inches. A slump range of 1 to 3-1/2 inches shall be used for concrete placed with a slip form paver, while
vibrated concrete shall have a slump range of 2-1/2 to 6 inches, when tested in accordance with ASTM C143 "Standard Test Method for Slump of Hydraulic-Cement Concrete." A slump test will be made for each sample of concrete obtained, or when slumps appear to be outside specification requirements. The allowable air content for moderate exposure is:

<table>
<thead>
<tr>
<th>AGGREGATE SIZE</th>
<th>% AIR CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2 Inch</td>
<td>2.5 - 4.5</td>
</tr>
<tr>
<td>3/4 Inch</td>
<td>3.5 – 5.0</td>
</tr>
</tbody>
</table>

The Engineer may reject any concrete shown to be outside of these requirements.

All concrete pavement shall have a minimum design compressive strength of 3,000 psi at 28 days. A minimum of 4 test cylinders shall be made for each 150 cubic yards, or portion thereof, placed each day. Samples shall be taken in accordance with ASTM C172 “Standard Practice for Sampling Freshly Mixed Concrete” and molded and cured in accordance with ASTM C31 “Standard Practice for Making and Curing Concrete Test Specimens in the Field.”

All test specimens shall be prepared in accordance with ASTM C617 “Standard Practice for Capping Cylindrical Concrete Specimens” and tested in accordance with ASTM C39 “Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.” Two specimens shall be tested at 7 days and two specimens shall be tested at 28 days. The acceptance test results shall be the average of the two specimens tested for each age interval. If one specimen in a test age indicates evidence of improper sampling, handling, molding or testing, it shall be discarded and the strength of the remaining specimen shall be considered the test result. Should both specimens in a test interval show any of the aforementioned defects, the Engineer may request that cores be taken in the affected area.

Additional test specimens may be required due to concrete placing conditions and due to use of high early strength concrete. No extra compensation shall be allowed for materials and work involved in fulfilling these requirements.

360.7 Equipment. All equipment necessary for the construction of concrete pavement shall be on the job and shall have been approved by the Engineer as to condition, before the Contractor will be permitted to begin construction operations on which the equipment is to be used.
Side forms shall be of metal of approved cross-section. The preferred depth of the form shall be equal to the required edge thickness of the pavement. Forms with depths less than the required edge thickness of the pavement will be permitted, provided the difference between the form depth and the edge thickness is not greater than 1 inch, and further provided that forms of a depth, less than the pavement edge are brought to the required edge thickness by securely attaching wood or metal strips, of approved section, to the bottom of the form, or by grouting under the form.

The length of form sections shall be not less than 10 feet and each section shall provide for staking in position with not less than 3 pins. Flexible or curved forms of wood or metal of proper radius shall be used for curves of 100 foot radius or less. Forms shall be of ample strength and shall be provided with adequate devices for secure setting so that when in-place they will withstand without visible springing or settlement, the impact and vibration of the finishing machine. The forms shall be free from warp, bends or kinks and shall be sufficiently true to provide a reasonably straight edge on the concrete. The top of each form section, when tested with a straight edge, shall conform to the requirements specified for the surface of the completed pavement. Sufficient forms shall be provided for satisfactory prosecution of the work.

A minimum of two hand vibrators is required at the jobsite when placing concrete. A hand vibrator shall be used around all load transfer devices and intersections where screeds or slip form pavers cannot be operated.

Pavement shall be finished by machine, except as hereinafter provided. Placement shall be the Contractor’s responsibility and shall be based upon equipment sequences utilized in accordance with the recommendations and practices of ACI 304R “Guide for Measuring, Mixing, Transporting, and Placing Concrete”, and with the approval of the Engineer.

The Contractor shall furnish and maintain at least two standard 10 foot steel or aluminum straight edges.

Where applicable, the Contractor shall furnish a sufficient number of bridges equipped to ride on the forms and span the pavement for finishing operations and for the installation and finishing of joints and center strips. All necessary finishing and edging tools shall be furnished as may be required to complete the pavement in accordance with the drawings.

360.8 Slip Form Paver. Slip form pavers are allowed by Harris County.
360.9 Subgrade and Forms. The subgrade shall be prepared as required by the applicable subgrade specification items. Rolling and sprinkling shall be performed as necessary, or as directed. The roadbed shall be completed to the elevation as required on the typical sections shown on construction drawings. Drainage of the roadbed shall be maintained at all times.

The subgrade shall be finished to the exact section of the bottom of the pavement as shown on plans. The subgrade shall be maintained in a smooth, compacted condition, in conformity with the required section and established grade until the pavement is placed, and shall be kept thoroughly wetted down sufficiently in advance of placing any pavement to insure its being in a firm and moist condition for at least 2 inches below the prepared surface. No equipment or hauling shall be permitted on the prepared subgrade, except on special permission of the Engineer, which will be granted only in exceptional cases and only where a suitable protection in the form of two-ply timber mats or other approved material is provided.

The subgrade under the forms shall be firm and cut true to grade so that each form section when placed will be firmly in contact for its whole length and base width, and exactly at the established grade. Any subgrade under the forms below established grade shall be corrected, using suitable material, placed, sprinkled and rolled as directed. Forms shall be staked with at least 3 pins for each 10 foot section. A pin shall be placed at each side of every joint. Form sections shall be tightly joined and keyed to prevent relative displacement. Forms shall be cleaned and oiled each time they are used.

Sufficient subgrade shall be prepared far enough in advance of concrete placement to allow a minimum of 300 feet of forms to be set in place in advance of concrete placement at all times (with exception of intersections, etc.) or as approved by the Engineer. Conformity of the grade and alignment of forms shall be checked immediately prior to placing concrete and all necessary corrections made by the Contractor. Where any form has been disturbed or any subgrade has become unstable, the form shall be reset and rechecked. In exceptional cases, the Engineer may require suitable stakes driven to the grade of the bottom of the forms to afford additional support. Sufficient stability of forms to support the equipment operated thereon and to withstand its vibration without springing or settlement shall be required. If forms settle over 1/8 inch under finishing operation, paving operations shall be stopped and the forms shall be reset to line and grade.

Forms shall remain in place for a minimum of 8 hours after the concrete has been placed. They shall be carefully removed so that there is little or no damage done to the edge of the pavement. Any damage resulting
from this operation shall be immediately repaired. After the forms have been removed, the ends of all joints shall be cleaned, and any honeycombed areas pointed up with an approved mortar.

Immediately after pointing is complete, the form trench shall be filled with earth from the shoulders in such manner as to shed water from rainfall or curing away from the edge of the pavement. On completion of the required curing, the subgrade or shoulders adjacent to the pavement shall be placed in condition to maintain drainage.

360.10 Reinforcing Steel and Joint Assemblies. All reinforcing steel, tie bars, load transmission units and splices used in accordance with plan provisions meeting the requirements of Item 440 “Reinforcing Steel”, shall be accurately placed and secured in position in accordance with the details shown on drawings.

Reinforcing bars shall be secured at all splices and at alternating intersections. The tie bars shall be installed in required position by the method and device shown on drawings, or by approved method and device equivalent thereto. Bar coatings required by plans, and of material specified, shall be completed and the bars and coating shall be free of rust, dirt or other foreign matter at the time of installation in the concrete. Reinforcing bars shall be supported on bar chairs or other approved devices placed on maximum 36 inches center each way, and placed so that the reinforcing bar is located at the centerline of the concrete.

Where plans require an assembly of parts at pavement joints, the assembly shall be completed, placed at required location and elevation, and all parts rigidly secured in required position as shown on plans, or by approved method and devices equivalent thereto. Dowel bars shall be accurately installed in joint assemblies in accordance with drawings, each parallel to the pavement, and shall be rigidly secured in required position by such means (as shown on plans, or approved equivalent thereto) that will prevent displacement of the dowels during placing and finishing of the concrete. The assembled units comprising the load transmission devices shall be accurately installed in joint assemblies in accordance with plans. Each unit shall be vertical with its length perpendicular to the centerline of the pavement, and all units shall be rigidly secured in required position by such means (as shown on drawings, or approved equivalent thereof) that will prevent displacement of the expansion joint during placing and finishing of the concrete. Joint filler shall be accurately notched to receive each load transmission unit. All load transmission units shall be free of rust and clean when installed in the concrete.

360.11 Concrete Placing. Except by specific written authorization of the Engineer, concrete shall not be placed when the ambient temperature is
below 40°F and falling. Concrete may be placed when the ambient temperature is above 35°F and rising, the ambient temperature being taken in the shade and away from artificial heat.

The Contractor shall have available a sufficient supply of approved cotton mats, polyethylene sheeting or other approved covering materials to immediately protect concrete if the air temperature falls to 32°F, or below, if the concrete has been in place for less than 4 hours. Such protection shall remain in place during the period the temperature continues 32°F or below, or for a period of not more than 5 days. Neither salt nor other chemical admixtures shall be added to the concrete to prevent freezing. The Contractor shall be responsible for the quality and strength of concrete under cold weather conditions and any concrete damaged by freezing shall be removed and replaced at the Contractor's expense.

When the concrete reaches a temperature of 85°F, retarders shall be introduced into the mixture.

If the concrete temperature continues to rise and reaches 95°F, a plasticizer shall be introduced into the mixture. Above 95°F, ice may be used to control temperature, in lieu of a plasticizer.

For concrete between temperatures of 85°F through 95°F, the slump shall be as specified in this Item. For concrete with temperatures between 95-100°F, slumps shall be as specified by the Engineer. The temperature of the concrete shall at no time exceed 100°F. Once concrete has reached a temperature above 100°F, it shall be rejected.

The amount of retarder or plasticizer, introduced into a mixture, shall be in accordance with the manufacturer’s recommendations. See Section 360.2, Materials, for requirements of admixtures.

No concrete shall be used if:

A. the concrete has developed initial set, or

B. the concrete has not been placed within 1-1/2 hours after the initial water has been added.

Pouring concrete during inclement weather, which would adversely affect the quality and/or finish of the concrete pavement does not relieve the Contractor of his responsibility to provide a pavement that complies with the Item.

360.12 Joints. All transverse and longitudinal joints in the pavement shall be at the locations and of the type shown on the drawings.
Expansion Joints:

Transverse expansion joints shall be formed perpendicular to the centerline and surface of the pavement, and shall be constructed in accordance with the drawings.

The seal space shall be created by either of the following methods:

A. Seal Space Form (aka Rip Strip) After the transverse finishing machine and before the longitudinal finishing machine has passed over the joint, the Contractor shall test the joint assembly for correctness of position and make any required adjustment in position of the joint assembly. After removal of the seal space form, the seal space above the joint assembly shall be thoroughly cleaned and the concrete faces of the seal space shall be left true to line and section throughout the entire length of the joint.

B. Other method as approved by the Engineer.

On completion of curing of the pavement, the expansion joint sealant of the type specified shall be placed in accordance with drawings. The faces of the seal space shall be washed and cleaned and surface-dry at the time sealant is placed. On completion of sealing, the pavement surface (adjacent to the joint) shall be left free of sealing material.

Sawcut Joints: - Transverse Contraction and Longitudinal

All contraction joints (transverse or longitudinal) that are not at the edge or end of a pour shall be saw cut. Metal or fiber “rip” strips placed in the uncured concrete will not be permitted. Where sawed joints are required, they shall be sawed as soon as sawing can be accomplished, without damage to the pavement, and as directed by the Engineer. Once sawing has commenced, it shall be continued until completed. The saw cut shall be made with one pass of the concrete saw. Sawing must be accomplished even in rain or cold weather. All sawing must be completed within 24 hours of the concrete pavement placement. Within 24 hours of completing the concrete pour, all sawcut joints shall be sawed and washed of all residue. Should the sawing for any day’s placement fail to be completed within 48 hours; the following concrete placement shall be limited to the amount that was sawed on time. The limitation shall continue until the sawing crew demonstrates it can handle a larger volume of sawing.

The sawed cut shall be a minimum of 1/4 inch width and have a depth of one-fourth the thickness of the pavement. After sawcutting, the joint shall
be sealed with joint sealer, in accordance with the instructions supplied by the manufacturer of the joint sealant. Sealant shall fill the joint from bottom to 1/4 inch below concrete surface. Use of backer rods in sawcut joints is prohibited.

Unless otherwise specified, transverse sawed control joints shall be constructed at 20 foot intervals measured along the centerline of the pavement section, or as directed by the Engineer.

Longitudinal Construction Joints:

When constructing a longitudinal construction joint, all applicable provisions of Section 360.7 shall apply in addition to the following requirements:

The face of the bulkhead at the joint shall be grooved or recessed as necessary to provide the required spaces for the top and bottom breaker strips as shown on plans. The bulkhead shall be either drilled or notched to receive the tie bars. Tie bars shall be secured in required position by use of adequate transverse bracing and vertical supports meeting the approval of the Engineer.

360.13 Terminating Concrete Placement:

Normal Terminating Procedures. Concrete placement shall be terminated at an expansion joint or a transverse construction joint that is coincidental with a location of a proposed contraction joint.

When the concrete placement is terminated at an expansion joint or a transverse construction joint, the complete joint assembly shall be installed and rigidly secured in the required position as shown on the plans.

A bulkhead of sufficient cross-sectional area to:

A. prevent deflection and

B. accommodate the dowels

shall be provided. The bulkhead shall be shaped accurately to the cross-section of the pavement and installed as a back-up for the expansion joint header or transverse construction joint header and rigidly secured in the required position to permit accurate finishing of the concrete up to the joint.
After the concrete has been finished to the joint, formation of the joint seal space and finishing of the joint shall be executed as specified herein and in accordance with plan requirements. The back-up bulkhead shall remain in place until immediately prior to the time when concrete placement is resumed. It shall then be carefully removed in such manner that no element of the joint assembly will be disturbed. The exposed portions of the joint assembly shall be free of adherent concrete, dirt or other material.

Unscheduled Terminating Procedures. When concrete placement must be terminated at a location other than an expansion joint or transverse construction joint, all applicable provisions of Section 360.7 shall apply, in addition to the following requirements:

A bulkhead shall be installed as a vertical form to pour the concrete against. The bulkhead adjoining the pavement end shall consist of upper and lower panels, with a gap of approximately two inches between, through which the reinforcing steel mat extends. During the concrete pouring process, some concrete will extrude through the gap, which is to be left in place to create a roughly formed “keyway” into the subsequent pour section.

Concrete shall be placed and finished to this bulkhead. Any concrete that falls onto the subgrade ahead of the bulkhead shall be removed and disposed of as directed. The seam created by a construction joint of this type shall have a saw-cut seal space and shall be sealed as required for construction joints.

360.14 Finishing. All finishing shall be in accordance with ACI 325.6R “Texturing Concrete Pavements”.

The Engineer shall approve the straightedge. The surface of the concrete shall not vary from the straightedge by more than 1/16 inch per foot from the nearest point of contact, and in no case shall the maximum deviation from a ten foot straightedge to the pavement be greater than 1/8 inch. Any high spots causing a departure from the straightedge in excess of that specified shall be ground down by the Contractor to meet the surface test requirements, when required by the Engineer.

360.15 Curing. The Contractor shall prevent surface drying of the pavement before application of curing system by means that may include water fogging, use of wind screens or the use of evaporation retardants. He shall provide for protection of freshly laid concrete against pitting and washing from rain, by placement of canvas and/or waterproof covering material to protect all placed concrete. The covering material is required to be on the jobsite at the time and place of pouring.
The curing system may be:

A. Liquid Membrane. Liquid membrane curing shall be used as per Item 526 “Membrane Curing”.

B. Additional Curing Methods. Other methods meeting the requirements of ACI 308R “Standard Practice for Curing Concrete” must be submitted by the Contractor in writing prior to concrete placement and approved by the Engineer.

360.16 Protection of Pavement and Opening to Traffic. The Contractor shall erect and maintain the barricades required by the plans, and such other barricades and approved devices necessary to exclude public traffic and traffic of his employees and agents from the newly placed pavement for the periods of time hereinafter prescribed. Portions of the roadway, or crossings of the roadbed required to be maintained open for use by traffic, shall not be obstructed by the above required barricades. Crossings of the pavement required by plans, or by construction sequence, during the period prior to opening to traffic as herein specified, shall be provided with an adequate and substantial bridge, approved by the Engineer.

Cracked pavement shall be cored by Harris County any time after the 28 day cure time is complete. The location of these cores shall be selected by the Engineer. Pavement that has developed full depth cracks (greater than t/4 inch depth, where t = thickness of pavement) may, at the County’s option, be left in place and repaired by the epoxy injection method. Otherwise the cracked pavement shall be removed and replaced. There shall be no additional payment for repairs or replacement. Basis of removal for cracked pavement shall be determined by the engineer and the extent of this pavement removal shall be based on the crack pattern and number of cracks in each panel. If the cracks are wide spread (vertically or horizontally) or close to expansion joint or control joint, and over a large area of 12 foot wide panel, then entire panel shall be removed and replaced as determined by the Engineer.

Surface cracks t/4 inches and less in depth may be repaired by the epoxy injection method at no cost to the County.

Prior to epoxy injection, the Contractor shall submit to the County for approval, the injection method to be used. The Contractor shall furnish a minimum of 2 year warranty when utilizing the epoxy injection method.

New pavement sections shall be closed to all traffic, both PUBLIC and CONSTRUCTION, until the concrete has attained a compressive strength of 2,700 psi. If the Contractor or the County desires to open the new
pavement section to traffic early, an additional set of test cylinders must be requested for an early test. If the early test indicates that the minimum compressive strength requirement has been met, and if all other requirements of this Item have been met, the pavement section can be opened to traffic. If the Contractor requests the early test, the Contractor will pay the cost. If the County requests the early test, the County will pay the cost. Such opening of a new pavement section, to PUBLIC or CONSTRUCTION traffic, shall in no manner relieve the Contractor from his responsibility of the work.

On those sections of pavement to be opened to PUBLIC traffic, the pavement shall be thoroughly cleaned, stable material shall be placed, graded, and compacted against the pavement edge or curb unless otherwise specified. Joints shall be sealed and cured, and all required traffic control work shall be performed for the safety of the traffic.

The Engineer may require the opening of pavement to traffic prior to the minimum strength specified above under conditions of emergency, which in his opinion, require such action in the interest of the public. In no case shall the Engineer order opening of the pavement to traffic within less than 72 hours after the last concrete in the sections is placed unless an approved high early strength concrete was used. The Contractor shall remove any curing mats, place earth against the pavement edges, and perform other work involved in providing for the safety of traffic as required by the Engineer in ordering emergency opening. Orders for emergency opening of the pavement to traffic will be issued by the Engineer in writing.

360.17 Backfilling Behind Curbs and in Medians and Directional Islands. The Contractor is required to backfill behind all curbs and within medians and directional islands, after completion of the paving operation. The backfill material shall be on-site material having the prior approval of the Engineer. No separate payment shall be made for backfilling behind curbs and in medians and directional islands, but it shall be considered incidental to this Item.

360.18 Deficient Pavement Thickness. It is the intent of this Item that the pavement be constructed in strict conformity with the thickness and typical sections shown on plans.

Concrete Placement Method.

A. Conventional Side Form Paving: The Engineer will check the pavement thickness in accordance with the dimensions shown on the plans. The Engineer will perform 1 thickness test consisting of 1 reading at approximately the center of the paving equipment.
every 500 feet or fraction thereof. All deficiencies from plan thickness shall be corrected prior to concrete placement.

B. Slip Form Paving: The Engineer will check the pavement thickness in accordance with TxDOT’s Test Procedure Tex-423-A. The Engineer will perform 1 thickness test consisting of 1 reading at approximately the center of the paving equipment every 500 feet or fraction thereof. Verify deficiencies of more than 0.2 inches from plan thickness and determine the limits of deficiencies of more than 0.75 inches from plan thickness by coring. Core where directed, in accordance with ASTM C174 “Standard Test Method for Measuring Thickness of Concrete Elements Using Drilled Concrete Cores.” Fill core holes using a concrete mixture and method approved by the Engineer.

Thickness Deficiencies Greater than 0.2 inches. When any depth test measured in accordance with Tex-423-A is deficient by more than 0.2 inches from the plan thickness, take one core at that location to verify the measurement.

If the core is deficient by more than 0.2 inches but less than 0.75 inches from the plan thickness, take 2 additional cores from the unit (500 foot length) at intervals of at least 150 feet and at locations selected by the Engineer, and determine the thickness of the unit for payment purposes by averaging the lengths of the 3 cores. (See Table for “Deficient Pavement Thickness price Adjustment Factor”).

Thickness Deficiencies Greater than 0.75 inches. If a core is deficient by more than 0.75 inches, take additional cores at 10 foot intervals in each direction parallel to the centerline to determine the boundary of the deficient area. The Engineer will evaluate any area of pavement found deficient in thickness by more than 0.75 inches. As directed, the Contractor shall remove and replace the deficient areas with concrete pavement of thickness shown on the plans, without additional compensation.

Pavement Units for Payment Adjustment. Limits for applying a payment adjustment for deficient pavement thickness from 0.20 inches to not more than 0.75 inches are 500 feet of pavement in each lane. Lane width will be shown on typical sections and pavement design standards.

For pavement thickness deficiencies greater than 0.75 inches, the limits for requiring removal will be defined by coring as determined by the Engineer. The remaining portion of the unit determined to be less than 0.75 inches deficient will be subject to the payment adjustment based on
the average core thickness at each end of the 10 foot interval investigation as determined by the Engineer.

Shoulders will be measured for thickness unless otherwise shown on the plans. Shoulders 6 feet wide or wider will be considered as lanes. Shoulders less than 6 feet wide will be considered part of the adjacent lane.

Limits for applying payment adjustment for deficient pavement thickness for ramps, widenings, acceleration and deceleration lanes, and other miscellaneous areas are 500 feet in length. Areas less than 500 feet in length will be individually evaluated for payment adjustment based on the plan area.

**TABLE FOR DEFICIENT PAVEMENT THICKNESS PRICE ADJUSTMENT FACTOR**

<table>
<thead>
<tr>
<th>DEFICIENCY IN THICKNESS DETERMINED BY CORES IN INCHES</th>
<th>PROPORTIONAL PART CONTRACT PRICE ALLOWED</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 to 0.20</td>
<td>100 Percent</td>
</tr>
<tr>
<td>0.21 to 0.30</td>
<td>80 Percent</td>
</tr>
<tr>
<td>0.31 to 0.40</td>
<td>72 Percent</td>
</tr>
<tr>
<td>0.41 to 0.50</td>
<td>68 Percent</td>
</tr>
<tr>
<td>0.51 to 0.75</td>
<td>57 Percent</td>
</tr>
<tr>
<td>Over 0.75</td>
<td>Remove and Replace</td>
</tr>
</tbody>
</table>

Any area found deficient in thickness by more than 0.75 inches shall be removed and replaced, at the Contractor's entire expense, with concrete of the thickness shown on drawings.

No additional payment over the contract unit price will be made for any pavements of a thickness exceeding that required on drawings and planing of concrete pavement shall not be allowed.

360.19 Non-Conforming Concrete. Any concrete deemed non-conforming, which in the opinion of the Engineer is unsatisfactory, shall be removed and replaced at the expense of the Contractor.

360.20 Quality Assurance. The Testing Laboratory's representative will sample concrete delivered to the site in accordance with ASTM C172 and will mold four specimens for each 150 cubic yards. Each time a set of specimens is molded, the slump will be determined in accordance with ASTM C143 and the air content in accordance with ASTM C173
“Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method” or ASTM C231 “Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.” Concrete cores, if required, shall be tested in accordance with ASTM C174 (9 point procedure) and ASTM C39.

360.21 Measurement. Concrete pavement shall be measured by the square yard of the specified mix design and thickness of completed and accepted pavement. Dowels, when required, are incidental to this Item, and do not require measurement.

360.22 Payment. The work performed and the materials furnished as prescribed by this Item and measured as provided under "Measurement" shall be paid for at the unit price bid for "Concrete Pavement", or "Concrete Pavement, High Early Strength", as required, or the adjusted unit price for pavement of deficient thickness as provided under "Penalty for Deficient Pavement Thickness", which price shall be full compensation for shaping and fine grading the roadbed, including furnishing and applying all water required; for furnishing, loading and unloading, storing, handling all concrete ingredients, including all freight and royalty involved; for mixing, placing, finishing and curing all concrete; for furnishing all materials for and placing longitudinal, warping, expansion, sawed control and contraction joints, and load transmission units, and joint filler material in proper position; for coating steel bars where required by plans, for furnishing and placing all reinforcing steel, for drilling dowel holes in the existing concrete pavement, providing and installing dowels and epoxy grouting them where required by the plans; and for all manipulations, labor, equipment, appliances, tools, traffic provisions and incidentals necessary to complete the work.

There are line code(s), description(s) and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 205 “Subgrade”
Item 421 “Structural Concrete”
Item 440 “Reinforcing Steel”
Item 526 “Membrane Curing”

END OF ITEM 360
ITEM 361

FULL DEPTH REPAIR OF CONCRETE PAVEMENT

361.1 Description. This Item shall govern for repairing deteriorated areas of concrete pavement as herein specified, in conformity with the existing roadway section including curbs as applicable, and as directed by the Engineer.

361.2 Materials. The Contractor shall furnish from a source approved by the Engineer, all concrete, and hot poured rubber joint sealing material. Rubber joint sealing material shall conform to ASTM D6690 “Standard Specification for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements.”

Concrete for Pavement Repair:

A. High Early Strength Concrete Mix shall contain 7 sacks of portland cement per cubic yard using a Type I, Type II, or Type III cement, which shall conform to ASTM C150 "Standard Specification for Portland Cement" and in accordance with Item 360 “Concrete Pavement”.

B. Rapid Setting High Early Strength Concrete Mix shall contain 7 sacks of portland cement per cubic yard, with other chemical admixtures and its applications are designed for early opening of the concrete road pavement to traffic 24 hours or less after completing the pour and finish.

An accelerating agent (Type C), conforming to ASTM C494 "Standard Specification for Chemical Admixtures for Concrete" may be used. All chemical admixtures shall be used in accordance with the manufacturer's recommendations.

Proposed concrete curbs may be either monolithically poured with the pavement replacement under this Item, or poured separately, using 5-1/2 sacks of Type I portland cement per cubic yard.

The Contractor shall furnish all reinforcing steel for replacement purposes, when the Engineer deems the existing steel is not salvageable. All reinforcing steel shall meet ASTM A615 “Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement”, minimum Grade 60. The rebar size should match the rebar in the existing pavement section unless it violates the following minimum rebar size:
A. No. 4 rebar for existing concrete pavement that is 7 inches thick or less.

B. No. 5 rebar for existing concrete pavement 8 inch thick to 10 inch thick.

Reinforcing steel shall be in accordance with Item 440 “Reinforcing Steel”.

The Contractor shall furnish all curing compound. Curing compound shall be in accordance with Item 526 “Membrane Curing”.

Construction Methods. When the areas to be repaired are located in an area that is overlaid with asphaltic concrete, the asphaltic concrete shall be removed over an area greater than that to be repaired, as directed by the Engineer.

The minimum dimensions for full depth concrete pavement repair are one lane-width, and not less than 6 feet long. Repair areas smaller than the minimum will show excessive “rocking” against the adjoining concrete pavement sections. Likewise, the minimum remainder of the slab shall be at least 6 feet (to the end of slab or next repair area).

Steel Reinforcement:

Where reinforcement is present, the following procedures shall apply:

A. A groove approximately 2 inches minimum depth shall be sawed along a line approximately 18 inches beyond the distressed area unless otherwise indicated on the drawings, except along the longitudinal construction joint if it is a pavement repair boundary. The concrete pavement and 6 inches of underlying base shall be removed. The concrete in the area inside the perimeter of the sawcut slab shall be carefully broken and removed leaving a clean vertical face, taking care to work around the reinforcing steel so as not to break the bond in the steel in the adjacent concrete pavement. At the perimeter, the breaking of the existing concrete will be accomplished by only the use of hand tools or lightweight jack hammers as approved by the Engineer. Concrete adjacent to the repair area shall not be spalled or fractured by the removal procedure. Base material shall be removed and replaced with a commercial grade cement stabilized sand base, as per Item 433 “Cement Stabilized Sand Bedding and Backfill Material” Section 433.2 and compacted to provide firm, even support to the concrete pavement.

B. or as shown in contract documents or approved by the Engineer
Reinforcing bars that are removed shall be replaced with new bars as per the drawings. The protruding reinforcing steel shall be inspected for damage and carefully straightened. New reinforcing bars shall be placed and firmly supported by approved bar chairs.

Longitudinal Reinforcement. The new bars shall be spliced to the existing protruding bars by lapping a minimum of 18 inches or lapping and welding as directed by the Engineer.

If three or more adjacent bars are seriously damaged or broken, they shall be replaced by drilling and grouting 30 inch long reinforcing bars (minimum #5 bars for 7 inch thick concrete; and #6 bars for concrete 9 inches or greater in thickness), using an epoxy adhesive. The 30 inch reinforcing bars shall be embedded a minimum of 10 inches horizontally into the existing concrete pavement at a spacing of 18 inches on center. If less than three adjacent bars are damaged or broken, splicing to broken bars will not be required. The accepted epoxy adhesive shall be in accordance with ASTM C881 “Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete”, Type I, II, IV, and/or V; Grade 3; and depending on the air temperature either Class A & B, or Class C.

For all concrete repair work, the following procedures shall apply. The removed concrete and excavated base shall be disposed of by the Contractor, as directed by the Engineer. Replacement of transverse joints will be required where the failed area necessitates the removal of existing joints. Concrete, used for repair, shall be High Early Strength in accordance with Item 360 “Concrete Pavement” or Rapid Setting High Early Strength.

Immediately prior to placing the concrete, the base and each face of existing concrete shall be wetted. Approved hand-operated mechanical vibrators shall be used to insure the proper consolidation of the concrete. The concrete shall be screeded off to the elevation of the adjacent concrete pavement and checked with a straight edge to insure that the riding surface will be satisfactorily repaired. Areas shall also be checked to insure there is adequate slope to provide for free drainage. The concrete shall be finished with a broom finish, as directed by the Engineer. Membrane curing shall be used until the pavement is opened to traffic. Membrane curing shall be in accordance with Item 526 “Membrane Curing”.

Part of the concrete repair work adjacent to existing concrete curb shall include replacement of grass sod and any backfill material needed behind the concrete curb, and these repairs shall be incidental to the bid item for concrete pavement repair. The Contractor shall locate any existing
improvements (waterlines, sprinklers, or landscape appurtenances) to mitigate damages. The Contractor shall be responsible for protecting these appurtenances, in the original condition, and if damaged by his operations, the Contractor shall replace them to the original condition or better, at no expense to Harris County.

High Early Strength Concrete:

The repaired area may be opened to traffic after 72 hours, when the concrete has attained a minimum average flexural strength of 500 psi, or a minimum average compressive strength of 2500 psi. All test specimens (tested in accordance with ASTM C78 “Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)” or ASTM C39 “Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens”) representing tests for opening to traffic, shall be cured using the same methods and under the same conditions as the concrete represented.

Rapid Setting High Early Strength Concrete:

The repaired area may be opened to traffic after 24 hours, when the concrete has attained a minimum average flexural strength of 400 psi, or a minimum average compressive strength of 2600 psi. All test specimens (tested in accordance with ASTM C78 or ASTM C39) representing tests for opening to traffic, shall be cured using the same methods and under the same conditions as the concrete represented.

If the time frame designated for opening traffic is less than 24 hours after concrete placement, concrete must be designed to attain a minimum average flexural strength of 255 psi or a minimum average compressive strength of 1,800 psi within the designated time frame as shown in the contract documents.

361.4 Measurement. Deteriorated areas repaired as prescribed for in this Item shall be measured by the square yard of surface area of the repaired section, regardless of the depth or type of pavement. Calculation for each patch shall be rounded off to the nearest one-hundredth square yard.

All 6 inch reinforced concrete curb shall be measured by the linear foot of curb, as replaced, complete in place, regardless of whether it was poured monolithically with the pavement, or placed separately or whether it was HES concrete or 5-1/2 sack concrete.

Dowelling, when shown on the plans, or required by the Engineer, shall be measured per each dowel placed. Doweling performed at the discretion
of the Contractor shall be incidental to this Item, and does not require measurement.

361.5 Payment. The work performed as prescribed by this Item and measured in accordance with the provisions of Measurement above, will be paid for at the unit price bid for "Full Depth Repair of Concrete Pavement", which price shall be full compensation for:

A. saw-cutting (full or partial depth as shown on plans or directed by the Engineer);

B. breaking the existing steel reinforced pavement structure and curb;

C. excavation of 6 inches of base;

D. removal, loading, hauling and disposal of the broken concrete pavement, curb and base;

E. for furnishing and installing all material including reinforcing steel and all joints, including expansion joints;

F. for all curing;

G. for placing joint sealant as required;

H. for cement stabilized sand base;

I. for the replacement of grass sod with required backfill;

for all manipulations, labor, equipment, appliances, tools and incidentals necessary to complete the work except as follows:

Dowelling performed as Directed by the Engineer Pavement dowelling performed as shown on the plans or as directed by the Engineer shall be measured in accordance with the provisions of Measurement above, will shall be paid for at the unit price bid for "Dowelling", which price shall be full compensation for drilling and grouting, including epoxy adhesive, for furnishing and installing all materials necessary, and for all manipulations, labor, equipment, appliances, tools, and incidentals necessary to complete the work.

The Contractor may choose to use full depth sawcut with drilled-in dowels shown on the typical concrete roadway widening detail drawing. If the Contractor so chooses, the sawcutting and dowels will be at his own expense (these items will only be paid for if the County requires the full depth sawcut and dowels).
Curb Installation:

Proposed concrete curb will be paid for at the unit price bid for 6” reinforced concrete curb, which shall include the removal and disposal of the existing curb as needed. The concrete curb is considered separate from the area measured and paid-for as “Repairing Existing Concrete Pavement”.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires Standard Civil Drawings that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications

Item 205 "Subgrade"
Item 440 “Reinforcing Steel”
Item 433 “Cement Stabilized Sand Bedding and Backfill Material”
Item 526 “Membrane Curing”

END OF ITEM 361
• 400 – Structural Excavation and Backfill
• 402 – Bank Sand Backfill
• 403 – Driving Timber Piling
• 404 – Driving Steel Piling
• 405 – Driving Concrete Piling
• 407 – Treated and Untreated Timber Piling
• 408 – Steel Sheet Piling
• 409 – Steel H Piling
• 410 – Prestressed Concrete Piling
• 411 – Drilled Shaft Foundations
• 420 – Concrete Structures
• 421 – Structural Concrete
• 423 – Prestressed Concrete Units
• 424 – Extending Concrete Structures
• 427 – Joint Sealant for Bridges
• 429 – Trench Safety System
• 430 – Construction of Underground Utilities
• 431 – Jacking, Boring or Tunneling Pipe
• 432 – Tunnel Construction
• 433 – Cement Stabilized Sand Bedding and Backfill Material
• 434 – Flowable Fill
• 435 – Timber Ordered Left in Trench
• 436 – Well Pointing
• 437 – Elastomeric Materials
• 438 – Preformed Joint Seal
• 439 – Polyurethane Joint Seal
• 440 – Reinforcing Steel
• 441 – Steel Structures
• 442 – Metals for Structures
• 445 – Structural Bolting
• 446 – Structural Welding
• 447 – Painting and Protective Coating
400 ITEMS

- 448 – Bridge Plaque
- 450 – Concrete and Steel Railing
- 451 – Removing and Replacing Damaged Railing
- 452 – Removing Railing
- 453 – Temporary Railing
- 455 – Timber for Structures
- 456 – Timber Structures
- 457 – Timber Preservatives and Treatment
- 458 – Hardware for Heavy Timber Construction
- 459 – Timber Bents
- 460 – Reinforced Concrete Pipe
- 461 – Corrugated Metal Pipe
- 462 – Clay Pipe
- 463 – Safety End Treatment
- 464 – PVC Pipe
- 465 – Remove and Dispose of Existing Concrete or Metal Pipe
- 471 – Precast Concrete Manholes and Junction Boxes
- 472 – Inlets
- 473 – Adjusting Manholes and Inlets
- 476 – Hydrostatic Testing of Pressure Lines
- 477 – Low Pressure Air Test – Sanitary Sewer Lines
- 480 – Precast Reinforced Concrete Box Sewers
- 481 – Monolithic Reinforced Concrete Box Sewers
- 491 – Reinforced Concrete Slope Paving
- 493 – Riprap
- 494 – Geotextiles
- 495 – Removing Old Structures
ITEM 400

STRUCTURAL EXCAVATION AND BACKFILL

400.1 Description. This Item shall govern for all excavation required for the construction of all structures within the roadway limits, except pipe or box sewers for the disposal of all excavated material; and for backfilling around completed structures to the original ground level or as required by the plans. The work shall include all necessary pumping, bailing, sheeting, drainage, and the construction and removal of any required cofferdams. Unless otherwise provided, the work included herein shall provide for the removal of old structures or portions thereof (abutments, wingwalls, piers, etc.), trees and all other obstructions to the proposed construction.

Excavation will not be classified, but will be considered as "Structural Excavation", which will include the removal of all materials encountered regardless of their nature or the manner in which they are removed as well as any required backfill, and as approved by the Design Engineer.

400.2 Structural Excavation. Unless specified on the plans, or approved otherwise by the Engineer, structural excavation shall be designated as follows:

A. Width and Length - From a vertical plane outside the structure equal to the thickness of the footing or slab.

B. Depth - From bottom of footing or slab to the finished groundline or natural groundline, whichever is lower in elevation.

C. When caissons are provided, excavation is not permitted outside the outer face of the caissons.

By definition, a cofferdam is a temporary or removable structure to keep surrounding earth, water, or both out of the excavation and may be earth, timber, steel, concrete or a combination thereof.

A caisson is a permanent part of the substructure which sinks gradually into place as material is excavated within the area protected by its sidewalls. It may be either open well type or a pneumatic type caisson.

400.3 Construction Methods. Excavation shall be done in accordance with the lines and grades indicated on the plans, or as established by the Engineer.
The final elevation to which a foundation is to be constructed shall be as shown on the plans or as raised or lowered by written order of the Engineer when such alterations are judged proper to satisfactorily comply with the design requirements for the structure. Should it be found necessary, in the judgment of the Engineer to increase or decrease the depth of footings from that shown on the plans, the necessary alterations in the details of the structure shall be accomplished as directed by the Engineer. Harris County shall have the right to substitute revised details resulting from a consideration of the changes in the design condition.

When a structure is to rest on an excavated surface, special care shall be taken not to disturb the bottom of the excavation, and the final removal of the foundation material to grade shall not be performed until just before the footing is to be placed.

Protect excavations from rainfall and surface water. If the supporting soil is exposed to adverse wet or dry conditions, excavate deeper and/or wider to sound material at no additional cost to Harris County. Prior to such activity, the Contractor shall notify the Engineer.

Excavated material required to be used for backfill may be deposited, by the Contractor, in storage piles at points convenient for rehandling of the material during the backfilling operations. The location of storage piles shall, however, be subject to the approval of the Engineer, who may require that the survey centerline of the structure and the transverse or hub line of any unit of the structure be kept free of any obstruction.

Excavated material required to be wasted shall be disposed of as directed by the Engineer, and the disposal shall be in such manner as not to obstruct a stream or otherwise impair the efficiency or appearance of the structure or other parts of the work.

400.4 Cofferdams and Caissons. The term cofferdam wherever used in this Item designates any temporary or removable structure which is constructed to hold the surrounding earth, water, or both out of the excavation, whether such structure is formed of earth, timber, steel, concrete, or a combination of these. It thus includes earthen dikes, timber cribs, any type of sheet piling, removable steel sheets and the like and all necessary bracing; and it shall also be understood to include the use of pumping wells or well points for the same purpose. The cost of cofferdams shall be included as an incidental cost to excavation.

The term caisson, wherever used in this Item, designates a permanent part of the substructure, so constructed as to sink gradually into place as material is excavated within the area protected by its sidewalls. Such
caisson may be of either the open-well or pneumatic type and quantities for same will always be included as bid items separate from excavation.

In addition to interior dredging, the lowering of caissons may be facilitated by the following methods:

A. Addition of weight by increasing the thickness of caissons, where such increase is permitted by the type of design, shall be requested by the Contractor prior to beginning the work. Increased quantities due to this change shall be at the Contractor's expense.

B. By the addition of removable loads to the caisson.

C. The use of water or air jets placed around the caisson.

D. Steel shell caissons may be driven with a drop or air hammer if the Contractor, at his own expense, provides a suitable driving ring. The driving ring shall be of sufficient strength and the manner of driving shall be regulated to preclude damage to the caisson.

When no provisions for caissons is shown on the plans, it shall be the intent of this Item to require that a suitable cofferdam be provided for all excavations where such cofferdam may be necessary to control water conditions or to preclude sliding and caving of the walls of the excavation. Where no ground or surface water is encountered, the cofferdam needs to be sufficient only to protect the workmen and to avoid cave-ins or slides extending beyond the excavation limits.

The Contractor shall submit, to the Engineer, upon request, drawings showing his proposed method of cofferdam construction and other details left open to this choice, or not fully shown on the plans. All shoring designs must meet the requirements of OSHA Standard 1926.650.

The type and clearance of the cofferdam, insofar as such details affect the character of the finished work, will be subject to the approval of the Engineer, but other details of design will be left to the choice of the Contractor, who will be responsible for the successful completion of the work. The interior dimensions shall be such as to provide sufficient clearance for the construction and removal of any required forms and the inspection of their exteriors and to permit pumping outside of the forms.

In general, sheet piling cofferdams shall extend well below the bottom of the footings and shall be well braced and as water-tight as practicable.

When foundation pilings are to be driven inside a caisson or cofferdam and when it is judged impractical to dewater the caisson or cofferdam
before placing a concrete seal, the excavation may be extended below the footing grade to a depth sufficient to allow for swell of the material during pile driving operations. After the pilings have been driven, all foundation material that has risen to a level above the footing grade shall be removed. It is the intention of this provision to establish a construction tolerance to be applied when a foundation is being constructed under water. Where it is possible to dewater the caisson or cofferdam before a seal is placed, it is considered practicable to remove the foundation material to the exact footing grades after foundation pilings are driven. Backfilling in a foundation to compensate for excavation which has been extended below grade, will not be permitted. Such areas below grade shall be filled with concrete at the time the seals or base courses are placed, and the concrete quantities involved shall be at the Contractor's expense. All caisson and cofferdam designs must meet the requirements of OSHA Standard 1926.650.

Caissons or cofferdams which tilt or move laterally during the process of sinking shall be righted or enlarged, as necessary, at the sole expense of the Contractor.

Unless otherwise provided, cofferdams shall be removed by the Contractor after the completion of the substructure. The removal shall be affected in such a manner as not to disturb or mar the structure. In lieu of the entire removal of the cofferdams, the Engineer may require the Contractor to remove any portion of them or to leave them entirely in place.

400.5 Pumping or Bailing. Pumping or bailing from the interior of any foundation enclosure shall be done in such a manner as to preclude the possibility of the movement of water through or alongside any concrete being placed. No pumping or bailing will be permitted during the time of the placing of concrete or for a period of at least 24 hours thereafter, unless it is done from a suitable sump separated from the concrete work by a watertight wall. Pumping or bailing to dewater a sealed cofferdam or caisson shall not be started until the seal has set for at least 36 hours.

400.6 Backfilling. All backfills shall be constructed in layers approximately parallel to the finished grade. After completion of the backfill, it shall be continuously maintained to its finished grade, until the project is accepted.

Backfill for retaining walls, headwalls, bridge abutments, and other special structures, shall be as shown on the plans.

Each layer of backfill shall be uniform as to material, density and moisture content before beginning compaction. Water required to bring the material
to the moisture content necessary for the required compaction shall be the responsibility of the Contractor.

Unless otherwise indicated, backfill compacted mechanically shall be in loose lifts not exceeding 8 inches. Backfill shall be clean bank sand, unless otherwise directed by the Engineer, free from clay and clay lumps, shale, loam, organic matter, salts and other deleterious materials and having a plasticity index less than 3. Backfill shall be compacted to 95 percent of Standard Proctor Density (ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft$^3$ (600 kN-m/m$^3$))”) using a moisture content between optimum and 3 percent above optimum.

Do not place backfill against walls for a minimum of 7 days after structure has been in place. Place backfill against walls of partially completed structure only after approval of the Engineer. Backfill around abutments and piers shall be deposited on both sides to approximately the same elevation at the same time.

Care shall be taken to prevent any wedging action or backfill against the structure and the slopes bounding the excavation shall be stepped or serrated to prevent such wedge action.

No backfilling shall be done except in the presence of the Engineer, or his authorized representative.

400.7 Quality Assurance. The Testing Laboratory’s representative will determine the moisture density relationship for each material proposed for use as backfill, in accordance with ASTM D698. In place density will be determined in accordance with ASTM D6938 “Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)” or ASTM D1556 “Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method”, and with each type of construction.

For walls and trenches, determine the in place density at minimum for each 100 foot of wall or trench, for each lift of fill placed.

For building pads and parking areas, determine the in place density for each 4,000 square feet for each lift of fill placed.

400.8 Measurement and Payment. Will not be paid for directly, but will be considered subsidiary to the bid for structures requiring excavation and/or backfilling.
There are no line code(s), description(s), and unit(s) for this Item.

END OF ITEM 400
ITEM 402

BANK SAND BACKFILL

402.1 Description. This Item shall govern for the furnishing, installing, manipulation, compacting and completing in place, Bank Sand as a bedding and backfill material for water and sewer lines, as construction fill for certain excavation areas, as construction fill for ruts, holes and other similar conditions; as a fill material for project clean-up and as directed by the Engineer. Bank sand shall be in accordance with these Standard Specifications and in conformity with the lines, grades and cross-sections shown on the plans and as directed by the Engineer.

402.2 Materials. Bank sand is to be free of organic matter, foreign material, clay balls, sticks, foreign objects and other objectionable material.

Bank sand shall have a plasticity index less than 3 and shall meet the following gradation:

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% PASSING, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 Inch</td>
<td>100</td>
</tr>
<tr>
<td>No. 200</td>
<td>5 – 30</td>
</tr>
</tbody>
</table>

Prior to use, Contractor shall identify the source of the proposed bank sand for testing.

402.3 Construction. After the water line, sewer line or other similar construction item, such as a trench, has been excavated and brought to grade, bank sand shall be furnished, placed, compacted complete in place, either as bedding or backfill material, as shown on the plan, described in these Standard Specifications or as directed by the Engineer. After the trench or excavation has been brought to grade, the bank sand shall be placed and compacted as a bedding material, the construction item shall be placed and joined properly around and over that construction item as required and as shown on the plans, described in the specifications or directed by the Engineer.

Bank sand shall be placed in layers not exceeding 8 inches. It shall be compacted with mechanical vibratory tamps to maximum dry density in accordance with ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³)” at a moisture content ranging from optimum to three percentage points above optimum. Water flooding will not be permitted.
402.4 Testing. The Testing Laboratory’s representative will determine the moisture density relationship for each material proposed for use as backfill, in accordance with ASTM D698. In place density will be determined in accordance with ASTM D6938 “Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods” or ASTM D1556 “Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method,” and with each type of construction.

402.5 Measurement. No separate payment shall be made for work performed under this Item, except as indicated below. Include the cost of same in the price bid per linear foot of pipe, or wall, for which this work is a component.

402.6 Payment. "Extra Bank Sand Backfill", where required, will be measured by the cross-sectional method in its compacted position and paid for at the contract unit price bid per cubic yard. Payment under this bid item is limited to such additional bank sand backfill not shown on the plans that may be required.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 402
ITEM 403

DRIVING TIMBER PILING

403.1 Description. This Item shall govern the driving of treated or untreated timber piling. The piling shall be of the type and dimensions shown on the plans and shall be in accordance with the lines and grades shown therein.

403.2 Construction Methods. Timber piling shall be driven with a gravity hammer or power hammer, water jets, a combination of water jets and hammer, or in bored pilot holes.

When the nature of the driving is such as to unduly injure the heads, timber piling shall be protected by caps of approved design preferably having a rope or other suitable cushion next to the pile head and fitting into a casting which in turn supports a timber shock block. When the area of the head of the pile is greater than that of the face of the hammer, a suitable cap shall be provided to distribute the blow of the hammer throughout the cross-section of the pile and thus avoid, as far as possible, the tendency to split or shatter the pile. Collars or bands to protect the piling against splitting and brooming shall be provided.

403.3 Driving Equipment Timber Piling shall be driven with gravity or power hammers, as described herein.

A. Gravity Hammer - Contractor shall furnish a certified scale weight of the hammer to be used. Gravity hammers for driving timber piling shall weigh not less than 2000 pounds and not more than 3500 pounds. The drop shall be regulated so as to avoid injury to the pile, and in no case shall exceed 15 feet.

B. Power Hammers shall ensure the designated stroke length and number of blows per minute. Power hammers shall operate at not less than 80 percent of the manufacturer's rated capacity. The weight of the ram shall be not less than 2000 pounds. Power hammers shall develop not less than 6000 and not more than 9000 foot pounds of energy per blow at each full stroke of the piston.

1. Diesel hammers shall be of the enclosed ram type, equipped with gauges and charts to evaluate equivalent energy produced during driving. Maximum ram stroke shall be 10 feet.
2. Steam, hydraulic or compressed air hammers shall be equipped with a boiler or air compressor with a capacity at least equal to that specified by the hammer manufacturer. The boiler or compressor shall be equipped with an accurate pressure gauge to ensure proper operating conditions. The maximum ram stroke shall be 5 feet.

403.4 Leads. Pile driver leads shall be constructed in such a manner as to afford freedom of movement to the hammer, and shall be held in position by guys or stiff braces to insure support to the pile during driving. Except where piling are driven through water, the leads shall be of sufficient length that the use of a follower will not be necessary.

403.5 Jetting. Jetting shall only be done when the specified penetration cannot be obtained by driving or other methods. Contractor shall provide sufficient power for jetting operation to operate one pump and two, 2-1/2 inch diameter pipes equipped with 3/4 inch diameter jet nozzles at a pressure of 150 psi. Drive piling with hammer to at least one foot below depth of jetting, or 100 hammer blows, but not less than the approximate penetration and required bearing value. For bridge piling, the piling shall be driven a minimum of 2 feet after jetting has ceased.

403.6 Pilot Holes. Contractor shall provide pilot holes when penetration cannot be obtained without damage to piling and for the purpose of maintaining alignment. The maximum depth of the pilot hole shall be 5 feet and the maximum diameter shall be equal to the diameter of the pile tip. Increase the diameter or depth of the pilot hole only after prior approval by the Design Engineer and drive piling 2 feet below bottom of hole to the required penetration.

403.7 Tolerance for Driving. Drive piling to the vertical or batter line indicated. Use templates, when necessary, to comply with allowable tolerances and variation from plan alignment as follows:

A. Perpendicular to the longitudinal centerline of the cap, top of piling to be not more than 2 inches from true position indicated on the plans for bridge trestle pile bents, bulkheads, etc.

B. Parallel to the longitudinal centerline of the cap, top of piling to be not more than 4 inches from true position indicated on plans for bridge trestle pile bents, bulkheads, etc.

C. For cluster piling, not more than 4 inches in any direction from true position indicated on the plans. If center of gravity of pile cluster varies by more than 3 inches from center of gravity determined
from plan location, structural analysis will be required at no additional cost to Harris County. Modifications required by this structural analysis shall be done at no additional cost to Harris County. Minimum edge distance from face of piling to edge of footing is to be 6 inches. Additional concrete and reinforcing required by modifications shall be provided at no expense to Harris County.

403.8 Driving. Foundation piling shall not be driven until after the excavation is approximately complete. The driving of piling with followers shall be avoided if practicable. Where a follower is required for driving piling underwater, one piling in each ten must be of sufficient length that a follower is not required.

All piling raised during the process of driving adjacent piling shall be driven again. Broken, split or misplaced piling shall be withdrawn and properly replaced. Piling driven below established cut-off grade, except when directed by the Engineer, shall be withdrawn and replaced by new and if necessary, longer piling at the expense of the Contractor.

Unless otherwise indicated on the plans, the embankment at bridge ends shall be made to grade as shown on the plans and thoroughly compacted as provided in the governing specifications prior to the driving of end bent piling.

403.9 Penetration. The piling shall be driven approximately to the depth shown on the plans and to a greater depth whenever necessary to secure the bearing resistance. Bearing resistance shall be determined by the specified formula as directed by the Engineer. Except as noted, piling lengths shown on the plans are lengths estimated to give required bearing and are for estimating purposes only.

When plans indicate a "required penetration" into a particular stratum of shale or other hard material, this penetration is required, although strata may be higher or lower in elevation than indicated. Where no required penetration is indicated on the plans, lengths shown on the plans are minimum.

403.10 Bearing Evaluation. Unless indicated on the plans, the bearing values of timber piling shall be determined by the following formulas:

A. For Gravity Hammers

\[ P = \frac{2WH}{S+1.0} \]
B. For Single Acting Power Hammers

\[ P = 2WH \]
\[ S + 0.1 \]

C. For Double Acting Power Hammers

\[ P = 2E \]
\[ S + 0.1 \]

Where,

\[ P \] = Dynamic Resistance in pounds.

\[ S \] = Average penetration in inches, per blow, for the last 20 blows.

\[ W \] = Weight of ram, in pounds.

\[ H \] = Height of fall of ram in feet.

\[ E \] = Manufacturer's rated energy in foot-pounds (for double-acting power hammers).

\[ E \] = Equivalent energy in foot pounds determined by calibrated gauge attached to the hammer and taken when the average penetration in inches per blow is determined (for enclosed ram diesel hammers). Drive the piling to the penetration required by the plans and as defined herein. Use the appropriate formula to evaluate the bearing resistance.

In case water jets are used in connection with the driving, the bearing value shall be determined by the above formulas from the results of driving after the jets have been withdrawn.

403.11 Points & Shoes. Contractor shall point or square-cut piling as required by soil conditions. Where necessary, pile shall be shoed with metal shoes. Piling points shall be shaped to secure even and uniform bearing on shoes.

403.12 Cut-Offs. After driving, saw the piling off at a true plane as indicated on the plans. The final plan elevations are to be within 2 inches of the established elevation.

403.13 Treatment of Cuts, etc. After the necessary cutting has been done, the heads of treated timber piling shall be given three coats of hot creosote oil and one coat of hot tar pitch. When indicated on the plans, the pile heads
shall then be covered with a sheet of roofing felt weighing 55 pounds per 100 square feet or 20 gauge galvanized metal. The cover shall measure at least 6 inches more in each dimension than the diameter of the piling and it shall be bent down over the piling and the edges fastened with large headed galvanized nails.

The heads of untreated timber piling shall, unless otherwise provided, be thoroughly coated with a thick protective coat of red lead and oil, hot tar, hot asphaltum or hot tar creosote and when indicated on the plans, and covered with felt or galvanized metal as provided above.

All places where the surface of treated piling is broken by cutting, boring or otherwise, shall be thoroughly coated with hot creosoted oil and then with a coating of hot tar pitch. Hot creosote oil shall be injected under pressure into the bolt holes, before insertion of the bolts, in such a manner that the entire surface of the holes shall receive a coating of oil.

403.14 Measurement. Piling shall be measured as provided under the Item 407 “Treated and Untreated Timber Piling”.

403.15 Payment. No separate payment for work performed under this Item. Include the cost in the Item 407 “Treated and Untreated Timber Piling”.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 407 “Treated and Untreated Timber Piling”

END OF ITEM 403
ITEM 404

DRIVING STEEL PILING

404.1 Description. This Item shall govern the driving of steel piling. The piling shall be of the size and weight shown on the plans and shall be in accordance with the lines, grades and dimensions shown therein.

The lengths of piling to be driven shall be as shown on the plans, or as necessary to obtain the required bearing resistance and required minimum penetration.

404.2 Material. The steel piling shall be manufactured in accordance with the Item 408 "Steel Sheet Piling", and/or the Item 409 "Steel H Piling".

404.3 Storing and Handling. The methods of handling shall be such as to prevent damage to the piling. When steel piling are to be stored, they shall be placed on skids which will raise them above the ground. The stored piling shall be kept clean and fully drained at all times. A sufficient number of skids shall be used to prevent deflection of the stored piling.

404.4 Driving Equipment. Steel piling shall be driven with gravity or power hammers, as described herein.

A. Gravity Hammers:

Hammer shall weigh between 2000 and 5000 pounds. Contractor shall furnish the certified scale weight of hammer. The minimum hammer energy, in foot-pounds, shall be 250 times the design load, in tons. The drop shall be regulated to avoid injury to the piling, but in no case, shall the drop be greater than 10 feet.

B. Power Hammers:

Power hammers used for driving piles shall develop energy per blow, in foot pounds of not less than 250 X R, where R is the required minimum bearing resistance of the pile in tons. Hammers developing an energy of more than 18,000 foot pounds per blow shall not be used except for the driving of unusually heavy piles and then only with the written permission of the Engineer. Hammers shall not be operated at less than 80 percent of the manufacturer's rated capacity.

1. Diesel. Diesel hammers shall be the enclosed ram type, equipped with gauges and charts to evaluate equivalent
energy produced during driving. The minimum weight of the ram shall be 2,000 pounds. The maximum ram stroke shall be 10 feet.

2. Steam, Hydraulic or Compressed Air. Use boiler or air compressor capacity at least equal to that specified by hammer manufacturer. Equip boiler or compressor with accurate pressure gauge to ensure proper operating conditions. The minimum weight of the ram shall be 3,000 pounds. The maximum ram stroke shall be 5 feet.

C. Leads:

Pile drivers shall be equipped with leads which will afford free vertical movement for the hammer. The leads shall be stiff enough to resist bending during the driving operation and shall be held rigidly in the driving position by stiff braces or guys.

The axis of the leads shall coincide with the axis of the piling as nearly as practicable. The leads shall be of sufficient length to permit driving to the required penetration without a follower, except where piling are driven through water.

404.5 Protection of Pile Heads. A cast or structural steel driving head, fitted with a wood cushion block shall be used when necessary to prevent damage to the pile head. The cushioning provided shall be sufficient to prevent material damage to pile head. Rope mat, belting or similar cushioning material may be used in addition to a wood cushion block, when necessary.

404.6 Penetration. The piling shall be driven to approximately the depth shown on the plans, or to a greater depth, if necessary to secure the bearing resistance required. The bearing resistance shall be determined by the equations given herein.

Piling shall be driven in pile alignment holes, when necessary to secure proper alignment. The required depth of alignment hole shall not exceed 5 feet. In general, the maximum diameter of the alignment hole will be 4 inches less than the diagonal of the piling.

Except as noted herein, piling lengths shown on the plans are the lengths estimated to give required bearing and are for estimating purposes only.

The elevations shown on the plan is the minimum depth necessary to satisfy design requirements for lateral stability. Piling shall be driven to
this approximate elevation and to additional depths as required to obtain specified bearing resistance.

When plans indicate a required penetration into shale or other hard material, this penetration is required, although strata may be higher or lower, in elevation, than indicated.

404.7 Pilot Holes. In localities where water is not available for efficient jetting operations or where soil is of such material as will not permit jetting, the Contractor shall provide pilot holes as may be necessary to obtain the required pile penetration. Requirements for pilot holes shall be as follows. The size and depth of pilot hole required or permitted shall be determined by the Design Engineer from the results of trial operations made on the first few pilings driven. In general, the maximum diameter of hole permitted will be approximately 4 inches less than the diagonal of the piling. The size requirements may be varied by the Design Engineer as may be necessary to obtain penetration and/or bearing values.

In all cases, piling shall be driven with the hammer after being placed in the pilot holes. Such driving shall be at least sufficient to seat the pile and obtain the required bearing resistance. The load carrying capacity for the pile shall be determined from the results of this driving.

404.8 Jetting. Where material is suitable for jetting and water is available, the Contractor shall provide jetting equipment as an auxiliary to the hammer as a means of placing the piling. The equipment shall be as follows. Sufficient power shall be provided, in addition to that used for operating the hammer to operate one or more pumps and one or two (depending upon requirements of the material), 2-1/2 inch inside diameter jet pipes provided with a 3/4 inch diameter nozzle. The plant shall be such that with two jets operating at the same time, it shall be capable of delivering a minimum of 150 psi, to the nozzle.

The jetting operations may be done with one or two jets as determined by the Engineer from the results of trial jetting operations. The required jetting may be done ahead of the actual driving operations or simultaneously with the driving operations as determined by the Design Engineer from the results of trials.

If the jets and hammer are used together for the driving, the jet shall be withdrawn and the final penetration of the pile obtained by driving with the hammer alone. This procedure shall be varied to suit the job conditions and to obtain the desired penetration and load carrying results for the piling.
404.9 Tolerance for Driving. Trestle piling shall be driven to the required vertical or batter alignment. Allowable variations from plan alignment shall not exceed the following:

A. Transverse to the centerline of bent, the top of piling shall be not more than 2 inches from the position shown on the plans.

B. Parallel to the centerline of the bent, the top of the piling shall be not more than 4 inches from the position shown on the plans.

Foundation piling shall be driven to the required vertical or batter alignment. The top of the pile shall be not more than 4 inches in any direction from the position shown on the plans.

Foundation piling shall be cut off reasonably square at the elevation shown on the plans. A tolerance of not more than 2 inches above or below established cut-off grade will be permitted.

The minimum edge distance for a piling in a footing shall be 5 inches. Additional concrete required to obtain the specified reinforcing steel cover shall be at the Contractor's expense.

404.10 Bearing Evaluation. Unless otherwise shown on the plans, the dynamic bearing resistance of piling shall be determined by one of the following formulas:

A. For Gravity Hammers

1. \[ P = \frac{2WH}{S+1.0} \]

2. When energy delivered (W x H) by gravity hammer is 24,000 foot-pounds or greater, and the penetration does not exceed 1/2 inch per blow for the last 40 blows delivered (Without increasing), determine bearing resistance by:

\[ P + \frac{2WH}{3S} \]

B. For Single Acting Power Hammers

\[ P = \frac{2WH}{S+0.1} \]

C. For Double Acting Power Hammers
\[ P = \frac{2E}{S+0.1} \]

Where,

- \( P \) = Dynamic resistance in pounds.
- \( S \) = Average penetration in inches, per blow, for the last 20 blows.
- \( W \) = Weight of ram, in pounds.
- \( H \) = Height of fall of ram, in feet.
- \( E \) = Manufacturer's rated energy in foot-pounds (for double acting power hammers).
- \( E \) = Equivalent energy in foot-pounds determined by a calibrated gauge attached to the hammer and taken when the average penetration in inches, per blow, is determined (for enclosed ram diesel hammer).

Drive the piling to the penetration required by the plans and as defined herein. Use appropriate formula to evaluate the bearing resistance.

404.11 Measurement & Payment. No direct measurement or payment will be made for the work to be done or the equipment to be furnished under this Item, but shall be considered subsidiary to the Item, for steel piling.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 408 “Steel Sheet Piling”
Item 409 “Steel H Piling”

END OF ITEM 404
ITEM 405

DRIVING CONCRETE PILING

405.1 Description. This Item shall govern for the driving of precast, prestressed concrete piling. The piling shall be of the size shown on the plans and shall be in accordance with the lines, grades and dimensions shown therein. The driving of the piling shall be in accordance with Item 404 “Driving Piling” of the Texas Department of Transportation's Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges, Latest Edition.

The lengths of piling to be driven shall be as shown on the plans, or as necessary to obtain the required bearing resistance and the required minimum penetrations.

405.2 Materials. The concrete piling shall be manufactured in accordance with the Item 410 "Prestressed Concrete Piling".

405.3 Storing and Handling. The methods of handling shall be such as to prevent damage to the piling. Piling shall be lifted only at the pick-up points shown on the pile detail sheet. When concrete piling are to be stored, they shall be placed on skids, which will raise them above the ground. The stored piling shall be kept clean and fully drained at all times. A sufficient number of skids shall be used to prevent deflection of the stored piling.

405.4 Driving Equipment. Concrete piling shall be driven with gravity or power hammers, as described herein.

A. Gravity Hammers:

Hammer shall weigh not less than 3,000 pounds. Contractor shall furnish the certified scale weight of the hammer. The minimum hammer energy, in foot-pounds, shall be 250 times the design load, in tons. The drop shall be regulated to avoid injury to the piling, but in no case, shall the drop be greater than 10 feet.

B. Power Hammers:

Power hammers used for driving piles shall develop energy per blow, in foot pounds, of not less than 250 x R, where R is the required minimum bearing resistance of the pile in tons. Hammers shall be operated at not less than 80 percent of manufacturer's rated capacity.
1. Diesel. Diesel hammers shall be the enclosed ram type, equipped with gauges and charts to evaluate equivalent energy produced during driving. The minimum weight of the ram shall be 2,700 pounds. The maximum ram stroke shall be 10 feet.

2. Steam, Hydraulic or Compressed Air. Use boiler or air compressor capacity at least equal to that specified by hammer manufacturer. Equip boiler or compressor with accurate pressure gauge to ensure proper operating conditions. The minimum weight of the ram shall be 3,000 pounds. The maximum ram stroke shall be 5 feet.

C. Leads:

Pile drivers shall be equipped with leads which afford free vertical movement for the hammer. The leads shall be stiff enough to resist bending during the driving, operation and shall hold the piles rigidly in the driving position by stiff braces or guys.

The axis of the leads shall coincide with the axis of the piling as nearly as practicable. The leads shall be of sufficient length to permit driving to the required penetration without a follower, except where piling are driven through water.

D. Template:

The Contractor will be required to use a template to hold the piling in proper alignment, while driving. A transit will be required to check piling alignment during the driving operation.

405.5 Protection of Pile Heads. H cast or structural steel driving head, fitted with a wood cushion block shall be used when necessary to prevent damage to the pile head, rope mat, belting or similar cushioning material may be used in addition to a wood cushion block, when necessary. To control excessive stress in concrete piling during driving, the Engineer may require:

A. Increase in cushion thickness.

B. Reduction of ram stroke.

C. Reduced ram stroke for driving through very soft soil and longer ram stroke as soil resistance increases.
D. Combination of (A) and (B) above.

E. Heavier ram with a shorter stroke.

F. Combination of (A) and (E) above, or

G. Use of pilot holes or jetting when driving through hard or alternating hard and soft strata.

405.6 Penetration. The piling shall be driven to approximately the depth shown on the plans, or to a greater depth, if necessary to secure the bearing resistance required. The bearing resistance shall be determined by the formula given herein.

Piling shall be driven in pile alignment holes, when necessary to secure proper alignment. The required depth of alignment hole shall not exceed 5 feet. In general, the maximum diameter of the alignment hole will be 4 inches less than the diagonal of the piling.

Except as noted herein, piling lengths shown on the plans are the lengths estimated to give required bearing and are for estimating purposes only.

The elevations shown on the plan is the minimum depth necessary to satisfy design requirements for lateral stability. Piling shall be driven to this approximate elevation and to additional depths as required to obtain specified bearing resistance.

When plans indicate a required penetration into shale or other hard material, this penetration is required, although strata may be higher or lower, in elevation, than indicated.

405.7 Pilot Holes. In localities where water is not available for efficient jetting operations or where soil is of such material as will not permit jetting, the Contractor shall provide pilot holes as may be necessary to obtain the required pile penetration. Requirements for pilot holes shall be as follows. The size and depth of the pilot hole required, or permitted, shall be determined by the Design Engineer from the results of trial operations made on the first few pilings driven. In general, the maximum diameter of hole permitted will be approximately 2 inches less than the side dimension of square pile, or 1 inch less than the diameter of round pile. The site requirements may be varied by the Design Engineer, as may be necessary to obtain penetration and/or bearing values.

In all cases, piling shall be driven with the hammer after being placed in the pilot holes. Such driving shall be at least sufficient to seat the pile and
obtain the required bearing resistance. The load carrying capacity for the pile shall be determined from the results of this driving.

405.8 Jetting. Used only when specified penetration cannot be obtained by driving or other methods, and with the specific approval of the Engineer. The equipment shall be as follows. Sufficient power shall be provided, in addition to that used for operating the hammer to operate one or more pumps and one or two (depending upon requirements of the material), 2-1/2 inch inside diameter jet pipes provided with a 3/4 inch diameter nozzle. The plant shall be such that with two jets operating at the same time, it shall be capable of delivering a minimum of 150 psi, to the nozzle.

The jetting operations may be done with one or two jets as determined by the Engineer from the results of trial jetting operations; the required jetting may be done ahead of the actual driving operations as determined by the Engineer from the results of trials.

If the jets and hammer are used together for the driving, the jet shall be withdrawn and the final penetration of the pile obtained by driving with the hammer alone. This procedure shall be varied to suit the job conditions and to obtain the desired penetration and load carrying results for the piling.

405.9 Tolerance for Driving. Trestle piling shall be driven to the required vertical or batter alignment. Allowable variations from the plan alignment shall not exceed the following:

Transverse to the centerline of bent, the top of piling shall be not more than 2 inches from the position shown on the plans.

Parallel to the centerline of the bent, the top of the piling shall be not more than 4 inches from the position shown on the plans.

Foundation piling shall be driven to the required vertical or batter alignment. The top of the pile shall be not more than 4 inches in any direction from the position shown on the plans.

Foundation piling shall be cut off reasonably square at the elevation shown on the plans. A tolerance of not more than 2 inches above or below established cut-off grade will be permitted.

The minimum edge distance for a piling in a footing shall be 5 inches. Additional concrete required to obtain the specified reinforcing steel cover shall be at the Contractor's expense.
405.10 Unless otherwise shown on the plans, the dynamic bearing resistance of piling shall be determined by one of the following formulas:

A. For Gravity Hammers

\[
P = \frac{2\ W\ H}{S+1.0}
\]

When the energy delivered (WH) by the gravity hammer is 24,000 foot pounds or greater and the penetration does not exceed 1/2 inch per blow for the last 40 blows delivered, the bearing resistance will be determined by:

\[
P = \frac{2WH \times N}{3S}
\]

Where \(N\) = ratio of the weight of the ram to the weight of the pile, \(N\) will not be used in the equation when it is greater than 1.

B. For Single Acting Power Hammers

\[
P = \frac{2\ W\ H}{S+0.1}
\]

C. For Double Acting Power Hammers

\[
P = \frac{2\ E}{S+0.1}
\]

Where,

- \(P\) = Dynamic resistance, in pounds.
- \(S\) = Average penetration in inches per blow, for the last 20 blows.
- \(W\) = Weight of ram, in pounds.
- \(H\) = Height of fall of ram, in feet.
- \(E\) = Manufacturer's rated energy in foot-pounds (for double acting power hammers), or the equivalent energy in foot-pounds determined by a calibrated gauge attached to the hammer and taken when the average penetration in inches, per blow, is determined (for enclosed ram diesel hammer).
The maximum energy rating allowed for the double-acting (enclosed ram) hammer shall be approximately 85 percent of the rated output given by the manufacturer.

The piling shall be driven to the penetration required by the plans and defined herein. The appropriate formula shall be used to evaluate bearing resistance.

405.11 Measurement and Payment. No direct measurement or payment will be made for the work to be done or the equipment to be furnished under this Item, but shall be considered subsidiary to the Item 410 “Prestressed Concrete Piling”.

There are line code(s), description(s), and unit(s) for this Item

NOTE: This Item requires other Standard Specifications

Item 410 “Prestressed Concrete Piling”

END OF ITEM 405
ITEM 407

TREATED AND UNTREATED TIMBER PILING

407.1 Description. This Item shall govern for the furnishing of treated or untreated timber piling, in place and in accordance with the size, type and details shown on the plans.

407.2 General. Driving of piling shall be in accordance with the Item 403 "Driving Timber Piling".


Untreated piling may be of any species of durable timber which will satisfactorily stand driving. Treated piling shall consist of Southern Pine or Douglas Fir, impregnated with a preservative of such quantity and process as specified in the Item 457 "Timber Preservative & Treatment".

The minimum circumference of round piling at a section 3 feet from the butt, measured under the bark, shall be as follows:

<table>
<thead>
<tr>
<th>LENGTH OF PILING</th>
<th>MINIMUM CIRCUMFERENCE 3 FEET FROM BUTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>40' and Under</td>
<td>38&quot;</td>
</tr>
<tr>
<td>Over 40'</td>
<td>41&quot;</td>
</tr>
</tbody>
</table>

All piling shall be subject to inspection by a Commercial Laboratory selected by Harris County. The Commercial Laboratory may inspect piling before, during and after treatment and at the jobsite. Contractor shall replace piling found unsuitable at no additional cost to Harris County. The butt and tip of each acceptable pile will be branded with a marking hammer showing the identity of the inspection agency. The cost of inspection shall be paid to the laboratory by the Contractor.

Harris County shall receive the original and two copies of the inspection reports prior to driving piling.

407.4 Storing & Handling. At all points, suitable precautions shall be taken to prevent excessive splitting, checking, warping, distortion or any other damage which may cause the piling to be rejected. Treated timber piling
shall be carefully handled without dropping, breaking of outer fibers, bruising or penetrating the surface with tools. The piling shall be handled with rope slings. “Cant dogs”, hooks or pike holes shall not be used where such tool will penetrate untreated wood.

407.5 Cut-offs & Build-ups. The tops of piling shall be sawed to a true plane as shown on the plans and at the elevation established by the Engineer. Piling which support timber caps or grillage work shall be sawed to the exact plane of the superimposed structure and shall fit it exactly.

Piling which must be driven below established grade in order to attain the required bearing capacity shall be built up to the required grade by splicing on an additional length of piling of the same diameter and quality, as the pile to be built up. Splices shall be made in accordance with the details shown on the plans after the pile head and the lower end of the build-up section have been squared up. The build-up shall be of such length as to preclude the use of more than one splice in any one pile, and no splices or build-ups will be permitted except under the conditions outlined herein.

407.6 Treatment of Cuts, etc. After the necessary cutting has been done, the heads of treated timber piling shall be given three coats of a preservative determined appropriate for the original preservative per AWPA Standard M4. Follow with one coat of coal-tar roofing cement meeting the requirements of ASTM D4022 “Standard Specification for Coal Tar Roof Cement, Asbestos Containing.” When indicated on the plans, the pile heads then shall be covered with a sheet of roofing felt weighing approximately 55 pounds per 100 square feet, or 20 gauge galvanized metal. The cover shall measure at least 6 inches more in each dimension, than the diameter of the piling and it shall be bent or folded down over the piling and edges fastened with large-headed galvanized nails, or secured by binding with galvanized wire as indicated on the plans.

The heads of untreated timber piling, unless otherwise provided, shall be coated thoroughly with a thick protective coat of coal-tar roofing cement and, when indicated on the plans, covered with felt or galvanized metal as provided above.

All places where the surface of treated piling is broken by cutting, boring, or otherwise, shall be coated thoroughly with coal-tar roofing cement. Coal-tar roofing cement shall be injected under pressure into the bolt holes, before insertion of the bolts, in such a manner that the entire surface of the holes shall receive a thorough coating.
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407.7 Measurement. Timber piling, treated or untreated, driven in accordance with the specifications will be measured by the linear foot of acceptable piling complete in place after all cut-offs and build-ups have been made.

No cut-off will be measured on any pile which is spliced and built-up.

Each authorized build-up splice, other than those made necessary be careless or improper handling or driving, shall be measured as one build-up.

Cut-offs for both regular and test piling will be measured by the linear foot of cut-off above grade. The pay length of cut-off for each pile will be determined by deducting the length of accepted pile in place, after cut-off has been made, from the approved length of pile. No measurement will be made of cut-offs necessitated by brooming, splitting or other damage resulting from improper driving.

407.8 Payment. Timber piling measured as provided above will be paid for at the unit price bid per linear foot for "Treated Timber Piling" or "Untreated Timber Piling", as the case may be.

Each completed authorized build-up splice for both regular and test piling, measured as provided above will be paid for at four times the unit price bid for "Treated Timber Piling" or "Untreated Timber Piling" as the case may be.

Cut offs, measured as provided above, will be paid for by the linear foot at one-half the unit price bid for "Treated Timber Piling" or "Untreated Timber Piling", as the case may be.

The foregoing shall be full compensation for furnishing all materials, tools, labor, equipment, driving, jetting, pilot holes, alignment holes and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 403 “Driving Timber Piling”
Item 457 “Timber Preservative and Treatment”

END OF ITEM 407
ITEM 408

STEEL SHEET PILING

408.1 Description. This Item shall govern for the furnishing of steel sheet piling with interlocking joints, in place, of the type and weight and in the locations shown on the plans.

The length and size of piling shall be as shown on the plans, or as necessary to obtain the required bearing resistance and required minimum penetration.

408.2 Materials.

A. All ferrous metals furnished for use under these Standard Specifications shall be manufactured by one of the following processes only:

1. Open-hearth
2. Basic Oxygen
3. Electric Furnace

B. Sheet piling shall conform to one of the following Specifications:

1. ASTM A328 “Standard Specification for Steel Sheet Piling”, Grade A
2. ASTM A572 “Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel”, Grade 50
3. ASTM A690 “Standard Specification for High-Strength Low-Alloy Nickel, Copper, Phosphorus Steel H-Piles and Sheet Piling with Atmospheric Corrosion Resistance for Use in Marine Environments”
4. ASTM A857 “Standard Specification for Steel Sheet Piling, Cold Formed, Light Gage”

C. Structural steel for wales, cap and ballast stops shall conform to the requirements of ASTM A588 “Standard Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi Minimum Yield Point, with Atmospheric Corrosion Resistance.”
D. Bolt and blind fasteners shall be of carbon steel, shall be of the size and grip shown on the plans and shall conform to the requirements of ASTM A325 “Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength.”

E. Other ferrous metals shall conform to the requirements of ASTM A325, with corrosion and coloring characteristics of ASTM A588.


H. Sheet piling, corners, connections and wyes shall be furnished from a single manufacturer. Furnished sheet piling shall be manufactured to assure a continuous interlock throughout the entire length. Sheet piling and interlocks shall be free from excessive kinks, camber or twist that prevent free sliding of pile.

   Piling may be provided with standard-size handling holes, located 4 inches from one end and removed at cut-off. Additional length beyond that indicated on plans may be required to provide for trimming of pile tops and removal of handling holes at no additional cost to Harris County.

408.3 Storing & Handling. Materials shall be delivered to the job site free from dirt, loose scale and rust, oil or other foreign material and in accordance with ASTM A6 “Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling.”

   Piling shall be stored above the surface of the ground on platforms, skids or other supports to prevent sagging. Piling shall be protected from mechanical damage and surface deterioration caused by exposure to conditions producing rust and corrosion.

   The methods of handling shall be such that no bending or warping occurs before and during placement.

408.4 Installation. Steel sheet piling shall be driven at the location and to the elevation shown on the plans or as designated by the Engineer. Piling shall be driven to within 0.5 foot of the founding elevation shown on the plans and shall be driven within 2 inches of plumb. When using ball and socket piling, drive the socket end over the ball end. Sheet piling shall be
driven in accordance with the Item 404 "Driving Steel Piling". Jetting is prohibited. The pile driving equipment shall include a helmet compatible with the shape of the sheet pile. Any piling damaged during the course of construction shall be replaced at no additional cost to Harris County.

408.5 Cut-Offs. After the pile has been driven to the approximate penetration and to the bearing resistance required, it shall be cut-off square at plan grade, or to the grade established by the Engineer. The top of piling shall be straight and true with the lip metal removed and shall be within 0.08 foot of the plan elevation.

408.6 Anchor Rods & Turnbuckles. Anchor rods shall be installed in the minimum width and depth of trench, located as shown on the plans. Clear threads of burrs and foreign matter and lubricate rod threads with suitable material immediately before installing nut or turnbuckle. No less than three full threads shall extend beyond the outside face of nuts and inside face of turnbuckles, at time of final project acceptance. Rod material extending more than 2 inches beyond the face of exposed nut shall be removed.

408.7 Field Welding. Welding of sheet piling, if required, shall be with low hydrogen type electrode in accordance with the Structural Welding Code, AWS D1.1. Splices shall only be butt welded. No butt welds shall be visible (exposed) at the completion of the project. Deposited material for welds of sheet piling shall have a similar atmospheric corrosion resistance as the sheet piling. Splicing of two consecutive piles will not be permitted.

408.8 Final Surface Treatment. Contractor shall brush blast visibly exposed surfaces of sheet piling to remove mill scale, oil, rust, or other blemishes. Brush blast shall produce a uniform color and texture throughout entire wall surface.

After driving and capping, all exposed portions of the piling shall be cleaned and painted, or applied with a protective coating, in accordance with the Item 447 “Painting and Protective Coating”.

408.9 Measurement. Steel sheet piling shall be measured by the horizontal linear foot of acceptable piling, in place, driven to the depth shown on the plans. Sheet piling driven below the elevation required by the plans or as directed by the Engineer, will not be measured for payment. No measurement will be made for cut-offs or splices.

408.10 Payment. Payment for steel sheet piling shall be made at the contract unit price bid per horizontal linear foot complete in place, which price is full compensation for furnishing all materials, driving, equipment, labor, tools and incidentals necessary to complete the work.
Anchor rods, wales, caps and fasteners, when shown on the plans, shall be included in the contract unit price bid per horizontal linear foot of steel sheet piling.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 404 “Driving Steel Piling”
Item 447 “Painting and Protective Coating”

END OF ITEM 408
409.1 Description. This Item shall govern for the furnishing of steel piles of H-section. The piling shall be of the type and weight shown on the plans and shall be placed in accordance with the lines, grades and dimensions shown therein.

The lengths of piling to be driven shall be as shown on the plans or as necessary to obtain the required bearing resistance and required minimum penetration.

409.2 Materials.

A. All ferrous metals furnished for use under these Standard Specifications shall be manufactured by one of the following processes only:

1. Open-hearth
2. Basic Oxygen
3. Electric Furnace

B. Steel H piling shall conform to the requirements of ASTM A36 “Standard Specification for Carbon Structural Steel.”

C. Structural steel for wales, cap and ballast stop shall conform to the requirements of ASTM A588 “Standard Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi Minimum Yield Point, with Atmospheric Corrosion Resistance.”

409.3 Storing & Handling. Materials shall be delivered to the jobsite free from dirt, loose scale and rust, oil or other foreign material.

H piling shall be stored above the surface of the ground on platforms, skids or other supports to prevent sagging. Piling shall be protected from mechanical damage and surface deterioration caused by exposure to conditions producing rust and corrosion. The methods of handling shall be such that no bending or warping occurs before and during placement.

409.4 Installation. Steel H piling shall be driven at the location and to the elevation shown on the plans or as designated by the Engineer. Piling shall be driven to within 0.5 feet of the founding elevation shown on the
plans or to the required bearing. Steel H piling shall be driven in accordance with the Item 404 "Driving Steel Piling". The embankment at bridge ends shall be in place, thoroughly compacted and to grade prior to driving piling therein unless otherwise shown on the plans.

409.5 Cut-Offs, Splices & Build-Ups. All splices for steel H piling shall be in accordance with the details shown on the plans. If the required penetration or bearing resistance has not been obtained, spliced piling may be driven the additional depth required as soon as the splice is completed.

The Contractor may, at his expense, fabricate piling by welding together not more than three sections of piling, provided the distance between welds is not less than 5 feet.

After the pile has been driven to the approximate penetration and to the bearing resistance required, it shall be cut-off square at plan grade, or to the grade established by the Engineer. Where pile caps are specified, the end surfaces of the pile shall be made as smooth as practicable before the head is welded in place. The pile cap shall conform to the plan details.

If the head of the pile is appreciably distorted or otherwise damaged below cut-off level, the damaged portion shall be cut-off and an undamaged section spliced in its place at the Contractor's expense. Any piling damaged during the course of construction shall be replaced at no additional cost to Harris County.

409.6 Field Welding. Welding of H piling, if required, shall be in accordance with the structural steel welding code AWS D1.1. Welding of splices shall be in accordance with the steel piling splice detail shown on the plans. Deposited material for welds of Steel H Piling shall have a similar atmospheric corrosion resistance as the Steel H Piling.

409.7 Final Surface Treatment. Contractor shall brush blast visibly exposed surfaces of sheet piling to remove mill scale, oil, rust or other blemishes. Brush blast shall produce a uniform color and texture over the H pile surface.

Steel H Piling shall not be painted before driving. After driving, capping and placing collars all exposed portions shall be cleaned and painted, if required, in accordance with the Item 447 "Painting & Protective Coating".

409.8 Measurement. Steel H Piling will be measured by the linear foot of acceptable piling in place after all cut-offs and build-ups have been made. A splice made necessary by driving beyond the authorized pile length to
obtain the required bearing will be measured as one splice. Each additional splice required for build-up will be measured as one splice, provided the distance between splice points is not less than 10 feet. Cut-off will not be measured for payment. No more than two splices per piling will be permitted.

Where a reinforced tip is ordered by the Engineer, it shall be measured as one pile tip.

For piling specified to be driven to a "minimum penetration", no measurement will be made on that portion driven below the elevation at which the penetration and bearing requirements were first obtained.

409.9 Payment. Steel H piling will be paid for at the unit price bid per linear foot of "Steel H Piling", of the specified size and weight.

No direct payment will be made for cut-offs, pile caps, painting or for excavation and backfill required by the placing or painting of portions of piling below the ground line. Payment for all work and materials required by these items shall be included in the unit price bid per linear foot of "Steel H Piling".

Payment for the work and materials (exclusive of additional length of piling) required in making each authorized splice will be made at a price equal to three times the unit price bid per linear foot of "Steel H Piling" of the size and weight on which the splice is made.

Payment for the work and materials required for each reinforced tip ordered by the Engineer will be made at a price equal to two times the unit price per linear foot for "Steel H Piling", of the size and weight on which the tip is added.

The foregoing shall be full compensation for furnishing all materials, tools, labor, equipment, driving, jetting, plot holes, alignment holes, and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 404 “Driving Steel Piling”
Item 447 “Painting and Protective Coating”

END OF ITEM 409
ITEM 410
PRESTRESSED CONCRETE PILING

410.1 Description. This Item shall govern for the casting, prestressing, and manufacture of prestressed concrete piling.

410.2 General. The method of manufacture and prestressing shall comply with the requirements of the plans and in accordance with the approved shop drawings. Prior to beginning the casting of concrete piling, the Contractor shall give the Engineer ample notice as to the location of the casting site and the date on which work will begin.

An inspector representing the Engineer shall have free entry at all times, while the work is being performed, to all parts of the manufacturer's works which concern the manufacture of the piling ordered.

Clean and legible shop drawings on sheets 22" x 34" will be submitted electronically, showing the following information, and shall be submitted for approval. The margin at the left end shall be 1-1/2 inches wide and the others 1/2 inch wide. The sheets shall include a title in the lower right hand corner, sheet number, name of structure, name of Fabricator and name of the Contractor. Preparation and submittal of drawings may be submitted electronically on 11 x 17 inch sheets, or full size drawings may be reduced to one-half scale, provided they are completely clear and legible.

A. Fabrication Details. Complete information necessary for fabrication shall be submitted for approval. On projects requiring several sizes of piling, an index sheet showing cast lengths, concrete strengths, strand data, etc., shall be furnished. Index sheets shall reflect the plant location where each piling is to be fabricated.

B. Prestressing Details. Complete prestressing details shall be submitted showing details of the piling, forms, devices for holding prestressed steel in place, methods and details of arranging strands, anchorage details, methods and details of prestressing the steel, elongations, jack pressures and all other features of proposed prestressing. Calculations shall be included to justify the system and method of prestressing to be used. The submittal of prestressing details shall be a "one-time" action of each Fabricator.

C. Methods of Handling and Transportation. Details of handling and transporting need not be submitted for approval, except special devices used for pick up shall be shown on the shop drawings.
All drawings and details shall be checked by the Fabricator before submittal for approval. Submission of drawings shall be in accordance with Harris County Engineering Department methods and procedures.

A casting schedule shall be prepared on standard forms and submitted to the Harris County Engineering Department, prior to stressing.

Prior to the casting of piling, detailed drawings reflecting the complete facilities to be used, in fabrication, are required by the Harris County Engineering Department.

The design of casting beds and facilities for pre-tensioned construction, including plans and specifications, shall be done by a Professional Engineer registered in the State of Texas and shall bear his seal. The Fabricator shall furnish a certificate bearing his signature, or that of a responsible officer of the company, that the bed, facilities, and hardware have been constructed in accordance with the above plans and specifications.

The Fabricator shall specify the maximum loading of which the bed is to be used. Prior to approval for that loading, the facilities shall be proof loaded to a minimum ten percent overload for four hours, if deemed necessary by the Engineer. Minor changes in facilities will not require proof loading, but will require submission of the details of changes accompanied with design calculations.

410.3 Materials. Materials for concrete and water for curing shall be in accordance with applicable portions of the Item 421 "Structural Concrete". Material for reinforcing steel (non-prestressed) shall be in accordance with the Item 440 "Reinforcing Steel". Other steel shall be in accordance with this Item.

All concrete materials and their preparation and placing shall be in accordance with the Item 421 "Structural Concrete", except that the concrete shall be proportioned to develop a compressive strength of not less than 5,000 psi in 28 days. The following limitations shall also be complied with:

<table>
<thead>
<tr>
<th>Material</th>
<th>Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Cement Content</td>
<td>6.25 sacks per cubic yard</td>
</tr>
<tr>
<td>Maximum Cement Content</td>
<td>7.00 sacks per cubic yard</td>
</tr>
<tr>
<td>*Maximum Water</td>
<td>6.00 gallons per sack</td>
</tr>
</tbody>
</table>
**Maximum Slump** 4 inches or as approved by the Engineer

<table>
<thead>
<tr>
<th>Minimum Compressive Strength</th>
<th>5,000 psi at 28 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Compressive Strength at Prestress Transfer</td>
<td>4,000 psi</td>
</tr>
</tbody>
</table>

* Water per sack of cement shall be reduced to the minimum amount that the required workability will permit.

An admixture must be used with Type I or Type III portland cement in lieu of air-entraining portland cement. Entrained air must not exceed 4 percent. Admixtures shall be in accordance with the Item 421 "Structural Concrete", and must be approved by the Engineer prior to use.

When tested in accordance with ASTM C136 “Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates,” coarse aggregate shall conform to the following grading requirements:

### COARSE AGGREGATE GRADATION

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% RETAINED, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2 Inch</td>
<td>0</td>
</tr>
<tr>
<td>1 Inch</td>
<td>0 – 5</td>
</tr>
<tr>
<td>3/4 Inch</td>
<td>20 – 50</td>
</tr>
<tr>
<td>1/2 Inch</td>
<td>50 – 75</td>
</tr>
<tr>
<td>No. 4</td>
<td>95 – 100</td>
</tr>
</tbody>
</table>

* The loss by decantation shall be a maximum of 1 percent

Fine aggregate shall consist of clean, hard, durable, uncoated grains of washed sand, free from soft or flaky particles and all other injurious materials. It shall be graded from coarse to fine and when tested by approved methods, shall meet the following grading requirements:

### FINE AGGREGATE GRADATION

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% RETAINED, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 Inch</td>
<td>0</td>
</tr>
<tr>
<td>No.4</td>
<td>0 – 5</td>
</tr>
<tr>
<td>No. 20</td>
<td>15 – 50</td>
</tr>
</tbody>
</table>
When subjected to the color test for organic impurities, fine aggregate shall not show a color darker than the standard color.

Prestressing Strands: Strands used to apply the prestressing load to precast prestressed concrete piling shall be uncoated seven wire strand conforming to the requirements of ASTM A416 “Standard Specification for Low-Relaxation, Seven-Wire Steel Strand for Prestressed Concrete.” The strands shall be of the size and number shown on the plans. Strands shall be free of rust, dirt, oil or other injurious materials, before placing concrete. The strands shall meet the following minimum requirements as to strength:

Yield Strength........................................90% Ultimate Tensile Strength

Ultimate Tensile Strength.............................. 270,000 psi

The materials for and the method of manufacture of precast concrete piling, shall be in accordance with the guidelines set out in ACI 543R "Design, Manufacture, and Installation of Concrete Piles".

410.4 Quality Assurance.

A. Concrete – Four standard size concrete cylinders shall be molded and cured according to current ASTM C31 “Standard Practice for Making and Curing Concrete Test Specimens in the Field” for each lot of piling cast. 2 cylinders shall be broken prior to transfer of prestress forces to insure that the concrete meets the requirements of 4,000 psi compressive stress at a stress transfer. The other two cylinders shall be tested at 28-days to insure that the minimum 28-day compressive stress of 5,000 psi is obtained. If the cylinders fail to indicate this strength, the mix shall be adjusted.

B. Prestressing Strands – Tests on at least 2 samples, taken at random, shall be made to insure that minimum requirements are met. Test samples shall be a minimum 7 feet long. However, if a certificate from the strand manufacturer shows that the strand meets or exceeds the minimum requirements is furnished, the testing of at least 2 samples will not be required.

410.5 Submittals. The Contractor shall submit 6 prints of shop drawings, showing complete information necessary for fabrication, for approval by the County Engineer. The drawings shall show type of member, member lengths, dimensions, bevels, erection devices, details of reinforcement, type of concrete, prestressing details, etc.
Fabrication of Piles.

A. Concrete Placement - Consolidate concrete using mechanical vibrators. Use no less than 3 vibrators for concrete placement in any individual unit and provide at least one standby vibrator for emergency use to avoid delays. Use vibrators of the high frequency type of not less than 7,000 impulses per minute.

All concrete shall be handled and placed in accordance with the applicable requirements of the Item 421 "Structural Concrete".

Concrete piling shall be cast using steel side forms. Do not use any device that requires that it be left in the member. Construct and maintain bed for casting prestressed members that will provide not more than 1/4 inch vertical variation in any 50 foot length.

Side forms shall be kept in place for a minimum of four hours. Forms may be removed after this time, if concrete has reached sufficient strength to prevent physical damage to member. Forms shall be removed in such a manner that curing of any member is not interrupted for more than 30 minutes. Provide forms with an acceptable contraction device and joints to prevent cracking due to form restriction, or loosen forms from members at proper time to prevent such cracking. Cracking due to form restriction will be cause for rejection.

After form removal, rub surface of members which are not true or that have porous or honeycombed areas. Extend rubbing over sufficient areas around blemished portions to blend rubbed area into surrounding surface. Remove unsightly discolorations and finish exposed surfaces of members reasonably uniform in color and texture.

Mat curing of concrete shall begin not later than 30 minutes after placement of concrete in forms. Steam curing may be started in 3 hours. Cure pretensioned members continuously, except as provided above for form removal, until concrete strength as indicated by compressive tests of cylinders has reached the required release strength. Curing may then be interrupted for a time interval of not more than 4 hours for removal of member from casting bed to curing area. Member shall be steam or water cured for 3 days after release of tension in member.

Air temperature surrounding the members shall be at 40°F or above from the time placing of concrete commences until curing
The cycle is complete. If external heating is required, use precautions to provide saturated humidity at surface of members to prevent drying. When steam curing is used, concrete may be placed when air temperature is below freezing, provided that steam is introduced into the jacket immediately behind placement of concrete and the temperature of the air surrounding the concrete kept above 40°F until steam curing is begun.

When steam curing is used, members shall be kept in a condition of saturated humidity and at a temperature not to exceed 150°F. If the temperature charts indicate that temperature inside the curing jacket is in excess of that shown below in Table 1, the piling shall not be accepted.

<table>
<thead>
<tr>
<th>MAXIMUM TEMPERATURE SHOWN ON CHART</th>
<th>MAXIMUM PERMISSIBLE TOTAL TIME IN EXCESS OF 150°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>151°F to 160°F</td>
<td>1 Hour</td>
</tr>
<tr>
<td>161°F to 170°F</td>
<td>30 Minutes</td>
</tr>
<tr>
<td>171°F to 180°F</td>
<td>15 Minutes</td>
</tr>
<tr>
<td>Over 180°F</td>
<td>None</td>
</tr>
</tbody>
</table>

If temperature charts indicate that temperature inside the curing jacket has fallen below 50°F, add 4 hours to the required curing time (at temperatures in excess of 50°F) for each hour below 50°F. Provide sufficient wet steam inside curing jacket so that the surface of the member is wet. Provide air space of not less than 6 inches between surfaces of member and covering material. Arrange steam outlets so that no live steam is directed at concrete or prestressing tendons. Apply steam slowly, so that the temperature rise inside the curing jacket is not more than 40°F per hour. Do not start steam curing until the concrete has been placed for a minimum of 3 hours.

Decrease temperature at the end of curing at the same rate as applied. Cut off steam and begin strand release operations when the temperature within the curing jacket has been reduced to within 30°F of the outside ambient air temperature or to 90°F, whichever is the lower temperature. Complete release of stress to concrete, while concrete is still warm and moist. Arrange location of steam lines, location of control points for output of steam into curing jacket, and number and type of openings for steam distribution
inside curing jacket so that the variation of temperature between any two points in the bed is no more than 20°F. Curing at elevated temperatures using other than steam is not permitted.

Curing of test cylinders to establish concrete strength for the release of tension, shall be in the same manner as members being prestressed. Test cylinders shall be placed at the points where the most unfavorable curing conditions are offered. The average strength of two cylinders shall be considered a test.

B. Pretensioning - Initially bring tendons to be prestressed in a group to a uniform initial minimum tension of 1,000 pounds (plus or minus 50 pounds) per tendon prior to being given their full pretensioning. Measure this uniform tension by some suitable means such as a dynamometer so that its amount can be used as a check against elongation computed and measured.

After initial stressing, stress group to total tension as required by means of hydraulic jacks equipped with gauges graduated to read directly to one percent of total load to be applied and calibrated to measure accurately the stress induced in the steel. Measure the induced stress by elongation of tendons and check by gauge pressure. Results to be within 5 percent. Provide means for measuring elongation to an accuracy of 1/16 inch for each 100 feet of length between jacking heads. In the event of apparent discrepancies between stresses indicated by gauge pressure and elongation of more than 5 percent, check entire operation, determine source of error, and check before proceeding further. Establish independent references adjacent to each anchorage to indicate any yielding or slippage between time of initial stressing and final release of tendons.

With tendons stressed to full tension, as prescribed above, and with reinforcing in place, cast members to necessary lengths to provide plan lengths after shrinkage and elastic shortening have occurred. Maintain tendon stress between anchorages until concrete has reached the compressive strength specified, as determined by compressive cylinder tests made for each continuous pour. If all test cylinders for tension release are broken and the required release strength has not been attained, maintain the tendon stress and cure the piling for an extended period of 24 hours for each 100 psi deficiency or fraction thereof before release of tension. After the above strength requirement is attained, gradually release tension in tendons and cut off tendons, using sequence to minimize shock and reduce premature tendon breakage.
C. Handling and Erection - Exercise care when handling members. Handle in accordance with approved fabrication and erection plans which indicate method of handling so as to preclude the possibility of overstressing any part of the member. Provide an adequate factor of safety in design to cover dynamic force or impact. Do not remove the members from the casting yard until after tensioning, curing and strength requirements have been attained. Members may be driven any time after curing and tensioning requirements have been fulfilled and the design strength cylinders indicate that the specified 28 day compressive strength has been attained. An adequate number of design strength test cylinders shall be cast to ensure that acceptance of members will be based on cylinder breaks. Design strength cylinder is to be cured initially with members. After the release of stress of members, cylinder shall be cured in accordance with the standard procedure for cylinder curing. Precast piling should be handled and hauled in the flat position. The piling, if so designed, may be picked up by either one or two point pickup.

D. Defects and Breakage - If a member or portion thereof is broken at any time during construction, it will be rejected and replaced with a satisfactory member at no expense to Harris County. Fine hair cracks on the surface of the member, which do not extend to the plane of nearest reinforcement, will not be cause for rejection unless such cracks are so numerous and extensive as to indicate inadequate curing, in which case, members will be rejected. Members having diagonal cracks on vertical surfaces, which indicate damage from torsion, will be rejected.

410.7 Workmanship and Tolerances. The following tolerances shall apply for fabrication of piling units:

A. Variation from plan lengths - plus or minus 1 inch

B. Variation from plan transverse dimensions - plus or minus 1/4 inch

C. Maximum sweep - 1/8 inch per 10 feet

D. Head out of square - Maximum 1/8 inch

E. At any point in the member, small areas of honeycomb which are purely surface in nature, not over 1/2 inch deep, may be repaired. Piling with honeycomb extending to plane of prestressed strands will not be acceptable.
F. Requirements not covered - conform to current Prestressed Concrete Institute standards.

G. Members not conforming to the above, shall be rejected, repaired and replaced at no cost to Harris County.

410.8 Finishing. Exposed surfaces of concrete piles shall be finished as follows: Handling wires and/or other protrusions shall be removed and resulting chips or indentations shall be pointed up with grout. The surfaces shall then be painted with two coats of "Daraweld" masonry paint, or equal.

410.9 Measurement and Payment. Measurement of prestressed concrete piling will be made by the linear foot of acceptable piling complete and in place after all buildups and cut offs have been made. Measurement of pile buildups will be made by the linear foot of the portion of the buildup which extends beyond the specified length of the pile. Measurement of cutoffs will be made by the linear foot, starting at the pile length shown on the plans.

Payment for piles will be made at the unit price bid per linear foot of prestressed concrete piling of the specified size bid.

Payment for the work and materials involved in making each pile buildup will be made at the rate of one and one half (1-1/2) times the unit price bid for Prestressed Concrete Piling. Payment will not be made for more than one buildup on any pile. Payment will be made for only the part of the buildup which extends beyond the pile length shown on the plans.

Payment for cutoffs will be made at the same unit price bid per foot of Prestressed Concrete Piling. Payment will be made for only the part of the cutoff which lies within the pile length shown on the plans.

The foregoing payments will be full compensation for all material, labor, tools, equipment and incidentals necessary to complete the work in accordance with the plans and specifications.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 421 “Structural Concrete”
Item 440 “Reinforcing Steel”

END OF ITEM 410
ITEM 411

DRILLED SHAFT FOUNDATIONS

411.1 Description. This Item shall govern for the construction of foundations consisting of reinforced concrete shafts or columns with or without bell type concrete footings. Concrete shafts shall be placed in drilled excavations when the shafts are without bell type footings and in drilled or underreamed excavations when shafts are with bell type footings. Such foundations shall be constructed in accordance with this Item and in conformance with the details and governing dimensions shown on the plans.

411.2 Materials. All concrete materials shall be in accordance with the Item 421 "Structural Concrete" and the requirements herein. Concrete shall be Class A1 or A2, but where casing is used, concrete shall be Class A1. The maximum size coarse aggregate shall be 1-1/2 inches or as specified for cased shafts. A retarder or water reducing agent will be required in all concrete when casing is used, or when shafts are placed in water. Reinforcing steel shall conform to the requirements of the Item 440 "Reinforcing Steel". The size and dimensions shall be as shown on the plans. Welding shall be in accordance with the Item 446 "Structural Welding".

411.3 Construction Methods

A. Excavation. The plans indicate the expected depths and elevations where satisfactory bearing material will be encountered.

The Contractor shall perform the excavation required for the shafts and bell footings, through whatever materials encountered, to the dimensions and elevations shown on the plans or required by the site conditions. If satisfactory material is not encountered at plan elevation, the bottom of the shaft will be adjusted, or the foundation altered, as determined by the Design Engineer, to satisfactorily comply with design requirements. Shaft vertical plumbness alignment shall be within a tolerance of one inch per ten feet of depth. Center of shaft located under column or footing, 1 inches of horizontal plan position.

Where caving conditions and/or excessive groundwater is encountered, no further drilling will be allowed until a construction method is employed which will prevent excessive caving.
Do not excavate a shaft within two and half (2-1/2) shaft diameters (clear) of an open shaft excavation, or one in which concrete has been placed in the preceding 24 hours.

Casing will be required when necessary to prevent caving of material or when necessary to exclude ground water. Casing shall be metal that is water tight, and of ample strength to withstand handling stresses from the pressure of concrete, the surrounding earth and backfill materials.

When casing is required, the outside diameter of the casing shall not be less than the specified diameter of shaft.

If the elevation of the top of shaft is below ground level at the time of concrete placement, an oversize surface casing from ground elevation to a point below the top of the shaft may be required to control caving of any material into the freshly placed concrete.

When casing is used, it shall be smooth, clean and free of accumulations of hardened concrete.

Under normal operations, the removal of the casing shall not be started, until all concrete placements are completed in the shaft. When unusual conditions warrant, the casing may be pulled in partial stages. Maintain sufficient head of concrete in the casing at all times during the withdrawal, a minimum of 6 foot head of concrete shall be maintained at all times above the bottom of the casing to overcome hydrostatic pressure. Casing extraction shall be at a slow, uniform rate with the pull in line with vertical axis of the shaft.

Do not use casing other than surface casing. Do not use surface casing longer than 20 foot without approval of Design Engineer. Do not leave any casing in place unless authorized by design Engineer or as shown on the plan. When the plans indicate that skin friction design has been used, any casing used will not be permitted to remain in place unless otherwise noted on the plans or permitted by written authorization of Design Engineer.

Bells shall be excavated to form a bearing area of the size and shape shown on the plans. Bell shapes varying slightly from those shown on the plans are permissible provided the bearing area equals that specified.

Bells shall be excavated by mechanical methods. Blasting shall not be permitted.
Material excavated from shafts and bells, including drilling mud shall not be used in the backfill around the completed bents or piers and shall be disposed by the Contractor in accordance with the plans and in compliance with current local, State and Federal Regulations. Unless otherwise shown on the plans, the slurry displacement method may also be used to construct drilled shafts. The drilling slurry is to contain 4 to 8 percent by weight of bentonite additive. Use drilling slurry that meets the requirements mentioned hereinafter as determined by TxDOT’s Test Procedure Tex-130-E.

<table>
<thead>
<tr>
<th>BEFORE INTRODUCTION INTO THE EXCAVATION</th>
<th>SAMPLE FROM THE BOTTOM OF THE EXCAVATION BEFORE CONCRETING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>% Sand Content</td>
</tr>
<tr>
<td>≤1.10</td>
<td>≤1</td>
</tr>
</tbody>
</table>

Use Mineral slurry consisting of processed bentonite or attapulgite clays mixed with clean fresh water. Do not use PHPA (partially hydrolyzed polyacrylamide), polymeric slurry or any other fluid primarily of a polymer solution.

Use this method to support the sides of the excavation with processed mineral slurry that is then displaced by concrete to form a continuous concrete shaft.

During and after drilling maintain a head of slurry in the shaft excavation at or near ground level or higher as necessary to counteract ground water pressure.

Just before placing reinforcing steel, use an air lift or proper size cleanout bucket to remove any material that may have fallen from the sides of excavation or accumulated on the bottom after the completion of drilling.

If the concrete placement is not started within 4 hours of completion of the shaft excavation, reprocess the hole with auger as directed (re-agitate for minimizing the mud cake built-up on the side walls), clean the bottom with an air lift or cleanout bucket, and check the slurry at bottom of the hole for compliance with slurry requirements herein and reprocess if required.

Before placing concrete, sample slurry from the bottom of the hole (shaft), and test it in accordance with TxDOT’s Test Procedure Tex-130-E. Use a pump or air lift to remove slurry that does not meet the above specified requirements while adding fresh clean
slurry to the top of the hole to maintain the slurry level. Continue this operation until the slurry sampled from the bottom of the holes meets the requirements.
Use a clean-out bucket or similar equipments to clean the bottom of the shaft. Drilling, de-sanding, setting reinforcing steel and concreting shall be one continuous operation.

Do not pre-drill unless it is authorized by the Design Engineer, if pre-drilling is authorized, a smaller size auger should be used for pre-drilling and the shaft shall not be drilled deeper than 20 feet above the shaft design bottom elevation. When drilling is resumed, the correct size auger should be used to ream out the pre-drilled portion of the shaft and complete the excavation to the design elevation.

If a shaft stayed open over night, it shall be reprocessed with auger (re-agitate for minimizing the mud cake built-up on the side walls), clean the bottom with cleanout bucket, and check the slurry at bottom of the hole for compliance with slurry requirements herein and reprocess if required, then set reinforcement and concrete.

At the time concrete is placed, the excavation shall be free from accumulated seep water. All loose material shall be removed from the bottom of the excavation, prior to placing concrete.

The Contractor shall provide suitable access and lighting for proper inspection of the complete excavation and to check the dimensions and alignment of shafts and underreamed excavation.

Any required lighting shall be electric. Any mechanical equipment shall be operated by air or electricity. The use of gasoline driven engines within the excavation, for pumping and drilling, will not be permitted.

When the plans require shafts in abutment bents, the embankment at the bridge ends shall be completed to grade and thoroughly compacted prior to drilling, unless otherwise permitted by the Design Engineer.

**B. Reinforcing Steel.** Unless otherwise designated on the plans, all bar reinforcement shall comply with Item 440 “Reinforcing Steel”. The cage of reinforcing steel, consisting of longitudinal bars and spiral reinforcement, lateral ties or horizontal bars shall be completely assembled and placed as a unit immediately prior to concrete placement.
Reinforcement shall be free of mud, oil, other surface contamination, and excessive corrosion at time of concrete placement in accordance with ACI 301, Latest Edition. The size and configuration of vertical reinforcing and tie steel shall be as shown on the project drawings. Splice vertical reinforcing steel in accordance with plans or the Latest Edition of ACI 318 for compression or tension. Submit splice details.

If the shaft is lengthened and the plans require full depth reinforcement, a minimum of one half of the longitudinal bars required in the upper portion of the shaft shall be extended to the bottom with proper lateral reinforcement. These bars may be lap spliced, or spliced by welding by a qualified welder. Any splices required shall be in the lower portion of the shaft.

Where spiral reinforcement is used, it shall be tied to the longitudinal bars at a spacing not to exceed 12 inches. Do not weld lateral reinforcement to longitudinal bars.

The cage shall be supported and/or held down by some positive method to minimize vertical displacement during concrete placement and/or extraction of the casing. The support shall be concentric with the cage to prevent racking and distortion of the steel. An adequate number of the vertical bars shall be supported.

In uncased shafts, concrete spacer blocks, or steel chairs shall be used at sufficient intervals to insure concentric spacing for the entire length of the cage. In cased shafts, concrete spacer blocks may not be used. Metal "chair" type spacers shall be placed at sufficient intervals to insure concentric spacing inside the casing.

The elevation of the top of the steel cage shall be carefully checked before and after casing extraction. Generally, any upward or downward movement of the steel not exceeding 2 inches, per 20 feet of shaft length will be acceptable. Displacement of the steel beyond the above limits will be cause for rejection.

The minimum length of steel required for lap with column steel shall be maintained. Dowel bars may be used if the proper lap length is provided both into the shaft and into the column.

C. Concrete. Concrete placement shall be performed in accordance with the provisions of the Item 420 "Concrete Structures", and in accordance with the requirements herein:
Concrete shall be placed as soon as possible after all excavation and de-sanding operation is complete and reinforcing steel placed, and shall be of such workability that vibrating or rodding will not be required.

Concrete placing shall be continuous for the entire length of shaft or, to the construction joint indicated on the plans.

Concrete shall be placed through a suitable tube or tremie, to prevent segregation of materials. For dry shafts of 24 inches or smaller diameter, limit free fall of concrete to 20 feet; concrete shall not strike the reinforcing cage or sides of the holes during the placement. When free fall is used, provide a hopper with minimum 3 foot long drop tube at the top of shaft to direct concrete vertically down the center of the shaft. Do not use shovel or other means to simply deflect the concrete discharge from the truck.

Use a suitable tube or tremie to prevent segregation of materials during the concrete placement. The minimum diameter of tremie shall be at least 8 times the largest aggregate size.

The tube or tremie may be made in sections to provide proper discharge and permit raising it as the placement progresses. A non-jointed pipe may be used if sufficient openings of the proper size are provided to allow for the flow of concrete into the shaft.

If slurry method is used for excavation, initially seal the bottom of tremie to positively separate the concrete from the slurry. The sealed tremie shall be kept on the bottom of shaft until full of concrete, then lifted slightly (no more than one foot) to force out the plug or lift off the bottom plate and permit the flow of concrete. A minimum of ten (10) feet of concrete head shall be kept above the bottom of tremie pipe during concrete placement. The displaced slurry shall be pumped to holding tanks. Do not spill onto or contaminate the site. Do not discharge slurry into or in close proximity to streams or other bodies of water. Do not excavate slurry pits. Disposal of slurry is the sole responsibility of the Contractor and must be in compliance with current local, State and Federal Regulations.

The elapsed time from the beginning of concrete placement in the cased portion of the shaft, until extraction of the casing is begun, shall not exceed one hour.

Placing of drilled shaft concrete under water may not be done without the permission of the Engineer. If permission is granted,
the concrete shall be placed with a closed tremie or may be pumped. Provisions shall be made for a sump, or other approved method, to channel disposed water away from the shaft.

A riser block of equal diameter as the column and of a maximum height of 6 inches may be cast at the top of the completed shaft.

The top surface shall be cured and any construction joint area shall be treated as prescribed in the Item 420 "Concrete Structures".

No extra compensation will be allowed for the additional concrete required to fill an oversize casing or oversize excavation.

411.4 Quality Assurance.

The Testing Laboratory representative will determine and report Slurry Properties as follows: % sand content in accordance with ASTM D4381 "Standard Test Method for Sand Content by Volume of Bentonitic Slurries", Density in accordance with ASTM D4380 “Standard Test Method for Density of Bentonitic Slurries”, Viscosity and Ph in accordance with ASTM D6910 “Standard Test Method for Marsh Funnel Viscosity of Clay Construction Slurries.” The drilled shaft inspection report shall include the following: the shaft identification (location, diameter and bell size if any, length, top and bottom elevation), Date, Start/finish time of excavation, method of excavation, description of material encountered, Description and location of any obstruction or difficulties encountered during excavation and its outcome, method of cleanout of shaft bottom. Description of groundwater conditions and the depth it was encountered. Description of casing placed (including purpose, inside diameter, thickness, length and top elevation), slurry information and depth it was introduced to the hole, start/finish time of de-sanding operation, record of reinforcing steel, method and start/finish time of concrete placement and removal of casing if any, record head of concrete above the bottom of casing before and during the withdrawal of casing, level of concrete drop off after removal of casing, volume of concrete placed versus theoretical volume of drilled shaft. The concrete delivered to site shall be sampled in accordance with ASTM C172 “Standard Practice for Sampling Freshly Mixed Concrete”, cylinders for strength tests shall be molded and laboratory cured in accordance with ASTM C31 “Standard Practice for Making and Curing Concrete Test Specimens in the Field.” Specimens shall be tested in accordance with ASTM C39 “Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens”; two (2) cylinders shall be molded for 7-day test and two (2) for 28-day test. One set of cylinders shall be molded per shaft or a pour of 50 yards per shaft. Each time a set of specimens is molded, the slump will be determined in accordance with ASTM C143 “Standard Test Method for Slump of
Hydraulic-Cement Concrete” and the air content in accordance with ASTM C173 “Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method” or ASTM C231 “Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.”

411.5 Measurement & Payment.

A. Drilled shafts shall be measured by the vertical foot, measured from bottom of footing or shaft to construction joint or bottom of abutment. No separate measurement will be made for the concrete, reinforcing steel or excavation. No measurement or payment will be made for casing left in place or drilling through earth above specified top of shaft elevation, or removing earth above specified top of shaft elevation for convenience of drilling.

B. Underreamed foundations (bells) shall not be paid for directly, but shall be subsidiary to drilled shaft foundations.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 420 “Concrete Structures”
Item 421 “Structural Concrete”
Item 440 “Reinforcing Steel”
Item 446 “Structural Welding”

END OF ITEM 411
ITEM 420

CONCRETE STRUCTURES

420.1 Description. This Item shall govern for the construction of culverts, retaining walls, abutments, bents, piers, girders, slabs and all other structures involving the use of concrete.

All concrete structures shall be constructed in accordance with the design requirements and the details shown on the plans; in conformity with the pertinent provisions of the items contracted for and the incidental items referred to; and in conformity with the requirements herein set forth.

420.2 General Requirements. Before starting work, the Contractor shall inform the Engineer fully as to the methods of construction he proposes to follow and as to the amount and character of equipment he proposes to use; the adequacy of which shall be subject to the approval of the Engineer. Concurrence on the part of the Engineer in any proposed construction methods and approval of equipment, shall not relieve the Contractor of the responsibility for the safety or correctness of his/her methods or the adequacy of his/her equipment or from carrying out the work in full accordance with his/her contract.

420.3 Materials. All concrete shall conform to Item 421 "Structural Concrete" or as indicated on the plans. For multi-component structures, the class of concrete for each portion of the structure, shall be as designated in the contract documents.

Preformed expansion joint materials shall meet the requirements of ASTM D994 “Standard Specification for Preformed Expansion Joint Filler for Concrete (Bituminous Type)” or ASTM D1751 “Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)”, as well as the Item 438 "Preformed Joint Seal".

Poured joints shall be asphalt that is homogeneous, shall be free from water and shall not foam when heated to 392°F. It shall conform to the following requirements:

<table>
<thead>
<tr>
<th>Requirement</th>
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<tbody>
<tr>
<td>Flash point (open cup), not less than</td>
<td>200°C (392°F)</td>
</tr>
<tr>
<td>Softening point (ring and ball method)</td>
<td>65°C to 110°C (149°F to 230°F)</td>
</tr>
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</table>
Penetration at 0°C (32°F), 200 gms., 60 sec., not less than 10

Penetration at 25°C (77°F), 100 gms., 5 sec., 30 to 50

Penetration at 46°C (115°F), 50 gms., 5 sec., not more than 110

Loss on heating at 163°C (325°F), 50 gms., 5 hrs., not more than 1.0%

Penetration at 25°C (77°F), 100 gms., 5 sec., of residue after heating at 163°C (325°F), as compared with penetration of asphalt before heating, not less than 60.0%

Ductility at 25°C (77°F), not less than 3.0 cm

Proportion of bitumen soluble in carbon tetrachloride, not less than 99.0%

Total bitumen (soluble in carbon disulphide), not less than 99.0%

All other materials such as reinforcing steel and structural steel shall conform to the requirements of the pertinent specifications.

420.4 General Construction Requirements. Before constructing forms and falsework for concrete superstructure spans over 20 feet in length; form and falsework plans shall be submitted to the Engineer for review and approval. Similar plans shall be submitted for other units of the structure if requested by the Engineer. The plans shall be prepared on standard sheets 22 inches x 34 inches overall size and shall be sufficiently complete to show all essential details of the proposed forms, falsework, and bracing for same. In general, not over six sets of such plans will be required.

Concurrence on the part of the Engineer in any proposed construction methods, approval of equipment, or approval of form and falsework plans shall not be considered as relieving the Contractor of the responsibility for the safety or correctness of his/her methods and adequacy of his/her equipment, or from carrying out the work in full accordance with the contract.

Unless otherwise provided, the following requirements shall govern for the time sequence in which construction operations may be carried on and for the opening of completed structures to traffic.
Steel I-beams or forms and falsework for superstructures shall not be erected on concrete substructures until the concrete in the substructures has cured at least 4 curing days. Concrete for concrete slab or girder spans or concrete slabs on steel I-beam spans shall not be placed until the substructure has cured at least 7 curing days.

Steel trusses or plate girders to be erected from the ground on approved falsework may be erected when the substructure has cured 4 curing days, but the falsework shall not be removed until the substructure has cured at least 7 curing days. Erection by means of a traveling crane on the span will not be permitted until the substructure has cured at least 7 curing days.

Forms for walls or columns shall not be erected on concrete footings until the concrete in the footing has cured at least 2 curing days. Concrete may be placed in the wall or column as soon as the forms and reinforcing steel placement is approved.

The use of completed portions of a structure as the site for mixing operations or for storage of materials will not be permitted until the particular portion of the structure has aged at least ten curing days.

A curing day shall be as defined in the Section 420.24 "Removal of Forms and Falsework". In continued cold weather the construction operations may be authorized at the end of a period of calendar days equal to twice the number of curing days specified above.

For bridges and direct traffic culverts, construction traffic and traveling public permitted in accordance with the following:

A. Authorization for light construction traffic not to exceed a three-quarter ton truck may be given after last slab of concrete has been in place at least 14 days.

B. Authorization for normal construction traffic, when necessary, and to traveling public may be given after last slab of concrete has been in place 30 days.

Forms or screed supports for bridges may be attached to I-beams or girders by welding.

420.5 Foundations. Excavation for foundations shall be made in accordance with the requirements of pertinent specifications.

Caissons shall be constructed of the materials and to the dimensions and details shown on the plans. Forms for concrete caissons may be of wood
or metal meeting the specified requirements. The operation of sinking will be permitted to proceed immediately after form removal.

Where necessary, falsework shall be provided to support the caisson during the construction and lowering period. Such falsework shall be of the strength required to support the caisson in combination with the forces of wind, water currents and drift.

Concrete foundation seals, if required, shall be of the thickness shown on the plans. The seals shall be Class D Concrete and shall be placed in accordance with the requirements herein for concrete placed in water. The completed seal shall not be higher or lower than the plan grade or the grade established by the Engineer, by more than 1/16 times the least inside caisson, cofferdam, or dredge well dimension at such grade.

The seal shall be allowed to set for at least 36 hours before the caisson or cofferdam is dewatered. After dewatering, the top of seal shall be cleaned off, all or other soft material readily loosened with a pick shall be removed, and all high spots which exceed the above limitation shall be cut off and removed.

Foundation piling shall be cut off square at the elevation shown on plans. A tolerance of not more than 2 inches above or below established cut-off grade will be permitted.

420.6 Drains. Weep hole drains shall be installed in abutments and retaining walls, and roadway drains or scuppers shall be installed in the roadway slabs in accordance with the details shown on the plans.

420.7 Expansion Joints and Devices. Expansion joints and devices to provide for expansion and contraction shall be constructed where and as indicated on the plans.

Unless otherwise provided on the plans, the bridge seat under the expansion ends of concrete slab spans and slab and girder spans shall be given a steel trowel finish, and the surfaces of substructure and spans and girders shall be separated by layers of roofing felt or a combination of roofing felt and sheet metal. Before installation, the contact areas of such roofing felt or sheet metal shall be coated with graphite grease. Layers of roofing felt or sheet metal shall be carefully placed so that concrete or mortar will not be worked around or under the material.

All joints constructed, to be left open or filled with poured joint material, shall be constructed using forms adaptable to loosening or early removal. In order to avoid jamming such forms by the expansion action of the spans and the consequent likelihood of injury to the adjacent concrete,
these forms shall be removed or loosened as soon as practicable after the concrete has attained its final set. A provision for loosening the forms to permit free expansion of the span without the necessity for full removal is preferred.

Armored joints shall be carefully constructed in order to avoid defective anchorage of the steel and to avoid porous or honeycombed concrete adjacent to same.

When premolded joint material is to be used in vertical joints of roadway and sidewalk slabs, the tops of such joints shall be adequately sealed with asphalt of the quality specified for poured joint materials. To accomplish this sealing, the top 2 inch depth of the joint shall be constructed open or the premolded material shall be plowed out and the space filled with liquid asphalt.

Premolded material, if specified, shall be used in expansion or contraction joints in abutment walls, wing walls and retaining walls. Metal flashing strips for the prevention of water seepage through wall joints shall be provided and installed in accordance with the plan provisions.

Premolded materials, wherever used, shall be anchored to the concrete on one side of the joint by means of copper wire not lighter than No. 12 B. & S. gauge. Such anchorage shall be sufficient to preclude the tendency of the material to fall out of the joint.

Careful workmanship shall be exercised in the construction of all joints to insure that the concrete sections are completely separated by an open joint or by the joint materials and to insure that the joints will be true to the outline indicated. Immediately after the removal of forms and again where necessary after surface finishing, all projecting concrete shall be removed along the exposed edges of premolded materials in order to secure full effectiveness of the expansion joint.

Where roofing felt or premolded material is specified for horizontal joints, the material shall, if practicable, extend 2 inches beyond the form for the top member. The projecting portions shall be subsequently trimmed to the face of the member after the forms are removed.

420.8 Construction Joints. The joint formed by placing plastic concrete in direct contact with concrete that has attained its initial set shall be deemed a construction joint. When concrete in a structure or a portion of a structure is specified to be placed monolithic, the term monolithic shall be interpreted to mean that the manner and sequence of concrete placing shall be such that construction joints will not be created.
Construction joints shall be of the type, location and spacing shown on the plans. Additional joints shall not be provided, without written authorization from the Engineer. Any additional construction joints shall have details equivalent to those shown on the plans for joints in similar locations.

Unless otherwise provided, construction joints shall be square and normal to the forms. Bulkheads shall be provided in the forms for all joints except horizontal joints.

The top surface of a concrete placement which terminates at a horizontal construction joint shall have the surface cement film removed and shall be thoroughly roughened as soon as practicable after the concrete has attained initial set. The surface at bulkheads shall be roughened as soon as the bulkhead forms are removed.

Before joining plastic concrete to concrete that has already set, the surface of the concrete in place shall be thoroughly cleaned up of all loose materials, dirt or foreign matter; shall be washed and scrubbed clean with stiff brooms and thoroughly drenched with water until saturated, and shall be kept wet until the plastic concrete has been placed. Immediately prior to the placing of additional concrete, all forms shall be drawn tight against the concrete in place, and the surface of the concrete in place shall be flushed with a coating of grout mixed in the proportions of one part of cement to two parts of sand.

If shown on the plans, construction joints shall be provided with concrete keyways, reinforcing steel dowels, and/or metal flashing strips. The method of forming keys in keyed joints shall be such as to permit the easy removal of forms without chipping, breaking, or damaging the concrete in any manner.

420.9 Falsework. All falsework shall be designed and constructed so that no excessive settlement or deformation will occur, and so that the necessary rigidity will be provided. Details of falsework construction shall be subject to review and approval by the Engineer in accordance with the provisions of Section 420.4 "General Construction Requirements".

For calculating the loads on falsework, a weight of 150 pounds per cubic foot shall be assumed for concrete, and a live load allowance of 50 pounds per square foot of horizontal surface of the form work shall be included. The maximum stresses shall not exceed 125 percent of the allowable stresses used for the design of the structure.

All timber used in falsework centering shall be sound, in good condition, and free from defects which will impair its strength.
Steel members shall be of adequate strength and of such shape as to be suitable for the purpose intended.

Timber piling may be of any species of wood which will withstand driving satisfactorily and which will adequately support the superimposed load.

Where sills or timber grillages are used to support falsework columns, unless founded on, shale or other hard materials, shall be placed in excavated pits and backfilled to prevent the softening of the supporting material by drip from the forms or by rains that may occur during the construction process. Sills or grillages shall be of ample size to support the superimposed load without settlement.

Falsework which cannot be founded on a satisfactory spread footing shall be supported on piling which shall be driven to a bearing capacity sufficient to support the superimposed load without settlement. The safe bearing capacity of piling shall be determined by the formula specified elsewhere.

In general, each falsework bent shall be capped transversely at the proper elevation by a cap of adequate size. If desired by the Contractor, however, a short cap section forming a T-head may be substituted at the top of each pile or column in order to permit the removal of portions of the forms without disturbing the falsework. Caps shall be securely fastened to each pile or column in the bent and shall be set at the proper elevation to produce, in conjunction with the use of approved hardwood wedges or jacks, permanent camber indicated on the plans or specified, plus a construction camber covering allowance for deformation of the forms and falsework. The use of wedges to compensate for incorrectly cut bearing surfaces will not be permitted. Each falsework bent shall be securely braced to adjacent bents by bracing material of ample size to provide the stiffness required. The bracing shall be securely spiked or bolted to each pile or column it may cross.

420.10 Forms. Forms shall be built mortar-tight and of material sufficient in strength to prevent bulging between supports and shall be set and maintained to the lines designated until the concrete is sufficiently hardened to permit form removal. During the elapsed time between the building of the forms and the placing of the concrete, the forms shall be maintained in a manner to eliminate warping and shrinking. All details of form construction shall be subject to the approval of the Engineer, and permission to place concrete will not be given until all of such work is complete to his/her satisfaction.

Forms shall be designed for the pressure exerted by a liquid weighing 150 pounds per cubic foot. The rate of placing the concrete shall be taken into
consideration in determining the depth of the equivalent liquid. An additional live load of 50 pounds per square foot shall be allowed on horizontal surfaces. The maximum stresses shall not exceed 125 percent of the allowable stresses used for the design of the structures.

If, at any stage of the work, the forms show signs of bulging or sagging, that portion of the concrete causing such condition shall be immediately removed, if necessary, and the forms shall be reset and securely braced against further movement.

Lumber for forms shall be properly seasoned and of good quality. It shall be free from loose or unsound knots, knot holes, twists, shakes, decay, and other imperfections which would affect its strength or impair the finished surface of the concrete. The lumber used for facing or sheathing shall be finished on at least one side and two edges and shall be sized to uniform thickness.

The use of nominal 2 inch lumber, as a minimum thickness, will be required for forms for the bottoms of all superstructure girders except that in case of special forming of girders, as for curved-bottom girders where facing boards are transverse to beam, the Engineer may permit the use of 1 inch lumber. Nominal 1 inch thickness lumber will be permitted for general use on other portions of the structure if backed by a sufficient number of studs and wales.

Timber forms for exposed concrete surfaces which are required to be surface finished in accordance with these Standard Specifications shall be face lined with an approved type of form lining material such as masonite or plywood. If desired by the Contractor, facing for such surfaces may be constructed of 3/4 inch thick plywood backed by adequate studs and wales, and in this case form lining will not be required.

Forms or form lumber to be re-used shall be maintained clean and in good condition as to accuracy, shape, strength, rigidity, tightness, and smoothness of surface. Any lumber which is split, warped, bulged, marred, or has defects that may produce work inferior to that resulting from using new material, shall not be re-used.

Studs shall not be less than 2 inches by 4 inches nominal section and shall be spaced center to center not more than 20 times the actual thickness of the facing lumber. Wherever practicable, studs shall be capped at the top with a plate of not less than 2 inches by 6 inches nominal size, carefully selected as to straightness. All joints in plates shall be scabbed at least 4 feet each way to provide continuity.
Wales shall be spaced at such intervals as to hold forms securely to the designated lines. All wales shall be scabbed at least 4 feet on each side of joints to provide continuity. A row of wales shall be placed within 6 inches of the bottom of each placement.

Forms shall be rigidly braced to prevent movement while placing the concrete.

All face form material shall be fastened to all studs and shall have true horizontal and vertical joints. Facing material on horizontal and other surfaces shall be placed with parallel and square joints.

Molding specified for chamfer strips or other uses shall be made of redwood, cypress or pine materials of such grade that will not split when nailed and which can be maintained to a true line without warping. The molding shall be mill cut and dressed on all faces. Unless otherwise provided, forms shall be filleted at all sharp corners and edges with triangular chamfer strips. The strips shall be 3/4 inch measured on the sides.

Forms for railings shall be constructed to standards equivalent to first class mill work. All moldings, panel work, and bevel strips shall be straight and true with neatly mitered joints and of such design that the finished work shall be true, sharp and clean cut.

All forms shall be so constructed as to permit removal without damage to the concrete. Particular and special care must be exercised in framing forms for copings, offsets, and railing so that there will be no damage to or marring of the concrete when the forms are removed. If desired by the Contractor, the forms may be given a slight draft to permit ease of removal.

Metal form ties of an approved type shall be used to hold forms in place. Such ties shall be of a type especially designed for use in connection with concrete work, and they shall have provision to permit ease of removal of the metal as hereinafter specified. The use of wire form ties will not be permitted except for minor or special form areas where the use of rigid type metal ties would be impracticable.

All metal appliances used inside of forms to hold them in correct alignment shall be removed to a depth of at least 1/2 inch from the surface of the concrete and shall be so constructed that the metal may be removed without undue injury to the surface by chipping or spalling. Such devices, when removed, shall leave a smooth opening in the concrete surface. Burning off of rods, bolts, or ties will not be permitted.
Metal ties shall be held in place by devices attached to wales. Each device shall be capable of developing the strength of the tie.

Pipe spreaders will not be permitted.

Metal and wooden spreaders which are separate from the forms shall be entirely removed as the concrete is being placed.

Where wire ties are used, all wires, upon removal of the forms, shall be cut back at least 1/2 inch from the face of the concrete with a sharp chisel or nippers.

All cavities produced by the removal of metal ties shall be carefully cleaned and completely filled with re-tempered sand cement mortar mixed in proportion of one to three, and the concrete shall be left smooth and even.

Whenever practicable, forms shall be erected complete before the reinforcement is placed.

For narrow walls and other locations where access to the bottom of the forms is not readily attainable otherwise, adequate clean-out openings shall be provided.

At the time of placing concrete, the forms shall be clean and entirely free from all chips, dirt, sawdust, and other extraneous matter.

The facing of all forms shall be treated with oil before concrete is placed. In hot weather, both sides of face forms may be required to be treated with oil to prevent warping and to secure tight joints. The oil must be applied before the reinforcement is placed. The oil used for this purpose shall be a light clear oil which will not discolor or otherwise injuriously affect the concrete surface.

In general, all forms shall be thoroughly wetted before the concrete is placed therein.

The foregoing specifications for forms, regarding design, mortar-tightness, filleted corners, beveled projections, bracing, alignment, removal, re-use, oiling and wetting shall apply with equal force to all forms, except that metal forms will not require lining unless noted on the plans.

The metal used for forms shall be of such thickness that the forms will remain true to shape. All bolt and rivet heads on the facing sides shall be countersunk. Clamps, pins, or other connecting devices shall be designed to hold the forms rigidly together and to allow removal without
injury to the concrete. Metal forms which do not present a smooth surface or line up properly shall not be used. Special care shall be exercised to keep metal free from rust, grease, or other foreign material such as will tend to discolor the concrete.

420.11 Placing Reinforcement. Reinforcement in concrete structures shall be carefully and accurately placed and rigidly supported as provided in the Item 440 "Reinforcing Steel".

420.12 Placing Concrete, General. The Contractor shall give the Engineer sufficient advance notice before starting to place concrete in any unit of the structure to permit the inspection of forms, the reinforcing steel placement, and preparations for casting. Unless authorized by the Engineer, no concrete shall be placed in any structure until prior to the completion of the formwork and the placement of the reinforcement. No concrete shall be placed before the completion of all adjacent pile driving or other operations which might prove detrimental to the concrete.

Whenever it is necessary to continue the mixing, placing, and finishing of concrete after the daylight hours, the site of the work shall be brilliantly lighted so that all operations are plainly visible. In general, however, concrete placing shall be so regulated as to permit finishing operations to be completed in the daylight hours.

The Engineer reserves the right to order postponement of the placing operations when, in his/her opinion, impending weather conditions may result in rainfall or low temperatures which will impair the quality of the finished work. In case rainfall should occur after placing operations are started, the Contractor shall provide ample covering to protect the work. In case of drop in temperature, the provisions set forth in the Section 420.13 "Placing Concrete in Cold Weather" shall be applied.

The sequence of placing concrete shall be as provided on the plans or in the specifications. The operation of depositing and compacting the concrete shall be conducted so as to form a compact, dense, impervious mass of uniform texture which shall show smooth faces on all surfaces. The placing shall be so regulated that the pressures caused by the plastic concrete shall not exceed the loads used in the design of forms.

The method and manner of placing shall be such as to avoid the possibility of segregation or separation of the aggregate or the displacement of the reinforcement. Concrete shall not have a free fall of more than 3 feet except in the case of thin walls such as culvert walls.

Spattering on forms or reinforcement bars shall be prevented if the concrete so spattered will dry or harden before being incorporated in the
mass. Any hardened concrete splatter ahead of the plastic concrete shall be removed.

Each part of the forms shall be filled by depositing concrete directly as near its final position as possible. The coarse aggregate shall be worked back from the face and the concrete forced under and around the reinforcement bars without displacing them. Depositing large quantities at one point in the forms and running or working it along the forms will not be allowed.

After the concrete has taken initial set, the forms shall not be jarred or any strain placed on projecting reinforcement.

Chutes, troughs, conveyors or pipes used as aids in placing concrete shall be arranged and used so that the ingredients of the concrete will not be separated. When steep slopes are necessary, the chutes shall be equipped with baffle boards or be made in short lengths that reverse the direction of movement. Open troughs and chutes shall extend, if necessary, down inside the forms or through holes left in the forms, or the ends of such chutes shall terminate in vertical downspouts. All chutes, troughs, and pipes shall be kept clean and free from coatings of hardened concrete by a thorough flushing with water before and after each placement. Water used for flushing shall be discharged clear of the concrete in place. The use of chutes in excess of 35 feet total length for conveying concrete will not be permitted except by specific authorization from the Engineer.

Where the Contractor's operations involve the placing of concrete from above, that is, directly into an excavated area or through the completed forms, particularly in the case of abutments, piers, columns, retaining walls, and deep girders, and excepting thin walls such as culvert walls less than 12 inches, all concrete so placed shall be deposited through a vertical sheet metal or other approved pipe not less than 6 inches nor more than 10 inches in diameter. The pipe shall be made in sections so that the outlet may be adjusted to proper heights during placing operations.

Concrete shall be placed in continuous horizontal layers approximately 12 inches in thickness. Not more than one hour shall elapse between the placing of successive layers of concrete in any portion of the structure included in a continuous placement. The Contractor shall avoid unauthorized construction joints by placing required portions of abutments, pier walls or superstructures in one continuous operation. Laitance or foreign matter of any kind shall not be permitted to accumulate inside the forms. Openings in forms necessary for removal of shall be provided.
All concrete shall be well compacted and the mortar flushed to the surface of the forms by continuous working with concrete spading implements or mechanical vibrators of an approved type. Vibrators of the type which operate by attachment to forms or reinforcement will not be permitted. The vibrators shall be applied to the concrete immediately after deposit and shall be moved throughout the mass, thoroughly working the concrete around the reinforcement, embedded fixtures, and into the corners and angles of the forms until it has been reduced to a plastic mass. The mechanical vibrator shall not be operated so that it will penetrate or disturb layers placed previously which have become partially set or hardened. The vibration shall be of sufficient duration to accomplish thorough compaction and complete embedment of reinforcement and fixtures but shall not be done to an extent that will cause segregation. Vibration shall be supplemented by hand spading if necessary to insure the flushing of mortar to the surface of all forms.

Holes for anchor bolts in piers, abutments, bents, or pedestals may be drilled or may be formed by the insertion of oiled wooden plugs or metal sleeves in the plastic concrete. The plugs or sleeves shall be withdrawn after the concrete has set. When the holes are formed, they shall be of such diameter to permit horizontal adjustment of the bolts. The bolts shall be carefully set in mortar. In lieu of the above methods of placing, anchor bolts may be set to exact locations in the concrete when it is placed.

The placing of concrete for floor slabs of I-beam spans, girder spans, or truss spans preferably shall be done from a mixing plant located off the structure. If the mixer plant is to be located on the structure, it shall not be placed on a section of the roadway slab which has not aged for at least 10 curing days. Carting or wheeling concrete batches on a completed concrete floor slab will not be permitted until the slab has aged at least 4 curing days. If carts are used, the carts shall be wheeled on timber planking so that the loads and impact will be distributed over the slab. Carts shall be equipped with pneumatic tires. Curing operations shall not be interrupted for the purpose of wheeling concrete over finished slabs.

Stockpiling of concrete aggregate or cement on bridge floors will be permitted only when authorized by the Engineer, and, when permitted, the stock piles shall be uniformly distributed and shall be limited to not over 2 feet maximum depth. The storing of reinforcing or structural steel on completed roadway slabs shall generally be avoided, and, when permitted, such storage shall be limited to quantities and distribution that will not induce excessive stresses.

Placing Concrete In Cold Weather. No concrete shall be placed when the atmospheric temperature is at or below 40°F (taken in the shade away
from artificial heat) unless permission to do so is given in writing by the 
Engineer. When such permission is given or in cases where the 
temperature drops below 40°F after the concreting operations have been 
started, the Contractor shall furnish sufficient canvas and framework or 
other type of housing to enclose and protect the structure in such way that 
the air around the forms and fresh concrete can be kept at a temperature 
not less than 50°F for a period of five days after the concrete is placed. 
Sufficient heating apparatus such as stoves, or steam equipment and fuel 
to furnish all required heat shall be supplied. The treatment of mixing 
water and aggregates used in mixing concrete shall be as specified in 
"Concrete". The placing of concrete in cold weather shall conform to the 
requirements of ACI 306.

It is understood that the Contractor is responsible for the protection of 
concrete placed under any and all weather conditions. Permission given 
by the Engineer to place concrete during freezing weather will in no way 
relieve the Contractor of the responsibility for satisfactory results. Should 
concrete placed under such conditions prove unsatisfactory, it shall be 
removed and replaced at the expense of the Contractor.

420.14 Placing Concrete in Hot Weather. Unless otherwise directed by the 
Engineer, when the temperature of the air is above 85°F, an approved 
retarding agent will be required in all concrete or direct traffic culverts. An 
approved retarding agent will be required in all cased drilled shafts, 
regardless of temperature.

420.15 Placing Concrete In Water. Concrete shall be deposited in water only 
when specified on the plans or with the permission of the Engineer. The 
forms, cofferdams, or caissons shall be sufficiently tight to prevent any 
water current passing through the space in which the concrete is being 
deposited. Pumping will not be permitted while the concrete is being 
placed, nor until it has set for at least 36 hours.

The concrete shall be carefully placed in a compact mass by means of a 
tremie, closed bottom-dump bucket or other approved method that does 
not permit the concrete to fall through the water. The concrete shall not 
be disturbed after being deposited. Depositing shall be regulated to 
maintain an approximately horizontal surface at all times.

When a tremie is used, it shall consist of a tube having a diameter of not 
more than 10 inches, constructed in sections having watertight 
connections. The means of supporting the tremie shall permit the 
movement of the discharge end over the entire top surface of the work 
and shall permit the tremie to be rapidly lowered when necessary to choke 
off or retard the flow. The number of times it is necessary to shift the
location of the tremie, for any continuous placement of concrete, shall be held to a minimum.

During the placing of concrete, the tremie tube shall be kept full to the bottom of the hopper. When a batch is dumped into the hopper, the tremie shall be slightly raised, but not out of the concrete at the bottom, until the batch discharges to the level of the bottom of the hopper. The flow shall then be stopped by lowering the tremie. The placing operations shall be continuous until the work is complete.

When concrete is placed by means of a bottom-dump bucket, the bucket shall have a capacity of not less than 1/2 cubic yard. The bucket shall be lowered gradually and carefully until it rests upon the concrete already placed. It shall then be raised, very slowly, during the upward travel, the intent being to maintain, as nearly as possible, still water at the point of discharge and to avoid agitating the mixture.

420.16 Placing Concrete in Slab Spans. Concrete in slab spans shall be placed in longitudinal strips. Placing preferably shall be started at a point in the center of the span adjacent to one curb and the longitudinal strip thus started shall be completed by depositing concrete uniformly in both directions toward the ends of the span. The width of longitudinal strips shall be such that the concrete in any strip will not take its initial set before the adjacent strip is placed. The concrete in the curbs shall be placed in proper sequence to be monolithic with the adjacent longitudinal strip of the slab.

The forms for the bottom surface of the slab shall be maintained true to the required vertical alignment during the placing of concrete in the span. For convenience in checking the vertical alignment, an approved system of "tell-tales" shall be installed and maintained by the Contractor. The "tell-tales" shall be attached to the form and shall provide a convenient means of matchmarking with reference to points set on stakes or other suitable reference points set independent of the forms and falsework for the span being placed.

On completion of the filling of the curb forms, the curbs shall be brought to the correct camber and alignment, and then they shall be struck off and float finished.

As soon as concrete is placed in a longitudinal section of the slab of a width necessary to permit finishing operations, the slab shall be finished in accordance with the requirements of "Finish of Roadway Slabs".

420.17 Placing Concrete in Deck Girders Spans. Unless otherwise provided, the girders, slab and curbs of deck girder spans shall be placed in one
continuous operation. Concrete shall be placed in longitudinal sections. Placing preferably shall commence with a section adjacent to one curb, and successive sections continuing across the roadway shall follow. The width of each longitudinal section shall be governed by the size of the mixing apparatus and shall be such that each successive section shall be placed before the adjacent completed section shall have attained its initial set. The placing of concrete in curbs shall be in the proper sequence to be monolithic with the adjacent slab or girder section. Except for spans on a grade of 1-1/2 percent or more, concreting in each longitudinal section preferably shall be started at the middle of the span and shall be continued in both directions to the ends of the span. For spans on a grade of 1-1/2 percent or more, concreting shall be commenced at the low end of the span. The filling of the girder stems ahead of placing the concrete in the slab will be permitted provided the slab is placed not later than one hour after the filling of the girder stem.

During the operations of placing concrete in the span, the bottoms of the girders and overhanging slabs shall be maintained true to required vertical alignment. For convenience in checking the vertical alignment, the Contractor shall attach to the form of each girder an approved system of "tell-tales" which shall provide a means of matchmarking for reference to established grades fixed on stakes or other suitable reference points set independent of the forms and falsework for the span being placed. Care shall be exercised to assure that the "tell-tales" system is not altered or destroyed after the matchmarking is done.

On completion of the filling of the curb forms, the curbs shall be brought to the correct camber and alignment, and then shall be struck off and float finished.

The surface of the floor slab shall be finished as provided in Section, "Finish of Roadway Slabs". The finishing shall be done as soon as possible after the placing of concrete is completed in a section of slab of sufficient width to permit finishing operations.

420.18 Placing Concrete In Floors on Steel Spans. Before concrete floor slabs are placed on steel truss spans, the falsework under the span shall be released and the span swung free on its supports. The floor slab shall be placed symmetrically about the centerline of the span beginning at the center and working simultaneously toward each end, or beginning at the ends and working simultaneously toward the center. Where construction joints are provided at each panel point of the truss, variations from the above sequence will be permitted to the extent of one unsymmetrical panel; that is, concreting will be permitted in a panel on one side of the centerline of span provided that the corresponding panel on the opposite side of the centerline shall be the next panel placed.
Placing of the slab in each panel and the placing of the slab on steel I-beam spans shall be in accordance with the provisions of Section "Placing Concrete in Slab Spans".

Concrete placed around steel shapes shall be deposited on one side of the shape and shall be spaded or vibrated until it flushed up over the bottom flange on the opposite side of the member, after which, it may be placed on both sides to completion.

On completion of the filling of the curb forms, the curbs shall be brought to the correct camber and alignment, and they shall then be struck off and float finished as described in Section 420.21 "Treatment and Finishing of Horizontal Surfaces Except Roadway Slabs".

The surface of the floor slab shall be finished as provided in Section 420.22 "Finish of Roadway Slabs". The finishing shall be done as soon as possible after the placing of concrete is completed in a section of slab of sufficient width to permit finishing operations.

420.19 Placing Concrete in Box Culverts. In general, the base slab, curtain walls, lower haunches, and the bottom portion of the sidewalls up to a height approximately one inch above the haunches, or sidewalls to a height approximately 4 inches above the base slab when no haunch is provided, shall be placed as a monolith. The top surface of the base slab and the top surface of the top slabs which do not carry direct traffic shall be accurately finished by hand floating methods before the concrete has attained its initial set. Before concrete is placed in the sidewalls, the footing area joining the walls shall be thoroughly cleaned of all shavings, sticks, sawdust, or other extraneous material.

In the construction of box culverts less than 4 feet in clear height, the sidewalls and top slab generally shall be placed monolithic. When box culverts are greater than 4 feet in clear height, a construction joint may, if shown on the plans, be provided between the sidewalls and the top slab. In case no joint is provided, an interval of not less than 1 hour or more than 2 hours shall elapse between the placing of concrete in the walls, and concrete in the haunches and top slab, such interval to allow for shrinkage in the wall concrete. Curbs and haunches at tops of walls shall be placed monolithic with the top slab.

The tops of culvert slabs which are intended to carry direct traffic shall be finished and surface tested in accordance with the provisions for finishing roadway slabs.
420.20 Placing Concrete in Foundations of Structures. Concrete shall not be placed in footings until the depth and character of the foundation has been inspected by the Engineer and permission has been given to proceed.

The placing of concrete bases above seal courses will be permitted after the caissons or cofferdams are free from water and the seal course cleaned. Any necessary pumping or bailing during the concreting operations shall be done from a suitable sump located outside the forms.

All temporary wales or braces on the inside of cofferdams or caissons shall be constructed or adjusted as the work proceeds, so that construction joints in bases or shaft, in addition to those shown on the plans, will not be necessary.

Concrete in deep foundations shall be placed in a manner that will avoid separation of the aggregates or displacement of the reinforcement. Suitable chutes or vertical pipes shall be provided.

When footings can be placed in dry foundation pits without the use of cofferdams or caissons, forms may be omitted, if desired by the Contractor and approved by the Engineer, and the entire excavation filled with concrete to the elevation of the top of footing. Where this procedure is followed, no measurement for payment will be made for concrete placed outside of the footing dimensions shown on the plans.

Concrete in columns shall be placed monolithically unless otherwise provided. Unless a construction joint is provided at the top of columns, an interval of not less than 1 hour or more than 2 hours shall elapse between the placing of concrete in columns and the placing of concrete above the top of columns. Such interval is intended to allow for shrinkage of the column concrete.

420.21 Treatment and Finishing of Horizontal Surfaces, Except Roadway Slabs. All upper surfaces not covered by forms, such as tops of railing posts, railings, caps, curbs, parapets, copings, bridge seats, and sidewalk areas shall be completed by placing excess material in the forms and removing or striking off such excess with a wooden template forcing the coarse aggregate below the mortar surface. The use of mortar topping for surfaces under this classification will not be permitted.

After the concrete has been struck off as described above, the surface shall be thoroughly worked and floated with a wooden, canvas, or cork float. After floating and before the finish has set, all surfaces, except sidewalks so finished, shall be lightly striped with a fine brush, to remove the surface cement film, leaving a fine grained, smooth but sanded
texture. That portion of curbs or parapets which is to be the seat for concrete rail posts or webs of concrete railings shall be roughened in an approved manner.

420.22 Finish of Roadway Slabs. As soon as concrete placing operations have been completed for a longitudinal roadway slab section of sufficient width to permit finishing operations, the concrete shall be approximately leveled and then struck off, screeded and tamped by a longitudinal screed. The screed shall be of a design adaptable for the purpose intended. It shall have provisions for adjustment to the desired camber and be sufficiently rigid to hold true to shape during use.

The first strike-off operation shall leave the concrete surface at an elevation above grade so that, when consolidation and finishing operations are completed, the slab will be at the exact grade elevation shown on the plans with proper allowance for finished camber as hereinafter provided. The tamping and screeding operations shall be continued until the concrete is properly consolidated and surface voids eliminated. The surface shall then be brought to a smooth true alignment by means of longitudinal screeding, floating, belting, and/or other methods approved by the Engineer. Spans over 40 feet in length may be screeded in two or more sections if suitable intermediate templates are installed. Unless otherwise provided, the templates shall be of such design as to permit early removal in order to avoid construction joints and to permit satisfactory finishing at and adjacent to the site of the template.

After the finishing operations are completed and while the concrete is still plastic, the surface shall be straightedged by the Contractor, using a standard 10 foot metal straightedge. Any deviations from the face of the straightedge greater than those prescribed under the following surface test shall be corrected before the concrete has attained its initial set. The final belting of the slab shall be done after this straightedging is completed.

After the concrete has attained its final set, the roadway surface shall be tested again with a standard 10 foot metal straightedge for irregularities, and the surface shall be corrected, if necessary, to conform to the following:

The straightedge shall be placed parallel to the centerline of the road so as to bridge any depression and touch high spots. Ordinates measured from the face of the straightedge to the surface of the slab shall not exceed 1/16 inch per foot from the nearest point of contact and the maximum ordinate shall not be greater than 1/8 inch. The surface shall be corrected by grinding off the high spots as may be required in order to conform to these limits.
In the case of concrete slab or girder spans, the floor shall be finished so as to provide a camber sufficient to offset the dead load deflection of the span; other spans shall be so finished if directed by the Engineer. Unless otherwise shown on the plans, the camber at the center of the span shall be made 1/8 inch for each 10 feet of span length with a maximum camber of 1/2 inch. When camber is provided, the ordinate to the straightedge may be as much as 3/16 inch at the end of the straightedge but shall not exceed 1/16 inch under its center.

420.23 Curing Concrete. Careful attention shall be given by the Contractor to the proper curing of all concrete in the structure. The Contractor, at his/her option, may elect to use other curing methods outlined in the Item 421 "Structural Concrete". If cotton mats are used, all upper surfaces not formed, except roadway and sidewalk slabs, shall be covered by cotton mats immediately following the floating operations and shall be kept thoroughly wet for a period of 4 curing days after the concrete is placed. All formed surfaces requiring a surface finish shall be covered with wet cotton mats immediately after the forms are removed and shall be kept covered and wet until the concrete has aged at least 4 curing days. Intermission will be permitted as needed to allow the surfaces to be finished. The mats shall be held in direct contact with the concrete. Water used for curing shall be free from injurious amounts of oil, acid, alkali, salt, or other deleterious substances.

When forms are removed from concrete caissons in less than 4 curing days and when the sinking operations do not immediately follow the form removal, the caissons shall be cured by being covered with wet cotton mats which shall remain in place until the caissons have aged at least 4 curing days.

Immediately following the finishing operations, concrete roadway and sidewalk slabs shall be covered with wet cotton mats or with a temporary covering of canvas or burlap. The temporary covering will be required in all cases where the size of span, size of mats, or other factors are such that the mats cannot be placed immediately following the finishing operation without marring the finish of the slab.

The canvas or burlap covering material shall weigh not less than 10 ounces per square yard, and the sections shall be placed with a lap at the edges of at least 8 inches. The material shall be saturated with water previous to placing and shall be kept saturated as long as it remains in place. Care shall be exercised in the placing of the cover material in order that the concrete surface shall not be disturbed.
When a temporary covering is used, it shall remain in place only until the slab has sufficiently hardened that a cotton mat covering can be substituted without disturbing or marring the finish of the slab. Cotton mats shall be thoroughly saturated before placing and shall be maintained in a saturated condition for a period of at least 8 curing days after the concrete is placed.

Ponding, instead of cotton mat covering may be used for curing roadway, sidewalk slabs, and top slabs of culverts. In addition, membrane curing as specified in the Item 526 "Membrane Curing", may also be used, where appropriate.

420.24 Removal of Forms and Falsework. Except as hereinafter provided, forms for surfaces required to be finished shall be removed when the concrete has aged not less than 1/2 nor more than 2 curing days after the concrete is placed. In order to facilitate slab finishing, forms for inside curb faces on roadway slabs may be removed in not less than 3 hours if the concrete has set sufficiently to permit form removal without damage to the curbs.

Forms and falsework for the portions of structures which do not require surface finish may be removed when the concrete has aged for the minimum number of curing days set forth in the following table:

| Forms and falsework under slabs or girders having span lengths of 10 feet and less | 7 Days |
| Forms and falsework under slabs or girders having span lengths over 10 feet and less than 17 feet | 7 Days plus one day for each foot of span over 10 feet |
| Forms and falsework under slabs or girders having spans over 17 feet in length | 14 Days |
| Forms and falsework under caps or tie beams of framed bents | 4 Days |
| Forms under caps of pile bents | 4 Days |
| Forms & falsework under webwalls of piers | 7 Days |
| Forms for walls, columns & sides of beams | 4 Days |
| Forms for concrete caissons | 2 Days |

The term "curing day" will be interpreted as any calendar day on which the temperature is above 50°F for at least 19 hours. Colder days may be counted if satisfactory provision is made to maintain the air temperature adjacent to the concrete constantly above 50°F throughout the entire day.
In continued cold weather, when artificial heat is not provided, the Engineer may permit the removal of forms and falsework at the end of a period of calendar days equal to twice the number of curing days stated in the above table. Test specimens may be made, at the option of the Engineer, for the purpose of determining a satisfactory time of form and falsework removal in cold weather. When tests made on specimens cured under like conditions to the curing of the structure indicate that strengths equivalent to the 7 day strengths as given in the Item 421 "Structural Concrete" have been attained, the forms and falsework may be removed. In no event shall this removal be done in less time than the curing periods given in the above table.

Forms for the portions of slabs that cantilever more than one foot beyond the outside beams shall not be removed in less than four curing days, nor shall falsework under girders and bent caps for framed bents be removed in less than the minimum time specified regardless of requirements for surface finish. The above provisions relative to form removal shall apply only to forms or parts of forms which are so constructed as to permit removal without disturbing forms or falsework which are required to be left in place for a longer period on other portions of the structures.

420.25 Defective Work. Any defective work discovered after the forms have been removed shall be repaired immediately. If the surface of the concrete is bulged, uneven, or shows excess honeycombing or form marks, which defects, in the opinion of the Engineer, cannot be repaired satisfactorily, the entire section shall be removed and replaced. In repairing honeycombed areas, all loose material shall be removed before the repair work is started. No extra compensation will be allowed for the extra work or materials involved in repairing or replacing defective concrete.

420.26 Finishing Exposed Surfaces. All railing, curbs, the underside of overhanging slabs, the outside and bottom of exterior girders or fascia beams, and all portions of piers, columns, bents, abutments, retaining walls and culverts, which are exposed to view after backfill and roadway embankments are placed shall be surface finished. The area inside of culvert barrels including both sidewalls and the underside of the top slab for a distance equal to 1/3 the clear height but not less than 18 inches shall be considered as exposed to view. The remaining surface inside of culvert barrels, the underside of roadway slabs between exterior girders or beams, the sides and bottoms of interior superstructure girders and bottoms of slab spans will not be required to be surface finished unless such surfaces are not true or have porous spots or honeycombed areas. In case these defects occur, the areas shall be given a first surface rubbing.
The operation of surface finishing shall be in accordance with the following provisions:

As soon as forms are removed, all necessary pointing shall be done. When the pointing has set sufficient to permit it, all surfaces requiring surface finish shall be wet with a brush and given a first surface rubbing with a No. 16 Carborundum Stone or an abrasive of equal quality. The rubbing shall be continued sufficiently to bring the surface to a paste, to remove all form marks and projections, and to produce a smooth dense surface without pits or irregularities. The use of cement to form a surface paste will not be permitted. The material which has been ground to a paste in this process shall be carefully spread or brushed uniformly over the surface and allowed to take a reset.

In general chamfered corners shall not be rubbed in the first surface rubbing.

During the process of conditioning the completed structure for final acceptance, the surfaces of the entire structure requiring finish shall be cleaned free from drip marks and discolorations and shall be given a final finish rubbing with a No. 30 Carborundum Stone or an abrasive of equal quality. On completion of this rubbing, the surface shall be neatly striped with a brush, and the mortar on the surface shall be allowed to take a reset. The surface shall then be washed down with clean water. The entire structure shall be left with a clean, neat, and uniform appearing finish and shall be uniform in color.

The surfaces of concrete roadway and sidewalk slabs shall be finished by floating, screeding, and belting as provided in Section 420.22 "Finish of Roadway Slabs".

420.27 Special Surface Finishes. When so specified, special surface finishes shall be employed for ornamental panels, copings, and like construction. In general, the method and manner of performing this work will be fully provided for in the plans or special provisions to these Standard Specifications.

In case of special finishes, the Contractor will be required to prepare test or sample panels showing the method and manner of finish. The choice and selection of the aggregate and other features affecting the work shall be approved by the Engineer before any further work is done.

420.28 Measurement and Payment. No direct compensation will be made for "Concrete Structures". Measurement and payment for quantities of concrete, railing, piling, excavation and other proposal items, which
constitute the completed and accepted structure, will be made in accordance with the provisions of the pertinent specifications.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 421 “Structural Concrete”
Item 438 “Preformed Joint Seal”
Item 440 “Reinforcing Steel”
Item 526 “Membrane Curing”

END OF ITEM 420
ITEM 421

STRUCTURAL CONCRETE

421.1 Description. This Item shall govern for the materials used; for the storing, measuring and handling of materials and for the proportioning and mixing of concrete for bridges, culverts, signal pole foundation, other concrete structures, and incidental construction. Concrete shall meet the requirements of:

A. ACI 318 "Building Code Requirements for Reinforced Concrete".

B. The ASTM Standards.

C. ACI "Manual of Concrete Practice".

421.2 Materials. Concrete shall be composed of portland cement, coarse and fine aggregate, water and chemical admixtures as outlined below:

A. Portland cement shall meet the requirements of ASTM C150 "Standard Specification for Portland Cement." Unless otherwise permitted or required, cement shall be Type I or Type III.

B. Mixing water for concrete shall conform to the requirements in ASTM C1602 "Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete."

C. Chemical admixtures shall conform to the following specifications:

1. Air-entraining admixtures shall conform to the requirements of ASTM C260 "Standard Specification for Air-Entraining Admixtures for Concrete."

2. Chemical admixtures shall conform to the following requirements of ASTM C494 "Standard Specification for Chemical Admixtures for Concrete":
   a. Water Reducing Admixtures: ASTM C494, Type A
   b. Retarding Admixtures: ASTM C494, Type B
   c. Accelerating Admixtures (Non-Chloride): ASTM C494, Type C
d. Water Reducing Retarding Admixtures: ASTM C494, Type D

e. High Range Water-Reducing Admixtures: ASTM C494, Type F and G

Admixtures containing calcium chloride are prohibited in any type of structural concrete.

Structural concrete for Bridge Decks: Accelerating admixtures and High Range Water-Reducing admixtures are prohibited.

3. High early strength concrete may be produced from either Type I or Type III portland cement. If Type I cement is used in lieu of Type III, the Contractor shall use an accelerating admixture conforming to ASTM C494, Type C. The accelerator shall be used in accordance with that manufacturer's recommendations.

D. Aggregates for normal weight concrete shall conform to the requirements of ASTM C33 "Standard Specification for Concrete Aggregates."

Coarse aggregates shall consist of durable particles of gravel, crushed stone, or combinations thereof; free from frozen material or injurious amounts of salt, alkali, vegetable matter, or other objectionable material. It shall not contain more than 0.25 percent, by weight, of clay lumps, not more than 1.0 percent, by weight, of shale not more than 5 percent, by weight, of laminated and/or friable particles. It shall have a wear of not more than 35 percent when tested in accordance with ASTM C131 “Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine”, "The Los Angeles Abrasion Test".

Coarse aggregate shall be subjected to five cycles of both the sodium sulfate and the magnesium sulfate soundness tests. Coarse aggregate which has a loss greater than 12 percent with sodium sulfate and/or 18 percent with magnesium sulfate shall not be accepted.

Gradation of coarse aggregate shall conform to the grading requirements shown in Table 1.
TABLE 1 - COARSE AGGREGATE GRADATION

<table>
<thead>
<tr>
<th>NOMINAL SIZE</th>
<th>PERCENT BY WEIGHT, RETAINED ON SIEVE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2&quot;</td>
</tr>
<tr>
<td>1-1/2&quot;</td>
<td>0</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>0</td>
</tr>
</tbody>
</table>

The loss by decantation of coarse aggregate shall be from 0 to 1%.

Fine aggregate shall consist of clean, hard, durable and uncoated particles of natural or manufactured sand or a combination thereof, with or without a mineral filler. It shall be free from frozen material or injurious amounts of salt, alkali, vegetable matter or other objectionable material and it shall not contain more than 0.5 percent by weight of clay lumps. When subjected to the color test for organic impurities, it shall not show a color darker than standard. The fine aggregate shall produce a mortar having a tensile strength equal to or greater than that of Ottawa sand mortar.

Mineral filler shall consist of stone dust, clean crushed sand or other approved inert material.

Gradation of fine aggregate shall conform to the grading requirements shown in Table 2.

TABLE 2 - FINE AGGREGATE GRADATION

<table>
<thead>
<tr>
<th>PERCENT BY WEIGHT, RETAINED ON SIEVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot; No. 4 No. 8 No. 16 No. 30 No. 50 No. 100 No. 200</td>
</tr>
<tr>
<td>0 0-5 0-20 15-50 35-75 65-90 90-100 97-100</td>
</tr>
</tbody>
</table>

Fine aggregate shall be subjected to the Sand Equivalent Test. The sand equivalent shall be not less than 80.

The fineness modulus for fine aggregate shall be between 2.30 and 3.10. The fineness modulus will be determined by adding the percentages, by weight, retained on the following sieves, and dividing by 100; Numbers 4, 8, 16, 30, 50 and 100. The fine aggregate shall have not more than 45% passing any sieve and retained on the next consecutive sieve of those shown in Table 2.
421.3 Storage of Materials. Cement shall be stored in well ventilated weathertight buildings, bins, or silos which shall exclude moisture and contaminants.

Aggregate stockpiles shall be arranged and used in such a manner as to avoid contamination, with other materials or with other sizes of like aggregates. To ensure that this condition is met, any test for determining conformance to requirements for cleanliness and grading shall be performed on samples secured in accordance with ASTM D75 “Standard Practice for Sampling Aggregates.” Frozen or partially frozen aggregates shall not be used. Unless otherwise authorized by the Engineer, all aggregate shall be stockpiled at least 24 hours prior to use, to reduce free moisture content.

Chemical admixtures shall be stored in such a manner as to avoid contamination, evaporation, or damage. For those used in the form of suspensions or non-stable solutions, agitating equipment shall be provided to assure thorough distribution of the ingredients. Liquid admixtures shall be protected from freezing and from temperature changes which would adversely affect their characteristics.

421.4 Proportioning of Concrete. Concrete for all parts of the work shall be of the specified quality, capable of being placed without excessive segregation and, when hardened, of developing all characteristics required by this Item and the contract documents.

The specified compressive or flexural strength of the concrete, for each portion of the structure, shall be as designated in the contract documents.

Strength requirements shall be based on the 28 day and 7 day compressive strength, respectively.

421.5 Concrete Classification. Concrete shall be classified as shown in Table 3.

<table>
<thead>
<tr>
<th>Harris County Class</th>
<th>Nominal Coarse Aggregate</th>
<th>Cement Sacks Per C.Y.</th>
<th>Minimum 28-day Compressive Strength (f'c) (psi)</th>
<th>Minimum 7-day Compressive Strength (f'c) (psi)</th>
<th>Water – Cement Ratio, by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>A&lt;sub&gt;1&lt;/sub&gt;</td>
<td>1-1/2&quot;</td>
<td>7</td>
<td>4,000</td>
<td>2,800</td>
<td>0.42 - 0.48</td>
</tr>
<tr>
<td>*A&lt;sub&gt;2&lt;/sub&gt;</td>
<td>3/4&quot;</td>
<td>7</td>
<td>4,000</td>
<td>2,800</td>
<td>0.48 - 0.55</td>
</tr>
<tr>
<td>B&lt;sub&gt;1&lt;/sub&gt;</td>
<td>1-1/2&quot;</td>
<td>6</td>
<td>3,500</td>
<td>2,400</td>
<td>0.49 - 0.56</td>
</tr>
<tr>
<td>*B&lt;sub&gt;2&lt;/sub&gt;</td>
<td>3/4&quot;</td>
<td>6</td>
<td>3,500</td>
<td>2,400</td>
<td>0.56 - 0.64</td>
</tr>
</tbody>
</table>
### Harris County Class Nominal Coarse Aggregate Cement Sacks Per C.Y. Minimum 28-day Compressive Strength (fc') (psi) Minimum 7-day Compressive Strength (fc') (psi) Water – Cement Ratio, by Weight

<table>
<thead>
<tr>
<th>Harris County Class</th>
<th>Nominal Coarse Aggregate</th>
<th>Cement Sacks Per C.Y.</th>
<th>Minimum 28-day Compressive Strength (fc') (psi)</th>
<th>Minimum 7-day Compressive Strength (fc') (psi)</th>
<th>Water – Cement Ratio, by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Non-Air Ent. Conc. Min. – Max</td>
</tr>
<tr>
<td>C₁</td>
<td>1-1/2&quot;</td>
<td>5.5</td>
<td>3,000</td>
<td>2,100</td>
<td>0.53 - 0.61</td>
</tr>
<tr>
<td>*C₂</td>
<td>3/4&quot;</td>
<td>5.5</td>
<td>3,000</td>
<td>2,100</td>
<td>0.61 - 0.70</td>
</tr>
<tr>
<td>D₁</td>
<td>1-1/2&quot;</td>
<td>5</td>
<td>2,500</td>
<td>1,750</td>
<td>0.59 - 0.67</td>
</tr>
<tr>
<td>*D₂</td>
<td>3/4&quot;</td>
<td>5</td>
<td>2,500</td>
<td>1,750</td>
<td>0.67 - 0.77</td>
</tr>
</tbody>
</table>

*Other nominal maximum aggregate sizes will be allowed, based on the thickness of section or spacing of reinforcing bar, or other criteria, as approved by the Design Engineer.

#### 421.6 Selection of Proportions

Proportions of materials for concrete shall be established to provide:

A. Workability and consistency to permit concrete to be worked readily into forms and around reinforcement under conditions of placement to be employed without segregation or excessive bleeding.

B. Strength requirements in accordance with Table 3.

C. Resistance to special exposure as required by the Engineer and as specified in the contract documents in any Special Provisions.

All classes of concrete shall have a 3 inch slump as determined in accordance with ASTM C143 "Standard Test Method for Slump of Hydraulic-Cement Concrete" with an allowable tolerance of ± 1 inch. The average slump for all classes of concrete may range to the wet side of the tolerance. If High Range Water-Reducing admixture is used, maximum acceptable placement slump shall be 9 inches.

The allowable air content for moderate exposures is:

<table>
<thead>
<tr>
<th>Aggregate Size</th>
<th>Allowable Air Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2&quot; aggregate (No. 2)</td>
<td>2.5 - 5.0 percent</td>
</tr>
<tr>
<td>3/4&quot; aggregate (No. 5)</td>
<td>3.0 - 5.0 percent</td>
</tr>
</tbody>
</table>

#### 421.7 Evaluation and Acceptance of Concrete

Samples for strength tests shall be taken in accordance with ASTM C172 "Standard Practice for Sampling Freshly Mixed Concrete.”

Cylinders for strength tests shall be molded and laboratory cured in accordance with ASTM C31 "Standard Practice for Making and Curing Concrete Test Specimens in the Field”, for 7 and 28 day testing. Specimens shall be tested in accordance with ASTM C39 "Standard Test
Method for Compressive Strength of Cylindrical Concrete Specimens.” Two cylinders shall be molded for the 28 day test and two cylinders for the 7 day test. For structural concrete, one set of cylinders shall be cast for a pour of 50 yards.

The strength level of an individual class of concrete shall be considered satisfactory, if both of the following requirements are met:

A. Average of all sets of three consecutive strength tests equal to or exceed specified f’c.

B. For concrete structures, no individual strength test (average of two cylinders falls below f’c by more than 500 psi.)

421.8 Production of Concrete. Ready mixed concrete shall be batched, mixed and transported in accordance with ASTM C94 "Standard Specification for Ready-Mixed Concrete."

The concrete shall be mixed in the quantities required for immediate use, and any concrete which has developed initial set or which is not in place within 1-1/2 hours after the initial water has been added, shall not be used.

No concrete shall be mixed while the air temperature is at or below 35°F. The temperature of the concrete shall at no time fall below 60°F or exceed 90°F. When the concrete reaches a temperature of 85°F, retarders shall be introduced into the mixture.

Chemical admixtures shall be charged into the mixer as solutions and shall be measured by means of an approved mechanical dispensing device. The liquid shall be considered as part of the mixing water. Admixtures that cannot be added in solution may be weighed or may be measured by volume if so recommended by the manufacturer.

If two or more admixtures are used in the concrete, they shall be added separately to avoid possible interaction that may interfere with the efficiency of either admixture or adversely affect the concrete.

When concrete arrives at the project with a slump below that suitable for placing, as indicated by the specifications, water may be added only if the maximum permissible water-cement ratio and maximum slump is not exceeded. The water shall be incorporated by additional mixing equal to at least half of the total mixing required.

421.9 Placing of Concrete. Concrete shall not be placed into any formwork, until that formwork has been inspected by the Engineer. It is the Contractor's
responsibility to determine if the formwork will support the load and that all of the reinforcement is in place.

Concrete shall be conveyed from mixer to place of final deposit by methods that will prevent separation or loss of materials and without interruptions sufficient to permit loss of plasticity between successive increments.

Concrete shall be deposited as near as practicable in its final position to avoid segregation due to rehandling or flowing. Depositing large quantities at one point in the forms and running and/or working it along the forms will not be permitted. Pumped concrete shall not be dropped more than 3 feet from the bottom of the "elephant trunk/boot".

Concrete that has partially hardened or been contaminated by foreign materials shall not be deposited in the structure.

In depositing the concrete, care shall be taken to entirely fill the form, and to consolidate the concrete by continuous vibratory means. The concrete shall be placed in forms designed to support the load and not bulge, distort the forms, or disturb their alignment.

Any porous section may be removed at the expense of the Contractor.

Sufficient placing capacity, as well as mixing and transporting capacity, should be provided so that the concrete can be kept plastic and free of cold joints while it is being placed. It should be placed in horizontal layers not exceeding 2 feet (60 centimeters) in depth, avoiding inclined layers and cold joints. For monolithic construction each concrete layer shall be placed before an initial set has taken place in the previous layers, and layers shall be sufficiently shallow to permit knitting the two together by proper means. Special care shall be taken in filling the forms, to thoroughly work the concrete under and around the reinforcement, embedded fixtures and into corners of forms.

After concreting is started, it shall be carried on as a continuous operation until complete as defined by its boundaries or predetermined joints. When construction joints are required, joints shall be made as specified in the contract documents.

After the concrete has taken its initial set, care shall be exercised to prevent walking on the concrete, to avoid jarring the forms or knocking or straining projecting reinforcement.

421.10 Concreting in Cold Weather. No concrete shall be placed when the atmospheric temperature is below 35°F unless permission to do so is
granted in writing by the Engineer. When such permission is given, the requirements of ACI 306R "Cold Weather Concreting", shall govern. The Contractor shall assume all risk connected with placing concrete during freezing weather. The Engineer’s permission in no way relieves the Contractor of proper and satisfactory quality concrete placement.

421.11 Concreting in Hot Weather. Hot weather is defined as any combination of high air temperature, low relative humidity, and wind velocity tending to impair the quality of fresh or hardened concrete or otherwise resulting in abnormal properties.

Concrete placement in hot weather should be performed in a period of time so as to reduce water demand and slump loss. This period of time should not exceed 1-1/2 hours after cement has been mixed in the batch.

Small increments of retempering water may be added, with Engineer's approval, to mixed batches to obtain the mix design slump. However, the production of concrete of excessive slump or adding water in excess of the mix design to compensate for slump loss resulting from delays in delivery or placing shall be prohibited.

The Contractor shall follow all requirements of ACI 305R "Hot Weather Concreting" for placing concrete in hot weather and assume all risk involved in its placing.

421.12 Curing Concrete. Concrete (other than high early strength) shall be maintained above 50°F, protected from the sun, and kept in a moist condition for at least the first 7 days after placement. High early strength concrete shall be maintained above 50°F, protected from the sun, and in a moist condition for at least the first 3 days.

Accelerated curing methods are not allowed.

Concrete shall be cured from loss of moisture for not less than 72 hours for pavement and not less than 7 days for structures from initiation of the curing process. Curing methods acceptable to Harris County are:

A. Sealing Materials: White, clear, or for cold weather, black plastic shall be used to completely cover and seal structure and/or pavement from moisture loss. The plastic material shall be no less than 0.004 inches (0.10 millimeters) in thickness. Two thicknesses shall be required on all finished concrete during cold weather (50°F and below). Precautions shall be taken to prevent traffic on and tears in plastic cover. All tears shall be remedied immediately to prevent moisture loss and deleterious material introduction. Plastic
shall conform to ASTM C171 "Standard Specification for Sheet Materials for Curing Concrete."

B. Liquid Membrane: Placed concrete not cured by plastic sealing method may be cured using liquid membrane curing. See the Item 526 "Membrane Curing". Abutment caps, bridge slabs, bridge sidewalks, bridge rails, retaining walls, culvert, and culvert headwalls shall not be cured using curing compounds.

C. Additional Curing Methods: Methods not listed will be noted in a Special Provision to this Item, by the Engineer and referenced to ACI 308 "Curing Concrete".

421.13 Inspection and Testing. Concrete materials and operations will be tested and inspected as the work progresses. Failure to detect any defective work or material shall not in any way prevent later rejection when such defect is discovered nor shall it obligate the Engineer for final acceptance.

421.14 Responsibilities and Duties of the Contractor. The Contractor shall:

A. Submit the proposed concrete mix design furnished by the supplier.

B. Provide other testing services needed or required by the Contractor.

C. Facilitate testing and inspection, by furnishing any necessary labor to assist the designated Testing Laboratory in obtaining and handling samples at the project or other sources of materials.

D. Advise the Testing Laboratory’s representative sufficiently in advance of operations to allow for completion of quality tests and for the assignment of personnel.

E. Submit copies of mill test reports for shipments of cement, reinforcing steel and prestressing tendons to the Engineer when required.

421.15 Supplementary Cementing Materials (SCM). The percent amount of supplementary cementing materials used in the mix design for structural concrete, shall be based on the Mix Design Options depicted in the Texas Department of Transportation's “Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges” Latest Edition, Specification Item 421 “Hydraulic Cement Concrete”, and as approved by the Design Engineer.
421.16 Quality Assurance. The Testing Laboratory’s representative will sample and test the concrete mixtures being used for the specific designations in accordance with the requirements given for that designation.

For structural concrete used in all except prestressed structures, the Testing Laboratory’s representative will mold four cylinders for each set of test specimens, from each batch sampled. The cylinders will be tested in accordance with ASTM C39 at 28 days.

The average strength for the set will be determined by use of the average of the two cylinders tested.

For structural concrete used in prestressed concrete structures, the manufacturer shall supply cylinder molds to the Testing Laboratory’s representative to cast early release test cylinders. These cylinders shall be cast and cured along side the precast/prestressed unit and tested by the manufacturer. The compressive strength test shall be performed in accordance with ASTM C39 and witnessed by the Testing Laboratory’s representative to insure that the concrete meets the minimum requirements of 4000 psi compressive strength prior to stress transfer. Four additional test cylinders shall also be cast and cured in accordance with ASTM C31 for each lot of precast concrete. Two cylinders shall be tested 7 days. The remaining two cylinders shall be tested at 28 days to insure that the minimum 28 day compressive strength is obtained.

421.17 Measurement. The method of measurement for structural concrete shall be as shown in the table below:

<table>
<thead>
<tr>
<th>STRUCTURAL COMPONENT</th>
<th>METHOD OF MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns</td>
<td>Cubic Yards</td>
</tr>
<tr>
<td>Caps</td>
<td>Cubic Yards</td>
</tr>
<tr>
<td>Wingwalls</td>
<td>Cubic Yards</td>
</tr>
<tr>
<td>Headwalls</td>
<td>Cubic Yards</td>
</tr>
<tr>
<td>Abutments</td>
<td>Cubic Yards</td>
</tr>
<tr>
<td>Bridge Decks</td>
<td>Square Yards</td>
</tr>
<tr>
<td>Retaining Walls</td>
<td>Cubic Yards</td>
</tr>
<tr>
<td>Bridge Sidewalks</td>
<td>Square Yards</td>
</tr>
<tr>
<td>Approach Slabs</td>
<td>Square Yards</td>
</tr>
<tr>
<td>Parapet Walls</td>
<td>Cubic Yards</td>
</tr>
<tr>
<td>Spread Footings</td>
<td>Cubic Yards</td>
</tr>
<tr>
<td>Concrete Bridge Medians</td>
<td>Cubic Yards</td>
</tr>
<tr>
<td>Signal Pole Foundations</td>
<td>Vertical Foot by Diameter</td>
</tr>
</tbody>
</table>
Any structural components not listed above shall be measured by the cubic yard.

421.18 Payment. Structural concrete shall be paid for at the contract unit price bid based on the measurement shown above.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 526 “Membrane Curing”

END OF ITEM 421
ITEM 423

PRESTRESSED CONCRETE UNITS

423.1 Description. This Item shall govern for the casting, prestressing, and erection of precast, prestressed concrete units in accordance with the plans, approved shop drawings and these Standard Specifications.

423.2 General. The method of construction and prestressing shall comply with the requirements of the plans and in accordance with the approved shop drawings. Prior to beginning the casting of units, the Contractor shall give the Engineer ample notice as to the location of the casting site and the date on which work will begin.

An inspector representing the Engineer shall have free entry, at all times while the work is being performed, to all parts of the manufacturer's works which concerns the manufacture of the units ordered.

Clean and legible shop drawings will be electronically submitted on sheets 22" x 34", showing the following information, and shall be submitted for approval. The margin at the left end shall be 1-1/2 inches wide and the others 1/2 inch wide. Each sheet shall have a title in the lower right hand corner. The sheets shall include a title in the lower right hand corner, sheet numbering, name of structure, name of fabricator and name of Contractor. Preparation and submittal of drawings will be electronically submitted on 11 x 17 inch sheets, or full size drawings may be reduced to one-half scale, provided they are completely clear and legible.

A. Erection Drawings. An erection drawing shall be submitted for approval, showing information for field erection (location, type member, erection mark of member, bearing pads with marks, etc.). The erection mark system employed shall not conflict with the beam designations shown on the contract drawings. On projects requiring numerous types of beams of various length and strand patterns, the erection mark system shall indicate the structure number, superstructure unit number and beam number. The Contractor shall submit six prints for approval.

B. Fabrication Details. Complete information necessary for fabrication shall be submitted for approval (member lengths, type, skew angle, dimensions for diaphragm holes, bearing pad data bevels, erection devices, details of reinforcement, inserts to be used in forming, etc.). On projects requiring several types of beams of various lengths and strand patterns, an index sheet showing all beam and concrete data (cast lengths, pay length, concrete strengths, strand
data, special casting devices, etc.) shall be furnished. Index sheets shall reflect the plant locations where each member is to be fabricated.

C. Prestressing Details. Complete prestressing details shall be submitted showing details of the member, forms, devices for holding prestress steel in place, methods and details of draping strand, anchorage details, methods and details of prestressing the steel, elongations, jack pressures and all other features of proposed prestressing. Calculations shall be included to justify the system and method of prestressing to be used. Fabricator shall submit six prints for handling. The submittal of prestressing details shall be a "one-time" action of each fabricator.

D. Methods of Handling and Transportation. Details of handling and transporting need not be submitted for approval, except that inserts used for pick-up shall be shown on the shop drawings.

All drawings and details shall be checked by the Fabricator before submittal for approval. Submission of drawings shall be in accordance with Harris County Engineering Department methods.

After completion of fabrication, a corrected set of final "as-built" drawings shall be submitted. In addition, when a railroad crossing structure(s) is constructed under this Item, the fabricator shall furnish reproducible tracings of the approved "as-built" shop drawings for railroad crossings, for submission to the railroad.

A casting schedule shall be prepared on standard forms and submitted to the Engineer, prior to stressing.

Prior to the casting of members, detailed drawings reflecting the complete facilities to be used in fabrication is required by the Engineer.

The design of casting beds and facilities for pretensioned construction, including plans and specifications, shall be done by a Professional Engineer registered in the State of Texas and shall bear his seal. The Fabricator shall furnish a certificate bearing his signature, or that of a responsible Officer of the Company, that the bed, facilities and hardware have been constructed in accordance with the above plans and specifications.

The Fabricator shall specify the maximum loading for which the bed is to be used. Prior to approval for that loading, the facilities shall be proof loaded to a minimum ten percent overload for eight hours. Additional proof loads shall be performed every twelve months at a ten percent
overload for four hours, if deemed necessary by the Engineer. Minor changes in facilities will not require proof loading, but will require submission of the details of changes accompanied with design calculations.

423.3 Materials. Materials for concrete and water for curing shall be in accordance with the applicable portions of the Item 421 "Structural Concrete". Material for reinforcing steel (non-prestressed) shall be in accordance with the Item 440 "Reinforcing Steel". Other steel shall be in accordance with this Item.

The steel used to apply the prestressing load to precast prestressed concrete members shall conform to the requirements of ASTM A416 “Standard Specification for Low-Relaxation, Seven-Wire Steel Strand for Prestressed Concrete.” The strands shall be of the size and number shown on the plans. The Contractor shall furnish representative samples and have them tested in accordance with the provisions for testing. Strands shall be free of rust, dirt, oil or other injurious material before placing concrete.

Contractor shall furnish and install bridge bearing pads in accordance with Item 437 “Elastomeric Materials.

All concrete materials and their preparation and placing shall be in accordance with the Item 421 "Structural Concrete", except that the concrete shall be proportioned to develop a compressive strength of not less than 5,000 psi, in 28 days. The following limiting requirements will also be complied with:

<table>
<thead>
<tr>
<th>Description</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Cement Content</td>
<td>6.25 sacks per cubic yard</td>
</tr>
<tr>
<td>Maximum Cement Content</td>
<td>7.00 sacks per cubic yard</td>
</tr>
<tr>
<td>*Maximum Water</td>
<td>6.0 gallons per sack</td>
</tr>
<tr>
<td>Maximum Slump</td>
<td>4 inches or as approved by the Engineer</td>
</tr>
<tr>
<td>Minimum Compressive Strength</td>
<td>5,000 psi at 28 days</td>
</tr>
<tr>
<td>Minimum Compressive Strength at Prestress Transfer</td>
<td>4,000 psi</td>
</tr>
</tbody>
</table>

* Water per sack of cement shall be reduced to the minimum amount that the required workability will permit.

An admixture must be used with Type I or Type III portland cement in lieu of air-entraining portland cement. Entrained air must not exceed four (4) percent. Admixtures shall be in accordance with the Item 421 "Structural Concrete", and must be approved by the Engineer prior to use.
When tested in accordance with ASTM C136 “Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates”, coarse aggregate shall conform to the following grading requirements.

**COARSE AGGREGATE GRADATION**

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% RETAINED, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2 Inch</td>
<td>0</td>
</tr>
<tr>
<td>1 Inch</td>
<td>0 – 5</td>
</tr>
<tr>
<td>3/4 Inch</td>
<td>20 – 50</td>
</tr>
<tr>
<td>1/2 Inch</td>
<td>50 – 75</td>
</tr>
<tr>
<td>No. 4</td>
<td>95 – 100</td>
</tr>
</tbody>
</table>

* The loss by decantation shall be a maximum of 1 percent

Fine aggregate shall consist of clean, hard durable uncoated grains of washed sand, free from soft or flaky particles and all other injurious materials. It shall be graded from coarse to fine and when tested by approved methods, shall meet the following grading requirements.

**FINE AGGREGATE GRADATION**

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% RETAINED, BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 Inch</td>
<td>0</td>
</tr>
<tr>
<td>No. 4</td>
<td>0 – 5</td>
</tr>
<tr>
<td>No. 20</td>
<td>15 – 50</td>
</tr>
<tr>
<td>No. 100</td>
<td>85 – 100</td>
</tr>
</tbody>
</table>

When subjected to the color test for organic impurities, fine aggregate shall not show a color darker than the standard color.

423.4 Pretensioning. For pretensioning, bring the tendons to be prestressed in a group to a minimum uniform initial tension of 1,000 pounds (plus or minus 50 pounds) per tendon prior to being given their full pretensioning. Measure this uniform tension by some suitable means, such as a dynamometer, so that this amount can be used as a check against elongation computed and measured.

After this initial stressing, the strand group shall be stressed to the total tension required, by means of hydraulic jacks equipped with gauges graduated to read correctly to one percent of total load and calibrated to measure accurately, stress induced in the steel.
Measure induced stress by elongation of tendons and check by gauge pressure. Results shall agree within 5 percent. Provide means for measuring elongation to an accuracy of 1/16 inch for each 100 feet of length between jacking heads. In the event of apparent discrepancies between stresses indicated by gauge pressure and elongation of more than 5 percent, check the entire operation and determine the source of error and correct before proceeding further. Establish independent references adjacent to each anchorage, to indicate any yielding or slippage between time of initial stressing and final release of tendons.

With the tendons stressed to full tension, as prescribed above and with reinforcing steel in place, cast members to the lengths necessary to provide plan lengths, after shrinkage and elastic shortening has occurred.

Maintain tendon stress between anchorages, until concrete has reached the compressive strength specified, as determined by test cylinders made for each continuous pour.

423.5 Construction Methods. Reinforcing steel shall be fabricated and placed in accordance with the plans and as required herein.

Post tensioning ducts, when required, shall be checked and cleaned of all obstructions and placed in accordance with the approved prestressing details, and in accordance with this Item. Immediately after concrete placement they shall be cleaned of any concrete, mortar or grout leakage which might clog the duct.

The construction of forms and the placing, curing and finishing of concrete shall be in accordance with the provisions contained herein and requirements of the plans.

A. Forms. All side and bottom forms for precast prestressed concrete construction shall be constructed of steel, unless otherwise noted on the plans. End headers and inside forms may be of other material as approved on the shop drawings.

Forms shall be of sufficient thickness, with adequate external bracing and stiffeners, and shall be sufficiently anchored to withstand the forces due to placement and vibration of concrete. Internal bracing and holding devices in forms will not be permitted if such would remain in the finished prestressed member. Joints shall be maintained reasonably mortar tight.

The grade and alignment of forms shall be checked each time they are set and shall be maintained during the casting of concrete.
Metal forms shall be free from rust, grease or other foreign materials. All forms shall be cleaned thoroughly prior to each casting operation.

Materials used for forming internal voids shall be inert, non-absorptive and be of adequate strength to maintain sufficient rigidity to withstand the forces of flow, vibration, buoyancy and weight of the plastic concrete during placing.

The soffit for casting members shall be constructed and maintained to provide not more than one-fourth inch variation in any 50 foot length of the bed from the theoretical plane of the bottom of the member.

Forms for internal voids in members shall be anchored securely to prevent movement or misalignment during the placing of concrete. For forming internal voids with a mandrel, special attention shall be given to maintaining the correct position and alignment of the mandrel throughout the casting operation.

The facing of all forms shall be treated with form oil or other bond breaking coating prior to placing of concrete. The oil or other materials used for this purpose shall be of a consistency and composition to facilitate form removal.

Materials which appreciably stain or react with the concrete will not be permitted.

All forms shall be constructed to facilitate removal without damage to the concrete. At the Contractor's option, side forms for piling and panels may be constructed with a one-eighth inch draft to permit ease of removal.

B. Placing Concrete. All concrete shall be placed in accordance with the Item 421 "Structural Concrete" and in accordance with the following. All concrete shall be placed during daylight hours unless the fabrication plant or site is provided with an approved lighting system.

The method of concrete placement shall avoid segregation of the aggregate or displacement of the reinforcing steel, prestressing steel or conduit. Concrete shall be deposited as near as possible in its final position in the forms. Depositing large quantities of concrete at one location in the forms and running or working it along the forms will not be permitted.
Special attention shall be directed toward working the coarse aggregate back from the face of the concrete and to forcing the concrete under and around the reinforcing steel, prestressing steel or conduit.

Placement of concrete in large members shall be subject to approval of the Engineer. Concrete may be placed in beams and girders in one lift or in multiple continuous horizontal layers. In the latter case the thickness of the first layer shall be slightly above the juncture of the bottom flange and web.

Vibration of subsequent layers of concrete shall extend into the previously placed layers as specified in this Item.

When casting concrete piling or concrete slab units, the concrete shall be placed in one continuous horizontal layer.

Concrete placement will not be permitted when impending weather conditions will impair the quality of the finished work. If rainfall should occur after placing operations are started, the Contractor shall provide ample covering to protect the work. In case of a drop in temperature the provisions set forth in Placing Concrete in Cold Weather shall be applied.

1. Placing Concrete in Cold Weather. When members are produced in a fabricating plant which has adequate provisions to protect the concrete when placed and which has approved elevated temperature curing facilities, concrete may be placed under any low temperature conditions provided;

   a. The temperature of the concrete is not less than 50°F. nor more than 85°F. when placed in the forms.

   b. The framework and covering are in place and heat is provided for the concrete and forms within one hour after the concrete is placed. This shall not be construed to be one hour after the last concrete is placed but that no concrete shall remain unprotected and unheated for longer than one hour.

   c. The air surrounding the concrete shall be kept between 50°F. and 85°F. for a minimum of three hours prior to beginning the temperature rise which is required for elevated temperature curing. The temperature of the concrete shall not be less than
50°F. at any time after all materials are added and mixing commences.

d. For central fabricating plants or job site casting operations which do not provide facilities necessary to accomplish the above provisions, concrete may be placed when the atmospheric temperature is 35°F. or greater, and rising. The temperature of the concrete at the time of placement shall not be less than 50°F. nor more than 85°F. The concrete shall not be placed in contact with any material having a temperature less than 32°F. or any material coated with frost.

e. Aggregates shall be free from ice, frost and frozen lumps. When required, in order to produce the minimum temperature specified above, the aggregate and/or the water shall be heated uniformly in accordance with the following. Water shall be heated to a temperature not to exceed 180°F. and/or the aggregate shall be heated to a temperature not to exceed 150°F. The equipment furnished shall be capable of heating the aggregate uniformly to eliminate overheated areas in the stockpile which might cause flash set of the cement. The temperature of the mixture of the aggregate and water shall be between 50°F. and 85°F. before introduction of the cement.

f. Protection shall be provided to maintain the temperature of the concrete at all surfaces above 50°F. until release strength is reached. Protection shall consist of providing additional covering and, if necessary, supplementing such covering with artificial heating. When weather conditions indicate the possibility of the need for such temperature protection, all necessary heating equipment and covering material shall be on hand ready for use before permission is granted by the Engineer to begin placement of concrete.

2. Placing Concrete in Hot Weather. When concrete is to be placed during hot weather, it shall be placed without the addition of more water to the concrete than required by the design (slump and consistency), and it shall be finished properly without adding water to the surface. Control of the initial set of the concrete and lengthening the time for
finishing operations, under adverse wind, humidity and hot weather conditions, may be accomplished with the use of an approved retarder.

The maximum time interval between the addition of mixing water and/or cement to the batch, and the placing of concrete in the forms shall not exceed the following:

<table>
<thead>
<tr>
<th>AIR OR CONCRETE TEMPERATURE (WHICHEVER IS HIGHER)</th>
<th>MAXIMUM TIME ADDITION OF WATER OR CEMENT TO PLACING IN FORMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NON-AGITATED CONCRETE</td>
<td></td>
</tr>
<tr>
<td>Over 80°F</td>
<td>15 Minutes</td>
</tr>
<tr>
<td>50°F to 79°F</td>
<td>30 Minutes</td>
</tr>
<tr>
<td>AGITATED CONCRETE</td>
<td></td>
</tr>
<tr>
<td>90°F or Above</td>
<td>45 Minutes</td>
</tr>
<tr>
<td>75°F to 89°F</td>
<td>60 Minutes</td>
</tr>
<tr>
<td>50°F to 74°F</td>
<td>90 Minutes</td>
</tr>
</tbody>
</table>

The use of an approved retarder in the concrete will permit the extension of each of the above temperature time maximum by 30 minutes, except that for non-agitated concrete, the maximum time shall not exceed 30 minutes.

Under conditions of extreme temperature, wind or humidity, when the specified temperature-time maximums are excessive, the Engineer may require the use of an approved retarder, or may suspend concrete placing operations, if quality concrete is not being placed.

The values which govern for minimum concrete strengths during different phases of construction shall be as shown on approved shop drawings.

The control of the concrete shall be by compressive tests of cylinders. An adequate number of cylinders will be made for each pertinent strength test required. Tests for determining "Release Strength" and/or "Handling Strength" of members, will be the average of the breaking strength of two cylinders.
All test specimens, beams or cylinders representing tests for removal of forms and/or falsework and for "Release Strength" shall be cured under the same conditions, be subjected to the same curing materials and to the same weather conditions as the concrete represented.

"Design Strength" cylinders for acceptance of members shall be cured with the member which the cylinders represent until release of stress or until partial tensioning strength is obtained. These cylinders shall then be cured for the remainder of the test period in accordance with TxDOT's Test Procedure Tex-704-I.

C. Vibration of Concrete. All concrete shall be thoroughly compacted with approved high frequency vibrators operating. When the forms are of steel, either external or internal vibrators or a combination of both may be used except that internal vibrators will be required, supplemented by external vibration if desired, for prestressed concrete beams and prestressed concrete box beams.

At least one stand-by vibrator of the type(s) being used shall be provided for emergency use.

Internal vibrators shall be inserted systematically into the concrete immediately after deposit. When the concrete is placed in more than one layer, the vibrators shall be operated so that they will penetrate the previously placed layer of concrete.

The size and spacing of external vibrators shall provide sufficient intensity of vibration to the desired area of form. The spacing, frequency and/or amplitude of external vibrators shall be varied to produce uniform consolidation of the concrete.

Supplemental vibrators or a modification of the vibration system shall be provided when it is deemed necessary by the Engineer to accomplish thorough compaction of the concrete and complete embedment of the reinforcing steel and prestressed tendons.

D. Finishing of Concrete. Top surfaces of prestressed concrete beams, against which cast-in-place concrete will be placed later shall be screeded or rough floated to bring grout to the surface and cover all aggregate. At the approximate time of initial set, the surface shall be roughened by brushing, brooming or other approved methods. Sound concrete shall not be removed or aggregate loosened. Concrete shall be removed from exposed reinforcing steel prior to shipment.
The top surfaces of beams upon which panels are to be placed shall be finished relatively smooth with a metal trowel, from the reinforcing bar (R-bar) out to the outside edges. The center portion of these beams shall be roughened.

When the plans require that a concrete overlay be placed on prestressed concrete box members, the top slab of the box shall be given a metal tine finish having an average texture depth of approximately 0.050 inches.

When the plans require that an asphaltic seal and overlay be placed on prestressed concrete box beams or for an additional slab to be placed on prestressed concrete panels, the top slab of the box, and the top surface of prestressed panels shall be given a lightly textured broom finish, similar to a sidewalk finish with the depth of striations not exceeding approximately 1/16 inch.

Erection holes (lifting eyes, form anchors, etc.) in exterior beams shall be filled with mortar and made flush with the surrounding surface. Holes in interior beams need not be filled unless steel is exposed. Erection or fabrication hole in the bottom of all beams shall be filled with non-stain, non-shrink mortar and made flush with the surrounding surface.

Form marks in excess of that permitted in Section 423.8, and all fins and rough edges along chamfer lines shall be removed in an acceptable manner.

Unless otherwise shown on the plans, strands shall be removed flush with the end of the member, or recessed approximately three-eighths of an inch.

In either case, the ends of the strands and a minimum of one inch around each strand shall be cleaned and coated with approximately 10 mils of an approved epoxy or epoxy grout.

After slab placement, the outside and bottom surfaces, of exterior beams or members shall be given the grade of surface finish specified for the structure. Other members shall be given the grade or class of finish required by the plans.

E. Curing of Concrete. Careful attention shall be given to the proper curing of concrete. The Contractor shall inform the Engineer regarding the methods and procedures proposed for curing; shall provide the proper equipment and necessary materials; and shall
have approval of the Engineer of such methods, equipment and materials prior to placing concrete.

Inadequate curing facilities or lack of attention to the proper curing of concrete shall be cause for the Engineer to stop all concrete placement until approved curing is provided. Inadequate curing may be cause for rejection of the member.

Side forms may be removed at any time after the concrete has reached sufficient strength to prevent physical damage to the member. Weight supporting forms shall remain in place until the concrete has reached the "Handling Strength" shown on the plans. Removal of the forms shall be done in such a manner that curing is not interrupted on any member by more than 30 minutes.

All concrete shall be cured with elevated temperature or water. An approved water or membrane cure (when permitted) shall be used as an interim measure prior to elevated temperature or other methods of curing.

Curing shall be commenced prior to the formation of surface shrinkage cracks. The mats, sheets, or blankets shall not be placed in contact with the prestressed concrete member until such time that damage will not occur to the surfaces.

Concrete shall be cured continuously, except as provided for form removal, until the concrete strength as indicated by compressive test of cylinders cured with the members, has reached the "Release Strength" or "Handling Strength" designated on the plans and/or shop drawings. Piling and roadway surfaces of prestressed concrete box beams shall be water cured an additional three days with the temperature of the concrete maintained above 32°F for this period.

A period not to exceed four hours will be permitted for removal to a storage area prior to resuming the balance of water curing for piling and box beams.

1. Water Curing. All exposed surfaces of the concrete shall be kept wet continuously for the required curing time. The water used for curing shall meet the requirements for concrete mixing water as specified in the Item 420 "Concrete Structures". Sea water will not be permitted. Water which stains or leaves an unsightly residue shall not be used.

Water curing will be permitted as follows:
a. Wet Mat Method. For water curing by the wet mat method, cotton mats, polyethylene sheeting, or polyethylene burlap blankets may be used.

The mats, sheets, or blankets shall be adequately anchored and weighted to provide continuous contact with all concrete surfaces. Any concrete surfaces which cannot be cured by contact shall be enclosed by mats, adequately anchored, so that outside air cannot enter the enclosure. Sufficient moisture shall be provided inside the enclosure to keep all of the surfaces of the concrete wet for the required curing time.

b. Water Spray Method. For water curing by the water spray method, overlapping sprays or sprinklers shall be used so that all concrete surfaces are kept wet continuously.

2. Elevated Temperature Curing. Curing by elevated temperatures will be permitted as follows:

a. Steam Curing. (Steam curing is defined as use of steam above 85°F). When steam curing of concrete is provided, the temperature inside the curing jacket shall not exceed 165°F for more than one hour during the entire steam curing period. Concrete exposed to temperatures exceeding 180°F will not be accepted.

Sufficient moisture shall be provided inside the curing jacket so that all surfaces of the concrete are wet.

An unobstructed air space of not less than six inches shall be provided between all surfaces of the concrete and the curing jacket. Steam outlets shall be positioned so that live steam is not applied directly on the concrete, reinforcing steel or tendons.

The location of steam lines, location of control points for discharge of steam into the curing jacket, and the number and type of openings for steam distribution within the curing jacket shall be arranged so that temperature variation between any points in the enclosure shall not exceed 20°F.
Steam curing shall not commence until the concrete has been in place a minimum of three hours, or until initial set of the concrete, as determined in accordance with ASTM C403 “Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance”, is attained.

During the application of steam the temperature inside the curing jacket shall be raised uniformly at a rate not to exceed 40°F per hour.

b. Alternate Methods. Other methods of elevated temperature curing may be permitted by the Engineer provided temperature maximums, rate of temperature variation, humidity control, etc., are in accordance with the requirements for steam curing. Permission shall be obtained from the Engineer, in writing, for use of any alternate method.

423.6 Handling, Hauling and Erection. The Fabricator and Contractor shall be responsible for proper handling, lifting, storing, hauling and erection of all members so that they may be placed in the structure without damage.

Unless approved on erection and/or shop drawings, prestressed members shall be maintained in an upright position at all times and shall be picked up and supported near the ends of the member in such a way to prevent torsion. Members may be lifted with the lifting devices as approved on the shop plans or by other methods approved by the Engineer in writing.

No member shall be moved from the casting yard until all requirements for tensioning (when pertinent), curing and strength requirements have been attained.

Prior to shipping to the job site, all beams, box beams, panels, and other prestressed members shall be marked for identification, as shown on approved shop drawings, with other project identification as required by the Engineer.

Storing of prestressed members shall be done with adequate blocking so that warpage or cracking will not occur. The blocking shall be of such nature that uneven settlement due to wet ground or inadequate material underneath the blocking will not occur. Members which are improperly stored and which become cracked, warped or otherwise damaged in storage will be subject to rejection. Concrete box beams shall be supported by the solid end block area during handling, storage, hauling and erection.
All concrete beams or girders, placed over a traveled roadway or railroad, shall be securely tied and/or braced to prevent overturning until diaphragms capable of providing lateral stability are permanently in place. When railroad or roadway traffic must be maintained beneath girders or beams already placed, traffic shall be protected against falling objects during the erection of diaphragms and other structural members, during the placing of cast-in-place concrete and during the erection and dismantling of forms therefor. The protection shall consist of safety nets (1 inch mesh maximum) or a flooring with openings not larger than 1 inch.

423.7 Defects and Breakage. Failure of individual wires in a seven wire strand, or of wires in a parallel wire tendon is acceptable provided the total area of wire failure is not more than two percent of the total cross-sectional area of tendons in any member. Failure of entire strand will be subject to structural review.

Fine hair cracks or checks on the surface of the member which, as determined by the Engineer, do not extend to the plane of the nearest reinforcement will not be cause for rejection unless they are numerous and extensive. Diagonal cracks, which indicate damage from torsion, will be subject to a structural review prior to acceptance. Vertical or horizontal cracks, which are 1/16 inch or less in width and which tend to close upon transfer of stress to the concrete, are acceptable. Cracks in excess of this are subject to review prior to acceptance.

Cracks which extend into the plane of reinforcing steel and/or prestressed tendons, but are acceptable otherwise, shall be repaired by sealing with an approved epoxy.

Small damaged or honeycombed areas which are purely surface in nature, (not over one inch deep) may be repaired with an approved epoxy grout. Damage or honeycomb in excess of this will be tentatively rejected, but will be subject to structural review.

For prestressed concrete box beams only, areas requiring repair work, except as noted herein, which will be covered by cast-in-place concrete (shear keys and end diaphragms) shall be explored and evaluated but, if structurally adequate, will not require repair at the plant. Areas of honeycomb which expose strands (except for the end of the box) will require evaluation and repair at the plant.

Any of the following conditions will be cause for rejection of prestressed panels:

A. Any crack that comes within 1 inch of two adjacent strands.
B. Corner cracks or breaks that involve two strands.

C. Isolated damage or honeycomb larger than approximately 6 inches in diameter or length that involves more than 1 strand.

D. Narrow honeycomb lines caused by grout leakage over 1/2 inches in depth involving more than 1 strand.

Any condition not covered by the above shall be subject to structural review.

423.8 Workmanship and Tolerance. Reinforcing steel shall not project above the top of the member more than 1/4 of an inch from plan dimension. In the plane of the steel parallel to the nearest surface of concrete, bars shall not vary from plan placement by more than 1/4 of an inch, or 1/12 of the spacing between bars, whichever is greater. In the plane of the steel perpendicular to the nearest surface of concrete, bars shall not vary from plan placement by more than 1/4 of an inch.

Where sections of forms are to be joined, an offset of 1/16 of an inch for flat surfaces and 1/8 of an inch for corners and bends will be permitted. Offsets between adjacent end header sections shall not exceed 1/4 of an inch.

Allowable tolerances for the dimensions and configuration shown on the approved shop drawings shall be as shown in this table.

<table>
<thead>
<tr>
<th>DIMENSION</th>
<th>BEAMS</th>
<th>BOXES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (Normal to strands for beams)</td>
<td>±3/4&quot;</td>
<td>* ±1&quot;</td>
</tr>
<tr>
<td>Width (Parallel to strands for beams)</td>
<td>+3/4&quot;, -1/4&quot;</td>
<td>±1/4&quot;</td>
</tr>
<tr>
<td>Depth Nominal (Thickness in case of beams)</td>
<td>+1/2&quot;, -1/4&quot;</td>
<td>±1/4&quot;</td>
</tr>
<tr>
<td>Top Slab or Flange</td>
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<tr>
<td>Thickness-Bottom Slab or Flange</td>
<td>+1/2&quot;, -1/4&quot;</td>
<td>±1/2&quot;</td>
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<tr>
<td>Web or Wall</td>
<td>+3/4&quot;, -1/4&quot;</td>
<td>±1/2&quot;</td>
</tr>
</tbody>
</table>
### DIMENSION

<table>
<thead>
<tr>
<th>Description</th>
<th>BEAMS</th>
<th>BOXES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Alignment-Upon Release of Stress Deviation from Straightness of mating edge of beams of length</td>
<td>±1/8&quot; per 10'</td>
<td>±1/4&quot;</td>
</tr>
<tr>
<td>Deviation of bearing edge of beam from designated skew (out of square) Horizontal</td>
<td>1/4&quot;</td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>Deviation of ends from designated skew or bevel Vertical</td>
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<td>1/4&quot;</td>
</tr>
<tr>
<td>Bearing Surfaces - Perpendicular to Vertical Axis</td>
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<td>N/A</td>
</tr>
<tr>
<td>Deviation from Plane</td>
<td>±1/16&quot;</td>
<td>±1/8&quot;</td>
</tr>
<tr>
<td>Anchor Hole Location-from End of Member</td>
<td>+3/4&quot;, -1/4&quot;</td>
<td>±1/4&quot;</td>
</tr>
<tr>
<td>Longitudinal Spacing</td>
<td>±3/4&quot;</td>
<td>±1/2&quot;</td>
</tr>
<tr>
<td>Transverse Location</td>
<td>±1/4&quot;</td>
<td>±1/4&quot;</td>
</tr>
<tr>
<td>Diaphragm or Lateral Tie Location</td>
<td>±1/2&quot;</td>
<td>±1/2&quot;</td>
</tr>
<tr>
<td>Position of Void** Longitudinal</td>
<td>N/A</td>
<td>1&quot;</td>
</tr>
<tr>
<td>Position of Strands</td>
<td>±1/4&quot;</td>
<td>±1/4&quot;</td>
</tr>
<tr>
<td>Position of Hold-Down Points</td>
<td>±6&quot;</td>
<td>±6&quot;</td>
</tr>
<tr>
<td>Position of Handling Devices</td>
<td>±6&quot;</td>
<td>±6&quot;</td>
</tr>
</tbody>
</table>

* Measured from Central Axis of Box  
** Length of Void Material +1", -6"

Variations greater than specified above shall be corrected to within these tolerances or be subject to structural review. Horizontal alignment (sweep) in beams and girders only, which may increase at a later time over that shown in the table, will be acceptable if the member can be hauled, erected and aligned to within the above tolerance without being damaged.

For prestressed concrete box beams only, variation from tolerances set forth in the specifications, which do not affect appearance or fit-up of the finished structure, and which will be covered with concrete as stated in Defects and Breakage, will not require correction.
When prestressed panels are erected, the fit of mating surfaces shall be such that excessive grout leakage will not occur. If such fit is not provided the joint shall be filled with grout or sealed with an acceptable caulking compound prior to the placing of the cast-in-place portion of the slab.

423.9 Measurement. Precast Prestressed Concrete Beams, Girders and Box Beams, of the type specified, cast and stressed as required by the plans, will be measured by the linear foot, as established on approved shop drawings.

423.10 Payment. Precast Prestressed Concrete Beams, Girders and Box Beams will be paid for at the unit price bid per linear foot for the structural member specified complete in place.

The above price shall be full compensation for constructing the members, furnishing and tensioning prestressed steel, conduit, when required, furnishing and placing reinforcing steel, bearing plates, bearing pads; all bars, anchorage plates and appurtenances which become an integral part of the structure; for grouting of holes; for any necessary repair and for any special treatment of end anchorages and shoes as indicated on the plans; and for furnishing all materials, tools, equipment, labor and materials necessary to fabricate, transport and erect the members in the structure as indicated on the plans.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 420 "Concrete Structures"
Item 421 "Structural Concrete"
Item 437 "Elastomeric Materials"
Item 440 "Reinforcing Steel"

END OF ITEM 423
ITEM 424

EXTENDING CONCRETE STRUCTURES

424.1 Description. This Item shall govern for extending existing concrete structures and for the preparation of the existing structures for extending or widening, including the materials used; the removal of portions of the existing structure, preparation of exposed surfaces of steel and concrete for bonding new construction to old; and the construction of the proposed extensions, all as indicated on the plans.

424.2 Materials. All materials shall conform to the requirements of Item 421 “Structural Concrete” and Item 440 “Reinforcing Steel”.

424.3 Construction Methods. The work shall be performed in accordance with the provisions of the Item 420 "Concrete Structures", and in conformance with the requirements as stated and outlined herein. Concrete shall be of the class shown on the plans.

The Contractor shall verify all pertinent dimensions of the existing structure, prior to ordering materials required for the extensions.

Portions of the old structure shall be removed to the lines and dimensions shown on the plans and these materials shall be disposed of as shown on the plans or as directed by the Engineer. Unless noted on the plans, metal railing shall be removed in such a manner that it will not be damaged, stacked neatly on the right-of-way at convenient loading points and will remain the property of Harris County. Any portion of the existing structure, outside of the limits designated for removal, damaged by the operations of the Contractor shall be restored to its original condition at the Contractor's entire expense. Explosives shall not be used in the removal of portions of the existing structure.

When the headwalls, wingwalls and apron are specified on the plans to be reused in the extended structure, the portion to be reused shall be severed from the old structure to the lines and details shown on the plans. The headwall unit shall be moved to the new location specified, by methods approved by the Engineer, and the extension concrete and reinforcement placed according to the plan details. Any portion of the headwall unit damaged by the moving operation shall be restored to its original condition at the expense of the Contractor.

Unless otherwise noted on the plans, a demolition ball or other swinging weight or impact tool, will be permitted on those portions of the structure not immediately adjacent to the break line of the concrete. The concrete
shall be severed at the break line by pneumatic tools, followed by the use of the demolition ball, or other methods acceptable to the Engineer. The final removal of concrete at the break line shall be with pneumatic tools. Damaged concrete shall be treated as specified above. Bridge slabs shall first be sawed along the break line one-half of an inch deep prior to the beginning of the removal of concrete.

Except where otherwise provided on the plans, new reinforcing bars shall be spliced to exposed bars in the old structures by lap splices in accordance with the Item 440 "Reinforcing Steel". When welded splices are permitted, they shall conform to the Item 446 "Structural Welding". For lap splices, not welded, new reinforcing steel need not be tied to existing steel, where spacing and/or elevation does not match that of existing steel, provided the proper lap length is attained.

Dowels, if required by the plans shall be installed by grouting reinforcement bars to a minimum length of 12 inches into the old structure. Holes for dowel bars shall be cleaned of all loose material and wetted and filled with a 1:3 mix grout or other approved material, immediately prior to placing of dowel bars.

Concrete surface which will be in contact with new construction shall be roughened and cleaned prior to placing of forms. These surfaces shall be dampened and coated with mortar just prior to placing fresh concrete. Roadway slabs shall be finished in accordance with the Item 420 "Concrete Structures". Where an overlay is required, the slabs shall be given a reasonably smooth surface finish by longitudinal or transverse screeding, without any straight edge requirements.

The widened portion of bridges and direct traffic culverts shall not be opened to construction traffic until authorized by the Engineer.

424.4 Measurement. The quantities of concrete of the various classifications which will constitute the completed and accepted structure or structures in-place will be measured by the cubic yard, each, square foot, square yard or linear foot as the case may be.

424.5 Payment. The concrete quantities measured as provided above, will be paid for at the unit price bid per "Cubic Yard", per "Each", per "Square Foot", per "Square Yard", or per "Linear Foot", in place, for the various classifications of concrete shown.

The unit price bid for the various classifications shown shall be full compensation for furnishing, hauling and mixing all concrete material; placing, curing and finishing all concrete; all grouting and pointing; furnishing and placing drains, furnishing and placing metal flashing strips;
furnishing and placing expansion joint material required by this Item; removing the designated portion of the existing structure; moving of headwall units for reuse; cleaning, bending and cutting of exposed reinforced steel; welding of new reinforcing steel to old; all grilling and grouting for dowels; cleaning and painting old concrete with neat cement mortar; and for all forms and falsework, labor, new reinforcing tools equipment and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 420 “Concrete Structures”
Item 421 “Structural Concrete”
Item 440 “Reinforcing Steel”
Item 446 “Structural Welding”

END OF ITEM 424
ITEM 427

JOINT SEALANT FOR BRIDGES

427.1 Description. This Item shall govern for the furnishing and installation of joint sealant materials, to be placed in bridge structure joints for the purpose of preventing the passage of water and other materials through the joint.

427.2 Materials. The joint seal shall be a low modulus silicone, conforming to TxDOT’s DMS-6310, Latest Edition, Class 7, of Table 1. The size shown on the plans shall be the nominal width of the seal. The depth of the seal shall be greater than the width.

Joint Types can be: concrete to concrete, steel to armored, and header type.

The manufacturer shall furnish certification as to compliance with the physical requirements of TxDOT’s DMS-6310.

427.3 Submittal. The manufacturer shall submit certification that the sealant proposed for installation is of the size, configuration and meets the Silicone material properties specified in TxDOT’s DMS-6310, of Table 3, for a Class 7 silicone joint sealant.

427.4 Construction Requirements. Just prior to installing the seal, the joint faces shall be abrasive blast cleaned, and blown out with high pressure air. The joint sealant shall be installed into the joint opening with an approved installation tool as recommended by the manufacturer. Installation by hammering, use of sharp tools or stretching of the seal will not be permitted.

427.5 Measurement. For each size of sealant specified, measurement will be made by the linear foot, along the centerline of the joint and at the surface of the bridge structure.

427.6 Payment. Payment shall be made at the contract unit price bid per foot, for the size of sealant specified.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 427
ITEM 429
TRENCH SAFETY SYSTEM

429.1 Description. This Item shall govern for furnishing all labor and materials for installation and maintenance of a trench safety system.

For any trench excavation in materials other than solid rock, greater than 5 feet in depth, or where shown on the plans, the Contractor shall provide a trench safety system. This trench safety system shall be in accordance with the appropriate requirements established in the Occupational Safety and Health Administration (OSHA), Safety and Health Regulations, Part 1926, Subpart P - "Excavations" (Latest Edition).

429.2 Measurement. Measurement of the "Trench Safety System" for gravity pipelines and boxes and for pressure pipelines shall be made by the linear foot of trench measured along the centerline of the trench, for the depth indicated. The depths shall be indicated as follows:

A. From 5 to 10 feet
B. From 10 to 15 feet
C. From 15 to 20 feet
D. Greater than 20 feet

429.3 Payment. Payment for "Trench Safety System" shall be made at the contract unit price bid, measured as stated in the preceding section, for the depth indicated.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 429
ITEM 430

CONSTRUCTION OF UNDERGROUND UTILITIES

430.1 Description. This Item shall govern for all excavation required for the construction of sewers, sewer structures, pipe culverts, appurtenances and connections and for the backfilling around completed sewers to the level of the original ground, all in conformity with the locations, lines and grades shown on the plans or as given by the Engineer and in accordance with these specifications. Trench excavation shall consist of the required excavation within the limits of the trench, the removal and proper utilization of all suitable trench excavation by placing in accordance with Item 132 “Embankment” or disposal of unusable material. This Item shall also govern for any necessary pumping or bailing and drainage and all sheeting and bracing of trench walls. Also governed by this Item are the cutting and restoration of pavement and base courses, the furnishing and placing of cement stabilized backfill, the hauling and storage of suitable excavated material for other uses and/or disposing of surplus or unsuitable materials and the bridging of trenches and other provisions for maintenance of traffic or access as provided herein.

430.2 Testing. Gravity sanitary sewer lines shall be "lamped". No sewer line shall be accepted, unless a clear lamp can be seen from manhole to manhole.

430.3 Excavation & Trench Preparation. Excavate trench to the alignment and depth required. All suitable excavated materials shall be utilized, insofar as practicable, in constructing the required underground utilities, roadway sections or in uniformly widening of embankment, flattening slopes, etc. or as directed by the Engineer. Unsuitable trench excavation and trench excavation in excess of that needed for construction shall be known as waste and shall become the property of the Contractor to be disposed of by the Contractor outside the limits of the right-of-way. The cost to haul and store suitable material for other uses or for disposal is incidental to this Item. Brace the trench and drain, as required, so that the work may be accomplished safely and efficiently. If necessary, install a dewatering system to provide a dry trench bottom. Pumps shall discharge into natural drainage channels or to drains. Shoring for excavations and trenches shall meet the requirements of the Latest Edition of OSHA Regulation 1926, Subpart P, and the Item 435 "Timber Ordered Left in Trench".

When disposing off site, the Contractor shall not place the waste (excess) material in an environmentally sensitive area, floodway or waters of the United States, including adjacent wetlands", as defined in the Clean Water Act and the Rivers and Harbors Act, unless he has previously
obtained the appropriate Department of the Army Permit authorizing the activity. It is the responsibility of the Contractor to contact the proper authorities to determine the land use classification and to obtain necessary permits. If a disposal site is designated in the plans and is classified as wetlands, then the County shall be responsible for ensuring that the appropriate Department of the Army permit has been obtained for the activity.

For pipes less than 30 inches in diameter, the minimum width of the trench shall be the width of the outside barrel of the pipe plus 24 inches, the maximum width of the trench shall be the width of the outside barrel of the pipe plus 36 inches. For pipe 30 inches and larger, the minimum trench width shall be the width of the outside barrel of the pipe plus 36 inches, and the maximum width of the trench shall be the width of the outside barrel of the pipe plus 48 inches.

Side sloping or benching of the trench, where permitted, will begin at one foot above the top of the pipe and will not encroach upon private property or endanger existing or future structures or underground utilities. Depth of trench, without sheeting or bracing shall comply with OSHA Regulation 1926.650.

The full width of the trench shall be excavated to a depth below the invert elevation of the pipe so as to permit placing the bedding material specified on the Standard Civil Drawings below the outside bottom of the pipe. Any additional depth excavated by the Contractor shall be replaced with an equal depth of cement stabilized sand. The cost of this additional material, in place shall be at the expense of the Contractor.

Where necessary, excavations shall have sheeting and bracing to prevent caving. At these locations, increase the trench width as required and leave the sheeting in place until the pipe has been laid and the backfill compacted to a depth of 2 feet over the pipe. Sheet ing and bracing shall be in accordance with the Item 435 "Timber Ordered Left in Trench". All sheeting and bracing shall be designed to the requirements of OSHA Standard 1926, Subpart P (Latest Edition).

Sewers shall not be constructed or sewer pipe laid in the presence of water. All water shall be removed from the excavation sufficiently prior to the sewer placing operation to insure a dry, firm bed on which to place the sewer and shall be maintained in such unwatered condition until all concrete, cement stabilized sand, and mortar are cured. Removal of water may be accomplished by bailing, pumping or by a well point system as conditions warrant. The well point installation shall be in accordance with the Item 436 "Well Pointing". A seal slab shall be installed when Well Pointing is used for dewatering.
In the event that the excavation cannot be dewatered to the point where the pipe subgrade is free of mud, excessive wet soil, sand silt or clay with water, a seal slab shall be used in the bottom of the excavation. Such seal slab shall consist of a lean concrete mixture in accordance with Item 421, "Structural Concrete". The cast-in-place seal slab (7" thick) shall be a Class "D", 5 sacks of cement per cubic yard with a minimum compressive strength of 1,750 P.S.I. at 7 days and 2,500 P.S.I. at 28 days. The seal slab shall have minimum #4 rebar at 18 inch on centers, in each direction.

A precast seal slab, minimum 6" thick, may be used, provided that the joints of the seal slab do not coincide with or at the joints of the pipe. Contractor shall have an option of using a three day cylinder break test at no expense to Harris County.

For unstable conditions requiring outside forms, seals, sheeting, and bracing, or where groundwater is encountered, any additional excavation in width and backfill required shall be done at the Contractor's expense.

Portable trench boxes may be used in lieu of sheeting upon approval in writing by the Engineer. The trench box must be in accordance with OSHA Regulation 1926.650 (Latest Edition).

Use of the trench box does not relieve the Contractor of any liability for damages to person or property. When a trench box is moved, the jointed pipe or in-place backfill shall not be disturbed.

All materials from excavation operations not required for backfilling, if considered suitable shall be placed in embankments or wasted, in accordance with the Item 132 "Embankment". All material not suitable for use in embankments will be declared surplus by the Engineer and shall become the responsibility of the Contractor to dispose of as he wishes. Such surplus material shall be promptly removed from the work following the completion of the portion of the sewer involved. The cost to haul and store suitable material for other uses or for disposal is incidental to this Item.

Unless otherwise specifically approved, Contractor shall use ladder or wheel type trench-digging machinery, except where hand methods must be employed to avoid damage to existing structures above or below ground, or where hand excavation is indicated.

Engineer may limit the amount of trench opened or partially opened at any time in advance of the completed pipe laying operation and the amount of
trench left unfilled. Open no more than 500 feet of trench on any street at any one time.

430.4 Pipe Laying. No pipe shall be laid in water or when the trench conditions or weather is unsuitable for such work, unless specifically approved by the Engineer.

Fit and lay the pipe to form a smooth and uniform invert. Laying of pipe shall commence at the lowest point, so that the spigot or tongue ends point in the direction of flow.

All other types of pipe shall be laid in accordance with the applicable provisions of this Item.

Field cutting of Polyvinyl Chloride pipe shall be in accordance with the pipe manufacturer's recommendations.

Minor deflections may be obtained in pipe joints. Contractor must obtain approval when the degree of deflection is necessary to deflect from a straight line. Where necessary to make major deflections in concrete pipe, use sections of pipe with beveled ends for deflections not greater than five degrees. For deflections greater than five degrees, use fabricated fittings for concrete pressure pipe.

When the pipe laying operation is halted, seal the open end of the pipe with a temporary plug. Plug is to remain in place until the pipe laying operation recommences.

Standard plugs shall be inserted into bells of all dead end pipe.

For gravity pipelines, use concrete a minimum of 6 inches on all sides of the pipe for encasing, embedding where indicated on the plans.

430.5 Backfilling. As soon as practicable after completion of laying and jointing of pipe, backfill the trench. Not more than 200 feet of the trench shall be left open after laying the pipe. Also backfill other structures, such as manholes, and junction boxes with material selected from the excavation, that is generally suitable for use as backfill.

Trenches shall be backfilled with material selected from sewer trench excavation, or obtained from other sources, shall be free from stones, which will interfere with compaction and free of large lumps which will not break down readily under compaction. Do not use material excavated in large lumps which will not break down or which cannot be spread in loose layers. Material excavated by trenching machine will generally be suitable
for use as backfill. Cement stabilized sand shall be in accordance with the Item 433, "Cement Stabilized Sand Bedding and Backfill Material".

In the pipe zone, as shown on the drawings, cement stabilized sand placed to the depth shown by those drawings, deposited in the trench simultaneously on both sides of the pipe for the full width of the trench and to the height shown by those drawings. Moisten if necessary and tamp in approximately 4 inch layers, thoroughly compacting under and on each side of the pipe to provide solid backing against the external surface of the pipe. Walking or working on the completed pipeline, except as necessary in tamping or backfilling, shall not be permitted until the trench has been backfilled to at least 12 inches over the top of the pipe. The cement stabilized sand shall be placed in accordance with Item 433 “Cement Stabilized Sand Bedding and Backfill Material.”

Backfill above the cement stabilized sand shall be placed as follows.

For trenches under proposed pavement or through asphaltic concrete, concrete, asphalt topped concrete flexible base with asphalt topping, shell or gravel surfaces on either public or private roads, streets or driveways, place backfill above the cement stabilized sand in approximately 6 inch layers, moistened if necessary and thoroughly compacted to 95% of standard proctor in accordance with ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³).” Tamped backfill shall be brought up to the required grade shown by the drawings. Where pipe is laid below the existing pavement or proposed pavement, the backfill material shall be the same, or an approved equivalent, as the material used below the pavement subgrade. For trenches through unimproved roadways, unsurfaced road shoulders or unimproved driveways, the procedures are the same as above, except that compaction above the pipe zone shall be 90 percent of standard proctor.

For trenches located in areas other than those previously stated, and not designated for improvement, place the in-situ material, used as backfill, above the cement stabilized sand as shown by the drawings, in approximately 6 inch layers, moistened if necessary and compacted to 90 percent of standard proctor density in accordance with ASTM designation D698. For the top layer of backfill, place a sufficient amount of previously excavated material neatly rounded over the trench to allow for settlement during consolidation. The Contractor shall supply any deficiency in quantity of materials for backfilling trenches or filling depressions caused by settlement.
Where required as shown in the plans, pipe to be installed under railroad embankment or highway or streets shall be in accordance with Item 431 “Jacking, Boring or Tunneling Pipe” or Item 432 “Tunnel Construction”.

430.6 Restoration of Surfaces. Replace or repair sidewalks, driveway culverts, inlets, curbing, gutters, shrubbery, trees, fences, sod and other like obstructions removed or disturbed, to the condition equivalent to that existing prior to commencement of this work. Use concrete having a compressive strength of not less than 3,000 psi in 28 days for the replacement of curbing, gutters, inlets and sidewalks.

Use reasonable care in the removal and replacement of shrubbery and trees designated to be replaced at original locations. Where at all possible, ditch alignment will be such as to minimize this work. The restoration of asphalt topped flexible base and concrete streets shall be as specified under other items of these Standard Specifications.

430.7 Clean-Up. The Contractor shall remove from the site of the work and from public and private property temporary structures, rubbish, and waste materials, including excess excavated materials. The Contractor is responsible for disposing of all surplus earth. Any excess material from excavation that is suitable for use in road or embankment will be salvaged, stored and protected from any contamination for reuse. The Contractor shall seek approval from the Engineer before disposal of any excess earth.

The pipe laying operation shall be temporarily suspended if the clean-up is further behind than 2,000 feet.

430.8 Quality Assurance. The Testing Laboratory’s representative will determine the moisture density relationship in accordance with ASTM D698 on material secured from the trench excavation. Samples secured from the cement stabilized sand supplier shall be blended with Portland cement in accordance with the Item 433 "Cement Stabilized Sand Bedding and Backfill Material.", and the moisture density relationship will be determined in accordance with ASTM D558 “Standard Test Methods for Moisture-Density (Unit Weight) Relations of Soil-Cement Mixtures”.

The Testing Laboratory’s representative will determine the in place density in accordance with ASTM D1556, “Standard Test Method for Density and Unit Weight of Soil in Place by Sand Cone Method” or D6938, “Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods”. The minimum level of testing will consist of at least one test for each 100 linear feet of trench per lift of backfill.
430.9 Measurement & Payment. Gravity pipelines shall be measured by the linear foot of pipe actually laid, at finished grade, exclusive of pipe installed in tunnel construction, special structures, boxes, manholes, or other special sections, along pipe of size and at depth installed. Measure depth at manholes, at intervals not to exceed 50 feet between manholes, and at breaks in profile of natural ground from flow line of pipe to natural ground surface over center of pipe. Payment for gravity pipeline, furnished, installed and measured as stated shall be at the contract unit price bid for the type of pipe, size, and depth measured, as per pipe material specification, e.g. Item 460 “Reinforced Concrete Pipe”.

Pressure pipelines shall be measured by the linear foot from the centerline of fitting to centerline of fitting, exclusive of pipe installed in tunnel construction, special structures or other special sections along pipe of the size and type installed. If depth of cut is shown on the proposal, measure depth at intervals not to exceed 50 feet and at breaks in profile of natural ground from flow line of pipe to natural ground surface over the center of the pipe.

If the depth of cut is not shown on the proposal, no consideration shall be made for depth at which the pipe is installed. Payment for pressure pipeline, furnished, installed and measured as stated shall be at the contract unit prices for the size and type (and depth, if shown on the proposal) measured.

No separate payment shall be made for concrete used for blocking, backing, encasement or embedding. Gravity lines and Pressure Pipelines shall be paid for in accordance with the applicable item of the material specification.

Concrete used in the repairing curbs, gutters and sidewalks shall be paid for by the linear foot or square yard, as designated on the proposal form. Pay for concrete used in repairing curbs, gutters and sidewalks, measured in the contract unit price bid for "Extra Concrete" of the class installed.

Pipe installed by tunneling shall be paid for in accordance with Item 431 or Item 432.

Street and driveway surfacing shall be paid for in accordance with the applicable item of those specifications.

No separate payment shall be made for ordinary bedding and select backfill, unless so indicated on the bid form. No separate payment shall be made for hauling and storing suitable excavated trench material for other uses or for disposal of excess or unsuitable materials.
No separate payment shall be made for any bedding and backfill installed in accordance with these Standard Specifications and the Standard Civil Drawings.

Well Pointing shall be measured and paid for in accordance with the Item 436 “Well Pointing.”

Seal slabs (with rebar) shall be measured by the square yard installed along the centerline of the structure. Payment for class “D” concrete seal slab shall be made at the unit price bid per square yard and shall include the price of all labor, material and equipment necessary to complete this Item.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires drawings that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications.

Item 132 “Embankment”
Item 421 “Structural Concrete”
Item 431 “Jacking, Boring or Tunneling Pipe”
Item 432 “Tunnel Construction”
Item 433 “Cement Stabilized Sand Bedding and Backfill Material”
Item 435 “Timber Ordered Left in Trench”
Item 436 “Well Pointing”
Item 460 “Reinforced Concrete Pipe”

END OF ITEM 430
ITEM 431

JACKING, BORING OR TUNNELING PIPE

431.1 Description. This Item shall govern for the furnishing and installation of pipe by the methods of jacking, boring or tunneling as shown on the plans and in conformity with this Item.

431.2 Materials. Pipe may be corrugated metal pipe conforming to the Item 461 "Corrugated Metal Pipe" or the Item 460 "Reinforced Concrete Pipe", of the size, type and class specified on the plans.

431.3 Construction Requirements. Where pipe is required to be installed under railroad embankments or under highways, streets or other facilities by jacking, boring or tunneling method, construction shall be made in a manner that will not interfere with the operation of the railroad, highway or other facility and will not weaken or damage any embankment or structure. During construction operations, barricades and lights to safeguard traffic and pedestrians shall be furnished and maintained, as directed by the Engineer, until such time as the backfill has been completed and then shall be removed from the site.

The drilling of pilot holes for the alignment of pipe prior to its installation by jacking, boring or tunneling will not be required, unless indicated on the plans or by special provisions. The drilling of pilot holes, when required, will be considered as incidental work and the cost thereof shall be included in the contract pay items.

The Contractor shall take the proper precautions to avoid excavating earth beyond the limits of excavation shown on the plans.

All damages by excavating, either to surface or sub-surface structures, shall be repaired or replaced by the Contractor at his own cost and expense.

The removal of any obstruction that may be found to conflict with the placing of the pipe will not be measured for payment or paid for as a separate contract pay item. The removal of such obstruction will be included in the contract pay items.

The Contractor shall dispose of all surplus materials at his own cost and expense.
431.4 Jacking. If the grade of the pipe at the jacking end is below the ground surface, suitable pits or trenches shall be excavated for the purpose of conducting the jacking operations and for placing end joints of the pipe. This excavation shall not be carried to a greater depth than is required for placing of the guide and jacking timbers.

At the other end of the pipe, an approach trench shall be excavated accurately to grade. All open trenches shall be braced and shored in such a manner as will adequately prevent caving or sliding of the walls into the open trench.

Heavy duty jacks suitable for forcing the pipe through the embankment shall be provided. In operating jacks, even pressure shall be applied to all jacks used. A suitable jacking pressure shall be applied to all jacks used. A suitable jacking head not less than 6 inches larger than the outside diameter of the pipe, usually of timber and suitable bracing between jacks and jacking head shall be provided so that pressure will be applied to the pipe uniformly around the ring of the pipe. The jacking head shall be of such weight and dimensions that it will not bend or deflect when full pressure is applied at the jack. The jacking head shall be provided with an opening for the removal of excavated material as the jacking proceeds. A suitable jacking frame or backstop shall be provided. The pipe to be jacked shall be set on guides which are straight and securely braced together in such manner to support the section of the pipe and to direct it in the proper line and grade. All timber and other materials used in the construction of the jacking assembly will be of such quality and dimensions that they will withstand all stresses to which they are subjected in such a manner as to insure even pressures on the pipe during jacking operations. The whole jacking assembly shall be placed so as to line up with the direction and grade of the pipe.

As the jacking proceeds, the embankment material shall be excavated slightly in advance of the pipe in such a manner to avoid making the excavation larger than the outside diameter of the pipe, with the excavated material being removed through the pipe. The excavation for the underside of the pipe, for at least one third of the circumference of the pipe, shall conform to the contour and grade of the pipe. The excavation for the top half of the pipe shall conform closely to the outside diameter of the pipe and a clearance greater than 2 inches will not be permitted.

The distance that the excavation shall extend beyond the end of the pipe depends on the character of the material, but it shall not exceed 2 feet in any case. The pipe, preferably, shall be jacked from the low or downstream end. Lateral or vertical variation in the final position of the pipe from the line and grade established by the Engineer will be permitted.
only to the extent of 1 inch per 10 feet, provided that such variation shall be regular and only in one direction and that the final grade of flow line shall be in the direction indicated on the plans.

If the Contractor desires, he may use a cutting edge of steel plate around the head end of the pipe extending a short distance beyond the end of the pipe with inside angles or logs to keep the cutting edge from slipping back onto the pipe.

When jacking of the pipe is once begun, the operations shall be carried on without interruption insofar as practicable, to prevent the pipe from being set firmly in the embankment. Any pipe damaged in the jacking operations shall be removed and replaced by the Contractor at his expense.

The pits or trenches excavated to facilitate jacking operations shall be backfilled immediately after the jacking of the pipe has been completed.

431.5 Boring. The boring shall proceed from a pit provided for the boring equipment and workmen. Excavation for pits and installation of shoring shall be as outlined under jacking. The location of the pit shall meet the approval of the Engineer. The hole shall be bored with a suitable mining machine designed to produce a smooth, straight shaft and so operated that the completed shaft will be at the established line and grade. The size of the bored hole shall not exceed the outside diameter of the pipe to be installed more than 1 inch. The use of water or other fluids in connection with the boring operation will not be permitted, except when boring through rock and then only to the extent necessary to lubricate the cuttings; jetting will not be permitted.

In unconsolidated soil formations, a gel-forming colloidal drilling fluid consisting of at least 10% high grade carefully processed bentonite may be used to consolidate cuttings of the bit, seal the walls of the hole and furnish lubrication for subsequent removal of cuttings and installation of the pipe immediately thereafter.

The allowable variation from line and grade shall be as specified under "Jacking". Overcutting in excess of one inch shall be remedied by pressure grouting the entire length of the installation.

431.6 Tunneling. Where the characteristics of the soil or the size of the proposed conduit make the use of tunneling more satisfactory then jacking or boring, or where called for on the plans, a tunneling method may be used.
The excavation for pits and the installation of shoring shall be as outlined under "Jacking". The lining of the tunnel shall be of steel of sufficient strength to support the overburden. The Contractor shall submit his proposed liner method to the Engineer for approval. Approval by the Engineer shall not relieve the Contractor of the responsibility for the adequacy of the liner method.

The space between the liner plate and the limits of excavation shall be pressure grouted or mud jacked. Access holes for placing concrete shall be spaced at maximum intervals of 10 feet.

431.7 Joints. If corrugated metal pipe is used, joints may be made by field bolting or by connection bands, whichever is feasible. If reinforced concrete pipe is used, where feasible, joints shall be mortared on the inside.

431.8 Measurement. Jacking, boring or tunneling pipe will be measured by the linear foot of pipe, complete in place.

Such measurement shall be made between the ends of the pipe, along the flow line, as installed.

431.9 Payment. The work performed and materials furnished as prescribed by this Item, measured as provided under "Measurement" will be paid for at the unit price bid per linear foot for "Jacking or Boring Pipe" or "Jacking, Boring or Tunneling Pipe" as the case may be, of the type, size and class specified on the plans, which price shall be full compensation for furnishing all materials, pipe liner materials required for tunnel operations, and for furnishing and placing all other materials including concrete backfill; for all jacking, boring, tunneling, excavation and backfill; for all sheeting, shoring, bracing and drainage; for disposal of all surplus materials; and for all labor, tools, equipment and incidentals necessary to complete the work, all in accordance with the plans and specifications.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 460 "Reinforced Concrete Pipe"
Item 461 "Corrugated Metal Pipe"

END OF ITEM 431
ITEM 432

TUNNEL CONSTRUCTION

432.1 Description. This Item shall govern for tunnel lines under railroads, state highways, and concrete paved streets or other obstructions indicated. All other street casing shall be made in accordance with the applicable item.

432.2 Materials. Steel pipe tunnel liner shall be in accordance with AWWA C200 Grade B, with butt welded joints in accordance with AWWA C200, Section 3. The steel pipe liner shall be 4 inches larger in diameter than the largest diameter of the enclosed pipe. Wall thicknesses shall be in accordance with Table 1.

<table>
<thead>
<tr>
<th>SIZE</th>
<th>MINIMUM THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 inch to 34 inch</td>
<td>1/4 inch</td>
</tr>
<tr>
<td>35 inch to 49 inch</td>
<td>3/8 inch</td>
</tr>
</tbody>
</table>

Steel pipe shall be given a factory applied hot coal tar coating inside and out in accordance with AWWA C203.

Tunnel liner plates shall be bituminous coated hot dipped galvanized sectional liner plates in accordance with Table 2. Design shall be per AASHTO standards with the following minimum safety factors applied to the design:

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buckling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seam Strength</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stiffness</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Corrugated metal pipe liner shall be bituminous coated hot dipped galvanized metal pipe with an I.D. of 4-1/2 inches plus the O.D. of the bell of the conveyance pipe. Corrugated pipe shall conform to Item 461 “Corrugated Metal Pipe” and shall be of the following gauges:
TABLE 3

<table>
<thead>
<tr>
<th>CORRUGATED METAL PIPE SIZE WITH 2-2/3 x 1/2 CORRUGATIONS</th>
<th>MINIMUM GAUGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 inch diameter and under</td>
<td>16</td>
</tr>
<tr>
<td>18 inch to 30 inch diameter</td>
<td>14</td>
</tr>
<tr>
<td>30 inch and 36 inch diameter</td>
<td>12</td>
</tr>
<tr>
<td>42 inch diameter</td>
<td>10</td>
</tr>
</tbody>
</table>

432.3 Grout Encasement. When conveyance pipe is reinforced concrete steel cylinder pipe, use grout encasement to fill the annular space between the conveyance pipe and tunnel liner. Grout encasement is not necessary on steel conveyance pipe and tunnel liner unless called for elsewhere. Use grout having a 3:1 sand-cement ratio and 100 pounds of bentonite per cubic yard of grout. Seal the ends of the encasement with 2 inch (thickness) creosoted timber.

432.4 Skids. For concrete conveyance pipe inside of smooth steel pipe liner, place additional mortar at the center and quarter points on each length of pipe inside the liner. This additional mortar shall extend approximately 1 inch outside of the diameter of the ball end. Each pad shall be approximately 2 feet long.

For steel, cast iron and asbestos-cement conveyance pipe inside of smooth steel pipe liner. Use PSI Projects pipeline casing insulators and seals or an approved equal. Use Model A61S, A81S, or A12 IS steel insulators and Model S end seals of the proper size to seal ends. For 6, 8, and 10 inch carrier pipe, use Model A61S, 14 gauge, 6 inch width bands; for 24 inch through 36 inch pipe, use Model A121S, 12 gauge, 12 inch bands. Skids to be steel capped plastic insulators. Place end insulators a maximum of 12 inches from the end of the casing pipe. Intermediate insulators shall be spaced to insure a minimum of two insulators per joint of conveyance pipe.

For corrugated metal pipe liners, use Southern Pine, dense number one structural, or better, S1S1E runners. Retaining bands shall be galvanized, heavy duty, box bandings, approximately 7/8 inch wide by 0.028 inch thick. The spacing of bands shall be one per pipe joint of 4 feet maximum. Cut notches at joints of pipe.

432.5 Construction. Install the conveyance pipe in the tunnel liner, where tunnel construction is indicated. Unless otherwise indicated, extend tunnel section 10 feet beyond each side of pavement for highways or road crossings and 10 feet beyond outside ends of ties, for railroads.
Construct the tunnel by machine boring (dry) and jacking metal pipe liner or by tunneling operation in conjunction with the installation of tunnel liner plates. Install to the alignment and grade shown. Diameter of bored or tunneled hole shall be not more than 1 inch greater in diameter than outside diameter of casing pipe.

Shafts will be excavated at points indicated on the plans or where directed by the Engineer, to such depth and location necessary to drive tunnels to the line and grade established by the Engineer. When shaft or shafts have been excavated to proper elevation and shored and braced adequately, the horizontal excavation for tunnel shall be started. Bracing, shoring, sheeting and roofing or metal tunnel linings, if used, shall be installed immediately upon completion of excavation to proper cross-section, and in no circumstances shall the finished section of tunnel precede such installation by more than two feet. Suggested details of timber work for installation in tunnel may be shown on the plans; however, it shall be the Contractor's responsibility to check same to verify the adequacy of design prior to use. Any alternate plan proposed by the Contractor shall be submitted to the Engineer for checking.

Cylindrical metal linings, either tunnel liner plates fabricated in place in the tunnel or corrugated culvert pipe, jacked ahead as the tunnel excavation proceeds, will, unless otherwise specified, be approved for use in lieu of timber linings. Liner Plates or culvert pipes shall have sufficient strength to provide safe support for all earth and other loads likely to be encountered and shall be equal in every respect to the strength of timber or other supports and linings that may be shown on the plans.

The inside diameter of tunnels for pipe sewers shall be ample to permit proper access for making up the joints. The inside diameter of tunnels for monolithic sewers shall be sufficient to provide for the inside diameter of the sewer plus twice the minimum thicknesses plus any additional diameter necessary to secure minimum wall thickness when forms cannot be placed in the exact center of the tunnel.

Where the length of tunnel is in excess of ten feet, the Contractor shall be required to bore holes from the surface to and through the roof of tunnel for depositing concrete. These holes shall be of such numbers and spaced as directed by the Engineer, and under no condition shall spacing of holes exceed ten feet. Tremies will be used for depositing concrete at these intermediate points along the sewer tunnel. Where monolithic sewer is required, inside forms shall be carefully placed to true line and grade as established by the Engineer, and shall be securely blocked in place to prevent floating or misalignment during the concreting operation. The consistency of concrete placed in the sewer tunnel shall be carefully controlled to insure flow to all parts of sewer barrel without pocketing or
honey-combing. Concrete shall be thoroughly vibrated to insure monolithic construction.

In lieu of placing concrete through holes bored from the surface the Contractor will be permitted to place grout by means of suitable pumping equipment, in tunnels containing pipe sewers. Such methods shall not be used for construction of monolithic sewers.

The shafts and tunnel shall be maintained in a dry condition during the excavation period, and shall continue to be kept in a dewatered state until after concrete has attained its final set. This shall be accomplished by pumping, bailing, or by well-point installation at the Contractor's own expense. Where precast concrete pipe is placed under this Item it shall be encased in concrete in accordance with the construction drawings.

Where the plans call for cast iron or other pipe in a bored hole the work shall be done as follows: when only one length of pipe is to be installed so that the pipe bell or other joint will not enter the bore, the inside diameter of the bored hole shall not exceed the outside diameter of the pipe by more than one inch. Where pipe bells or other types of joints must enter the bore, the inside diameter of the bored hole shall not exceed the outside diameter of the pipe bell or other type of joint by more than one inch. Leaded joints to be installed in bored holes shall be caulked with extra care with the maximum amount of lead and fully protected against any bending action.

On gravity lines where leakage tests are not made the Engineer may require that the pipe be plugged and filled with water to reveal any leakage. The tunnel shall be checked by the Engineer before the cast iron pipe is placed therein. If the tunnel at any point is more than 0.15 feet above grade, or more than 1/4 the inside diameter of the pipe below grade the hole shall be rebored or otherwise modified as directed by the Engineer to come within these tolerances.

To install the conveyance pipe, make up joints as specified in the applicable items of the technical specifications and in open trench. Place insulators and skids as specified above. Where wood runners are indicated, attach runners to the conveyance pipe. Skid the conveyance pipe into the tunnel liner. Provide blocking on top of conveyance pipes requiring grout encasement to prevent vertical displacement due to buoyance. Place grout encasement by pumping.

432.6 Method of Measurement. Conduit installed in tunnels in accordance with these Standard Specifications shall be measured by the linear foot, between the faces of shafts or portals at the ends of tunnels. When cast iron pipe is used, no additional payment will be made for cast iron pipe
projecting outside of the ends of tunnels, or for concrete collars joining same to concrete pipe.

432.7 Payment. Pipe in tunnel, measured as set out above and accepted by the Engineer, shall be paid for at the unit price bid by the Contractor of "Pipe Tunnel Construction" of the size indicated on the proposal sheet, which price shall be full compensation for furnishing all tools, equipment, labor and materials; all excavation, disposal of excess excavation; all shoring, bracing, sheeting and any liners; all pumping, bailing and operations used in dewatering; placing all forms, mixing and placing concrete, furnishing and placing tunnel liner, furnishing and placing conduit, all backfilling and other incidentals necessary to furnish the complete installation in the tunnel.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 461 “Corrugated Metal Pipe”

END OF ITEM 432
ITEM 433

CEMENT STABILIZED SAND BEDDING AND BACKFILL MATERIAL

433.1 Description. This Item shall govern for cement stabilized sand to be used for backfill and bedding as called for on the Standard Civil Drawings, in other parts of the Standard Specifications, or as directed by the Engineer.

433.2 Materials. Cement shall be Type I portland cement conforming to ASTM C150 “Standard Specification for Portland Cement.”

Sand shall be clean durable sand containing not more than the following:

A. Deleterious Materials

1. Clay lumps, when tested in accordance with ASTM C142 “Standard Test Method for Clay Lumps and Friable Particles in Aggregates” shall be less than 0.5 percent.

2. Lightweight pieces, when tested in accordance with ASTM C123 “Standard Test Method for Lightweight Particles in Aggregate” shall be less than 5.0 percent.

3. Organic impurities when tested in accordance with ASTM C40 “Standard Test Method for Organic Impurities in Fine Aggregates for Concrete” shall not show a color darker than the standard color.

B. The plasticity index shall be 6 or less when tested in accordance with ASTM D4318 “Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.”

C. Sand shall be free of organic matter and deleterious substances and shall meet the following gradation requirement.

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>% Passing, By Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 Inch</td>
<td>100</td>
</tr>
<tr>
<td>No. 200</td>
<td>5 – 30</td>
</tr>
</tbody>
</table>

Water shall be clean and clear, free of oils, acids, alkalis, organic matter or other deleterious substances and shall conform to the requirements of ASTM C1602 “Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete.”
433.3 Sand-cement Mixture Product. The mixture shall consist of not less than 1-1/2 sacks of portland cement per ton of material mixture as placed. The mixture shall contain sufficient water to hydrate the cement.

The cement, sand and water shall be mixed in a pugmill type mixer, which meets the approval of the Engineer. It shall be mixed for a minimum period of two minutes per batch.

433.4 Submittals and Responsibilities of the Contractor:

A. Submit the proposed design mix and test data for cement stabilized sand mixture.

B. Facilitate testing and inspection, by furnishing any necessary labor to assist the designated Testing Laboratory in obtaining and handling samples at the project site.

433.5 Placing. The sand cement mixture shall be placed in maximum 8 inch thick lifts, loose measure around the pipe, boxes, structures, bridge approaches and paving sections. Placement and compaction shall be performed in a manner that will thoroughly fill all voids without placing undue strain on or displacement of the structure.

Cement stabilized sand backfill placed below the top of sewers, manholes, inlets or other structures shall be placed equally along all sides of the structure. Cement stabilized sand backfill/bedding shall be placed in a manner that will completely fill all voids in the trench. Hand operated tampers may be used for compaction.

Materials not placed and compacted within 4 hours after mixing shall be rejected. Do not place or compact sand-cement mixtures in standing or free water.

Cement stabilized sand bedding and backfill placed in trenches shall be compacted in accordance with Item 430 “Construction of Underground Utilities” and Item 480 “Precast Reinforced Concrete Box Sewers.”

Provide excavation and trench safety system at locations and depths required for testing and retesting during construction, at no additional cost to Harris County.

In-place density tests shall be taken at each location, each day, to test the placement of bedding/backfill material. The minimum number of tests per day shall be 1 in-place density on the bedding and 2 in-place densities on backfill. The minimum number of tests shall be for each location at the rate of 1 in-place density test per 50 linear feet of bedding and 1 in-place
density test per 50 linear feet of backfill per lift placed above the top of pipe. In-place densities shall be determined in accordance with ASTM D6938 “Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods” or ASTM D1556 “Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.”

433.6 Performance. The sand cement mixtures shall produce a minimum unconfined compressive strength of 100 psi in 48 hours, when compacted to 95 percent of Standard Proctor density (ASTM D558” Standard Test Methods for Moisture-Density (Unit Weight) Relations of Soil-Cement Mixtures”), without additional moisture control and when cured in plastic bags at a temperature of 73.4º F. at plus or minus 3º F. and tested in accordance with ASTM D1633 “Standard Test Methods for Compressive Strength of Molded Soil-Cement Cylinders.”

Random samples of the delivered product will be taken in the field at the direction of the Engineer and tested at Harris County's expense. A minimum of 1 sample per week shall be taken at random to represent a production that is less than 100 tons per week. Two samples per week shall be taken at random to represent a production greater than 100 tons per week. The Engineer shall have the option to obtain additional samples for testing.

After the molding of the soil-cement cylinders, the specimens will be tested in accordance with ASTM D1633, Method A. Two specimens will be tested at 48 hours and two specimens will be tested at 7 days.

433.7 Notification. The Testing Laboratory's representative will notify the County, Engineer, Contractor and material supplier by facsimile of all tests indicating results falling below specified strength requirements.

433.8 Measurement. Cement stabilized sand shall be measured by the square yard of material, furnished and compacted in place to the thickness specified, or as shown in the plans or acceptable material mixture, as specified by this Item, shall be measured by the ton of 2,000 pounds. Measurement shall be made by tickets delivered to the Engineer. The dray tickets shall indicate the tare, gross and net weight of the load and the location of delivery.

433.9 Payment.

A. The payment for cement stabilized sand, complete and in place, shall be at the contract unit price per square yard of the specified thickness, which unit price shall include all costs of materials, furnished, hauled, dumped, spread, shaped, and compacted.
B. Where the bid sheet specifies FOB the plant, the materials shall be loaded on Harris County vehicles and paid for by the ton of 2,000 pounds.

C. Where the bid sheet specifies FOB the job, materials shall be transported to the job site specified on the bid sheet, and paid for by the ton of 2,000 pounds.

D. When the Project Manual, plans or other specifications indicate the use of cement stabilized sand is incidental to another pay item, no direct payment for the material will be made.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 430 “Construction of Underground Utilities”
Item 480 “Precast Reinforced Concrete Box Sewers”

END OF ITEM 433
434.1 Description. This Item shall govern for flowable fill to be used as backfill for construction of underground utilities, as called for on the drawings, or in other parts of the specifications. This material may be used in lieu of cement stabilized sand, at the option of the Engineer. Because of the time required for "setting up", this material can only be used at locations where the trench can be left open for approximately twelve hours prior to backfilling. Shoring for excavations and trenches shall meet the requirements of the latest edition of OSHA Regulation 1926, Subpart P.

434.2 Materials. Cement shall be Type I portland cement conforming to ASTM C150 “Standard Specification for Portland Cement.”

Fly ash shall meet the requirements of ASTM C618 “Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete”, Class C. Fly ash shall have a minimum CaO content of 20 percent.

Sand shall be clean, durable sand containing not more than the following:

A. Deleterious Materials

1. Clay lumps, when tested in accordance with ASTM C142 “Standard Test Method for Clay Lumps and Friable Particles in Aggregates”, shall be less than 0.5 percent.

2. Lightweight pieces, when tested in accordance with ASTM C123 “Standard Test Method for Lightweight Particles in Aggregate”, shall be less than 5.0 percent.

3. Organic impurities, when tested in accordance with ASTM C40 “Standard Test Method for Organic Impurities in Fine Aggregates for Concrete”, shall not show a color darker than the standard color.

B. The plasticity index shall be 6 or less when tested in accordance with ASTM D4318 “Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.”

C. Sand shall be free of organic matter and deleterious substances and shall meet the following gradation requirement:
Note: It is intended that the sand be a fine sand that will stay in suspension, in the mixture, to the extent required to obtain a flowable consistency. The gradation shall be adjusted to achieve this consistency.

Water shall be clean and clear, free of oils, acids, alkalis, organic matter, or other deleterious substances and shall conform to the requirements of ASTM C1602 “Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete.”

Admixtures shall conform to ASTM C1017 “Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete” and/or ASTM C494 “Standard Specification for Chemical Admixtures for Concrete.”

Mix Design. The following are given as typical mix designs for trial mixes. Adjustments of the proportions may be made to achieve proper solid suspension and optimum flowability. Admixtures may be used, if desired, to improve the characteristics of the mix. The suggested quantities of dry material per cubic yard are as follows:

<table>
<thead>
<tr>
<th>TRIAL MIX No. 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
</tr>
<tr>
<td>Fly Ash</td>
</tr>
<tr>
<td>Sand</td>
</tr>
<tr>
<td>Water</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TRIAL MIX No. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
</tr>
<tr>
<td>Fly Ash</td>
</tr>
<tr>
<td>Sand</td>
</tr>
<tr>
<td>Water</td>
</tr>
</tbody>
</table>

The above quantities will give an approximate yield of one cubic yard. The flowability of the mixture shall be observed by the Engineer and
flowability increased / decreased by adjusting the water content as well as increasing/decreasing the air entraining admixture content.

Provide a mix design per TxDOT’s Specification Item 401 “Flowable Backfill”, Latest Edition.

434.4 Consistency. The consistency of the mix shall be tested by filling an open-ended 3 inch diameter cylinder 6 inches high, to the top with flowable fill. The cylinder shall be immediately pulled straight up and the correct consistency of the flowable fill shall produce a minimum 8 inch diameter circular type spread, with no segregation. The flowable fill shall maintain its consistency when placed.

434.5 Batching, Mixing, and Transportation. Materials are to be measured by weight. The flowable fill may be mixed in a central concrete mixer, a ready mix truck, or other means acceptable to the Engineer. The flowable fill shall be transported to the point of placement in a revolving drum mixer or in an agitator unit.

434.6 Placement. The flowable fill shall be placed by direct discharge from the mixer truck, or other approved methods. If necessary to prevent segregation, boots shall be used.

The flowable fill shall be placed in accordance with Item 430 "Construction of Underground Utilities" and Item 480 "Precast Reinforced Concrete Box Sewers". It will be necessary to use cement stabilized sand as bedding, as shown by the Standard Civil Drawing. At the option of the Engineer, the flowable fill may be used above the bedding to the uppermost elevation shown on the referenced drawings.

434.7 Measurement. No direct payment shall be made for flowable fill when used as backfill in accordance with Items 430 and 480, and the Standard Civil Drawings pertaining thereto.

Where used as backfill at other locations, and where measured, flowable fill shall be measured by the cubic yard, computed from the dry weight of the material.

434.8 Where measured for payment in accordance with Section 434.7 of this Item, flowable fill shall be paid for at the contract unit price bid per cubic yard, for flowable fill, which price shall be full payment for all materials, equipment, labor, and transportation necessary to complete the work.

There are line code(s), description(s), and unit(s), for this Item.
NOTE: This Item required other Standard Specifications

Item 430 “Construction of Underground Utilities”
Item 480 “Precast Reinforced Concrete Box Sewers”

END OF ITEM 434
ITEM 435

TIMBER ORDERED LEFT IN TRENCH

435.1 Description. This Item shall govern for furnishing all labor and materials for installation of sheathing and bracing. The application will be where necessary to prevent caving. When requested by the Contractor and approved by the Engineer, floor boarding and special bedding shall be installed. When ordered for the protection of adjoining structures, utility lines, streets or other facilities, sheeting and bracing shall be left in place.

435.2 Quality Assurance. Bracing and sheeting shall meet the requirements of OSHA Regulation 1926.650.

435.3 Materials. Trench sheeting materials to be a minimum of 2 inches in thickness, solid and sound, free from weakening defects such as knots and splits and suitable for the use intended. Use bracing of similar quality and suitable in size and strength for intended use.

435.4 Installation. Timber placed in the trench shall be subject to the approval of the Engineer. Cut off the timber sheeting ordered left in trench, at a minimum distance of 18 inches below finished grade.

435.5 Measurement and Payment. No direct payment shall be made for timber ordered left in trench. Timber ordered left in trench shall be incidental to trench safety.

There are no line code(s), description(s), and unit(s) for this Item.

END OF ITEM 435
ITEM 436

WELL POINTING

436.1 Description. This Item shall govern for the temporary dewatering of trenches for the installation of utilities. Work, in general shall include:

A. Designing, furnishing, installing, testing, operating, monitoring and maintaining a system to control ground water and surface water as required to comply with the performance requirements specified.

B. Controlling and removing seepage and surface water from the excavation, including excavation slope erosion control.

C. Prevention of surface water from entering the trench and diverting the surface water away from the site.

D. Removal of the temporary dewatering system after completion of the specified portion of work.

E. Removal of ground water and surface water from all remaining excavation, after removal of the temporary dewatering system, until construction has reached finished grades.

436.2 Quality Assurance. The dewatering system work shall be performed by a firm which has at least 5 years of successful experience in the field of dewatering.

The Contractor or well pointing firm shall engage a qualified surveyor, to perform all layouts and measurements. The surveyor shall layout the work to the lines and grades required before installation and shall determine the location of each well point, piezometer and other data, as required.

The surveyor shall record and maintain all information pertinent to each well point and piezometer.

The temporary dewatering system as specified in these Standard Specifications shall be the minimum system required for controlling groundwater, regardless of source. The installed system shall be capable of lowering and maintaining the groundwater to at least 3 feet below the bottom of the excavation, until the required utilities are installed, and the seal slab with cement stabilized sand bedding has been set in place for a minimum of twelve hours. Within these limits, the Contractor shall be responsible for the design of the entire temporary dewatering system and
shall make whatever modifications and additions to the system as may be required for the system to fulfill its requirements.

436.3 Performance Requirements. The Contractor shall:

A. Design, furnish, install, test, operate, monitor and maintain the minimum well point system as specified herein, including all discharge piping and connections at point of discharge, sufficient to lower the ground water level or hydrostatic head at 3 feet below the bottom of the excavation, or lower, so as to prevent seepage of water into the excavation and permit installation of all utilities "in the dry". This "dry" installation of utilities shall include a seal slab with cement stabilized sand bedding that has been set in place for a minimum of twelve hours.

B. Design, furnish and install, test, operate, monitor and maintain whatever additional system that may be necessary to supplement the minimum wellpoint system as specified herein, and to maintain the excavation free of groundwater seepage and surface water, regardless of source.

C. The periphery of the entire excavation shall be suitably diked and the dikes maintained to prevent surface water from entering the excavation.

D. All water seeping, falling or running into the excavation as it is dug, and until the temporary dewatering system is removed as specified, shall be promptly pumped out.

E. Dispose of all seepage and surface water removed from the project, regardless of source, by methods approved by the Engineer.

F. Take appropriate and approved measures to prevent erosion of the excavated soils and ramp slopes.

436.4 Maintenance. The Contractor shall provide system maintenance including, but not limited to, at least daily supervision by someone skilled in the operation, maintenance, and replacement of system components and shall provide 1 spare (connected) diesel powered pump; and all other equipment and work required by the Engineer to maintain the excavation in a dewatered and hydrostatically relieved condition. Dewatering and pressure relief shall be a continuous operation and interruptions due to power outages, or any other reason, shall not be permitted. A responsible operator capable of starting, finishing and maintaining the dewatering system and starting standby equipment shall be on duty at all times.
Some responsible person shall continuously monitor the dewatering and surface water control systems, until the Contractor has received approval from the Engineer that he may discontinue surface and/or groundwater control.

436.5 Correction of Work. The Contractor shall be fully responsible for the failure of all components of the temporary dewatering work and for all damages to work in the excavation area caused by the failure to provide, maintain, and operate the temporary dewatering system, as specified. Contractor shall restore all damaged work, including failed components of the work in this Item to a condition as good as or better than existed prior to failure of components.

436.6 Job Conditions. The Contractor shall provide protection of persons and property by at least:

A. Barricading open excavations occurring as part of this work and post with warning lights. Operate warning lights during the hours from dusk to dawn, each day. All barricades, signs and other types of devices shall be installed in accordance with the "Texas Manual on Uniform Traffic Control Devices".

B. Protect structures, utilities, sidewalks, pavements and other facilities from damage caused by settlement, lateral movement, undermining, washout and other hazards created by temporary dewatering system installation and operation.

The Contractor shall restore all streets, driveways, curbs, sidewalks and other existing items to a condition as good as or better than existed before work was commenced, at no additional cost to Harris County.

436.7 Measurement. Well point systems or dewatering systems shall be measured by the linear foot of trench being dewatered. The measurement shall be taken along the centerline of the trench.

436.8 Payment. Shall be made at the contract unit price bid for "well-pointing" measured as outlined in the preceding section. Such payment shall be full compensation for all materials, equipment and labor necessary to furnish, install, operate and maintain the well point system, including any necessary traffic warning systems or any work necessary to restore the site to its original condition, including any damaged facilities.

There are line code(s), description(s), and unit(s) for this Item.
ITEM 437

ELASTOMERIC MATERIALS

437.1 Description. This Item shall govern for the materials, testing, fabrication and placement of elastomeric materials, except as otherwise covered in other specifications.

437.2 Materials. When specified on the plans, structural members shall be seated on elastomeric bearings.

These bearings may be either "plain" (consisting of elastomer only) or "laminated" (consisting of alternating individual layers of elastomer and nonelastic laminates) as shown on the plans. Elastomeric bearings shall be specified on the plans by hardness (durometer), size, configuration and, in the case of laminated bearings, by the thickness of individual layers of elastomer and the size and position of special connection members, if any, required to be vulcanized with the bearing.

Unless otherwise shown on the plans, the elastomer for bearings shall be formulated from previously unvulcanized 100 percent virgin polychloroprene rubber polymers meeting the requirements of AASHTO M251. Rubber like polymers provided in the elastomer formulation shall be exclusively of the polychloroprene type. Bearings will not be acceptable if the elastomer provided contains previously vulcanized rubber (natural or synthetic) or other synthetic rubber like polymers.

Nonelastic laminates shall be 1/16 of an inch thick steel strip or sheet. Metal for special connections including sole plates and bearing plates, shall conform to ASTM A36 “Standard Specification for Carbon Structural Steel.”

Elastomer formulated from polychloroprene shall meet the requirements shown in Table 1. Material tests shall be made in accordance with the test methods stipulated, except that all tests shall be made on the finished product. The values shown in Table 1, pertain to tests performed on samples taken from the finished product. The apparatus employed in preparing test specimens from the finished product shall be in accordance with ASTM D3183 “Standard Practice for Rubber—Preparation of Pieces for Test Purposes from Products.”

All components of a "laminated" bearing shall be molded together to form an integral unit free of voids or separations in the elastomer or between the elastomer and the nonelastic laminates or special connections unless specifically required or permitted by the plans or these Standard
Specifications. The elastomer between the laminates or special connections and the outer surface of the bearing shall be well vulcanized, uniform and integral such that it is incapable of being separated by any mechanical means into separate, definite, well defined elastomeric layers. Evidence of this layered construction, either at the outer surfaces or within the bearing, shall be cause for rejection of such laminated bearing shipments.

All edges of nonelastic laminates shall be covered by a minimum of 1/8 of an inch of elastomer except that exposure of the laminates will be permitted at approved laminate restraining devices and around holes that will be entirely enclosed in the finished structure. Unless otherwise shown on the plans, all laminates shall be parallel with the bottom surface of the bearings, subject to the tolerances that follow.

Plain bearings may be molded individually, cut from previously molded strips or slabs molded to the full thickness of the finished bearings, or extruded and cut to length. The finished bearings shall have no voids or separations detectable either at the bearing surfaces or within the bearing unless specifically required or permitted by these Standard Specifications. Plain elastomeric bearings, shall be well vulcanized, uniform and integral units of such construction that the bearing is incapable of being separated by any mechanical means into separate, definite and well defined elastomeric layers. Evidence of layered construction either at the outer surface or within the bearing, shall be cause for rejection.

<table>
<thead>
<tr>
<th>HARDNESS (DUROMETER)</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Physical Properties Hardness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTM D2240, Type A Durometer</td>
<td>50±5</td>
<td>60±5</td>
<td>70±5</td>
<td>80±5</td>
<td>90±5</td>
</tr>
<tr>
<td>Tensile Strength, Minimum psi ASTM D412</td>
<td>2250</td>
<td>2250</td>
<td>2250</td>
<td>1800</td>
<td>1800</td>
</tr>
<tr>
<td>Elongation at Break, Minimum Percent</td>
<td>405</td>
<td>360</td>
<td>270</td>
<td>135</td>
<td>90</td>
</tr>
<tr>
<td>Accelerated Tests to Determine Long Term Aging Characteristics Oven Aged 70 Hr. at 212°F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### HARDNESS (DUROMETER)

<table>
<thead>
<tr>
<th>Hardness</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM D573 Hardness, Points Change Maximum</td>
<td>0 to +15</td>
<td>0 to +15</td>
<td>0 to +15</td>
<td>0 to +15</td>
<td>0 to +15</td>
</tr>
<tr>
<td>Elongation at Break, % Change Maximum</td>
<td>-40</td>
<td>-40</td>
<td>-40</td>
<td>-40</td>
<td>-40</td>
</tr>
<tr>
<td>Ozone: 100 PPHM in Air by Volume 20% Strain at 100+2°F, ASTM D1149* 100 Hrs.</td>
<td>No Cracks</td>
<td>No Cracks</td>
<td>No Cracks</td>
<td>No Cracks</td>
<td>No Cracks</td>
</tr>
<tr>
<td>Compression Set - 22 Hr. at 158°F, ASTM D395 (Method B)** % Maximum</td>
<td>-25</td>
<td>-25</td>
<td>-25</td>
<td>-25</td>
<td>-25</td>
</tr>
<tr>
<td>Low Temperature Resistance, ASTM D746, Procedure B Brittleness, at 26°C</td>
<td>No Failure</td>
<td>No Failure</td>
<td>No Failure</td>
<td>No Failure</td>
<td>No Failure</td>
</tr>
</tbody>
</table>

Adhesion (Prequalification Only)

For laminated bearings, bond between the elastomer and laminates will be qualitatively evaluated by the procedure outlined in TxDOT’s Test Procedure Tex-601-J.

* Samples to be solvent wiped before test to remove traces of surface impurities.

** Modified in that test is performed on specimens of essentially full bearing or layer thickness with the 25 percent compression obtained through the use of appropriate spacer bars and/or shims.

INTERPOLATE BETWEEN VALUES SHOWN FOR OTHER HARDNESS VALUES

Waterstops. Waterstops shall be furnished and installed in accordance with the details shown on the plans. Except when otherwise indicated on the plans, waterstops may be manufactured from either natural (plain) or synthetic rubber or from polyvinyl chloride (PVC) as specified.
Natural (plain) rubber waterstops shall be manufactured from a stock compound of a high grade compound made exclusively from new plantation rubber, reinforcing carbon black, zinc oxide, accelerators, antioxidants and softeners. This compound shall contain not less than 72 percent by volume of new plantation rubber.

Synthetic rubber waterstops shall be manufactured from a compound made exclusively from neoprene or GRS, reinforcing carbon black, zinc oxide, polymerization agents and softeners. This compound shall contain not less than 70 percent by volume of neoprene or GRS.

The physical properties of natural or synthetic rubber for waterstops shall be as shown in Table 2.

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>NATURAL (PLAIN) RUBBER</th>
<th>SYNTHETIC (NEOPRENE GRS) RUBBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Physical Properties Hardness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTM D2240 (Durometer)</td>
<td>60±5</td>
<td>55±5</td>
</tr>
<tr>
<td>Tensile Strength, Minimum psi</td>
<td>3500</td>
<td>2500</td>
</tr>
<tr>
<td>ASTM D412</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elongation at Break, Minimum Percent</td>
<td>550</td>
<td>425</td>
</tr>
</tbody>
</table>
| Accelerated Tests to Determine Aging Characteristics
| Either:                               |                        |                                  |
| After 7 Days in Air at 158°(±2°)F, ASTM D573 or After 48 Hours in Oxygen (ASTM D572) at 158°(±)F and 300 psi Pressure Tensile Strength, Percent Change Maximum | 35                      | 35                              |
| Elongation, Percent Change, Maximum   | 35                     |                                  |
Polyvinyl Chloride waterstops shall conform to Corps of Engineers Specification No. CRD-C 572-60.

The Manufacturer shall furnish certified test results, indicating compliance with this Item, for each batch of waterstops furnished.

Rubber waterstops shall be manufactured with an integral cross-section which shall be uniform within plus or minus 1/8 of an inch in width, and the web thickness or bulb diameter, within plus 1/16 and minus 1/32 of an inch. No splices will be permitted in straight strips. Strips and special connection pieces shall be well cured so that any cross-section shall be dense, homogeneous and free from all porosity. All junctions in the special connection pieces shall be full molded. During the vulcanizing period, the joint shall be securely held by suitable clamps.

The requirements for PVC waterstops shall be the same as rubber waterstops, except that splicing of PVC shall be done by heat sealing the adjacent surfaces in accordance with the manufacturer's recommendations. A thermostatically controlled electric source of heat shall be used to make all splices. The heat shall be sufficient to melt but not to char the plastic.

When so specified on the plans, rail posts, rail members, metal shoes or minor structural members shall be insulated, leveled, shimmed or otherwise protected by elastomeric pads, sheets or washers. Such bearings may be any elastomeric material, plain, fibered or laminated, having a hardness (durometer) between 70 and 100 as certified by the manufacturer to the Engineer.

Construction Methods. Unless otherwise shown on the plans, concrete bearing seats shall be float finished to the required elevation. Variation from a level plane shall not exceed 1/16 of an inch within the limits of the bearing.

After erection of members of steel structures only, the horizontal distortion of the bearings shall be measured, corrected for temperature and adjusted, if necessary, so that the horizontal displacement between top and bottom of bearing at 70°F. does not exceed 15 percent of the elastomer thickness.

Welding in the vicinity of the bearings shall be done with care to avoid injury to the elastomer.

Field splices shall be either vulcanized; mechanical, using stainless steel parts; or made with a rubber splicing union of the same stock as the
waterstop, at the option of the Contractor. All finished splices shall have a tensile strength not less than 50 percent of the unspliced material.

437.5 Measurement and Payment. Unless otherwise specified on the plans elastomeric bearings used in conjunction with structures will be measured and paid for by each elastomeric bearing, of the type shown on the plan.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 437
ITEM 438

PREFORMED JOINT SEAL

438.1 Description. This Item shall govern for the furnishing and installation of preformed materials, to be placed in armored bridge deck joints for the purpose of preventing the passage of water and other materials through the joint.

438.2 Materials. The joint seal shall be an extruded, multi-channeled elastomeric shape, conforming to ASTM D3542 "Standard Specification for Preformed Polychloroprene Elastomeric Joint Seals for Bridges." The size shown on the plans shall be the nominal width of the seal. The uncompressed depth of the seal shall be equal to or greater than the width.

When tested in accordance with ASTM D3542, the pressure measured shall be no less than 3 psi at 85 percent, nor more than 100 psi at 50 percent of the nominal width.

Lubricant-adhesive shall be a one part moisture curing polyurethane and part hydrocarbon solvent mixture with the physical properties: complying with ASTM D3542.

The manufacturer shall furnish certification as to compliance with these physical requirements.

438.3 Inspection and Testing. The Engineer shall conform that the seal proposed for installation is of the size, configuration and meets the requirements of this Item. In addition, the Engineer shall examine the seal for any undue distortions such as dissymmetry, to impair the performance of the joint. If the magnitude of the distortions is sufficient to create doubt as to the performance of the seal, the Engineer may direct that the seal be replaced, or that samples representing the worst of the lot be subjected to further testing, at the expense of the Contractor, to verify the performance.

438.4 Construction Requirements. Just prior to installing the seal, the joint faces shall be abrasive blast cleaned, blown out with high pressure air and lubricant adhesive applied to the joint faces. The sides of the seal shall be cleaned with xylol solvent, lubricant adhesive applied to the sides and installed into the joint opening with an approved compression installation tool as recommended by the manufacturer. Installation by hammering, use of sharp tools or stretching of the seal will not be permitted.

The Contractor shall furnish the fabricator of the armor joint with the actual
depth of the seal to be furnished so that the stop for the bottom of the seal will be placed in the correct position (actual depth plus 1 inch). In no case shall the top of the seal, after installation, be closer than 1/2 of an inch to the roadway surface.

The seal shall be installed in the joint in one continuous piece for the full joint including vertical and horizontal angle changes. One shop splice for each 40 feet of length will be permitted but no field splice will be allowed. Failure of a splice at any time prior to final acceptance of the work will be cause for rejection and replacement of the entire seal.

The bottom portion of the seal may be cut or portions removed to facilitate vertical bending only. Any authorized cutting shall be to smooth lines and rounded curves. The word top shall be printed on each seal at intervals not to exceed 25 feet.

Uniform joint openings of the proper width and with parallel joint faces shall be provided. Joint openings shall be adjusted for the difference between 70°F and the temperature of the superstructure at the time the opening is set. The amount of adjustment shall be approximately 1/16 of an inch per 10°F temperature difference per 90 feet of length expanding through the joint. Adjustments in joint opening shall not be made for reasons other than temperature at setting.

438.5 Measurement. For each size of seal specified, measurement will be made by the linear foot, along the centerline of the joint and at the surface of the roadway, curb, sidewalk and up the roadway surface.

438.6 Payment. Payment shall be made at the contract unit price bid per foot, for the size of seal specified.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 438
ITEM 439

POLYURETHANE JOINT SEAL

439.1 Description. This Item shall govern for the furnishing and placing of a polyurethane base joint sealing compound in those joints designated on the plans.

439.2 Materials. The sealant shall be a polyurethane base, two component, cold applied joint sealing compound suitable for sealing horizontal joints in concrete slabs. The sealant shall be a two package system consisting of a base compound and an accelerator compound. The two components shall be easily identifiable by color difference which also aids in showing proper mixing. When properly mixed and packaged, the sealant shall convert to a rubber-like compound meeting the requirements specified herein. If primers are recommended by the manufacturer, they will be required and shall be used in construction.

The sealant shall be Machine Extruded type.

439.3 Test Requirements. When tested in accordance with TxDOT’s Test Procedure Tex-525-C, the sealer shall meet the following requirements:

The sealer shall be of such consistency that it can be extruded into a sloping joint in one operation without excessive flow.

<table>
<thead>
<tr>
<th>Stability when stored for months at a temperature not exceeding 80° F</th>
<th>Continue to pass six other requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing Ratio</td>
<td>Equal parts base and accelerator</td>
</tr>
<tr>
<td>Viscosity of individual components at 77° F ± 2° F, Poises</td>
<td>50 Minimum 750 Maximum</td>
</tr>
<tr>
<td>Viscosity of sealer, based on Volume Ratio of Components, Poises</td>
<td>50 Minimum 500 Maximum</td>
</tr>
<tr>
<td>Application Life at 77° F ± 2° F, and ± 5% Relative Humidity after proper mixing</td>
<td>3 Minutes, Minimum 10 Minutes, Maximum</td>
</tr>
<tr>
<td>Tack Free Time, Hours</td>
<td>24 Maximum</td>
</tr>
<tr>
<td>Weight Loss after Heat Aging, Percent</td>
<td>10 Maximum</td>
</tr>
<tr>
<td>Compression Set, Percent</td>
<td>15 Maximum</td>
</tr>
<tr>
<td>Resilience at 77° F, Percent</td>
<td>80 Minimum</td>
</tr>
</tbody>
</table>
Resilience after Heat Aging, Percent | 80 Minimum
--- | ---
Initial Adhesion - 150% Extension (1/2” to 1-1/4”)
Normal Curing | Pass*
Rapid Curing | Pass*
Adhesion after Water Immersion | Pass*
Adhesion after Heat Aging | Pass*
Adhesion after Cycling at 20° F | Pass*

* Tensile force at 150 percent extension shall not be less than 8 psi nor more than 75 psi. There shall be no evidence of crack, separation or other opening that at any point is over 1/8 inch deep in the sealer or between the sealer and test blocks.

439.4 Construction Methods. The bonding surface of joints shall be cleaned free of laitance, concrete, paint, corrosion, mill scale, oil or grease by an approved method prior to application of the primer.

Metal surfaces shall be abrasive blast cleaned in accordance with TxDOT Item 438 "Cleaning and Sealing Joints". After cleaning, the joint shall be blown out to remove all loose dust.

Priming of surface for proper bond and materials for priming shall be as recommended by the sealant manufacturer. The primer shall be applied to metal surfaces soon after cleaning and before new corrosion begins and shall be allowed to dry a minimum of 30 minutes, but not more than eight hours before applying the sealant.

In open type joints, a backing shall be provided to hold the fluid sealant in place. Backing shall be a compressible type material such as closed-cell, resilient foam or sponge rubber stack of vinyl, butyl, or neoprene; or, expanded polyethylene or polyurethane. In all cases, bond must be broken between the backing and sealant.

The depth of the sealant shall conform the requirements of Table 1. The top surface of the sealant shall be approximately 1/4 inch below the top of the joint.
The sealant shall be placed in the open joint to the depths required in Table 1, in one pass so that it will flow and level out a smooth surface across the joint. The sealant shall be of such consistency that it can be placed into a sloping joint without excessive flow down the cross slope of the structure.

439.5 Measurement and Payment. No direct measurement or payment will be made for the materials, work to be done or equipment to be furnished under this Item, but it shall be considered subsidiary to the particular item required by the plans and the contract.

There are no line code(s), description(s), or unit(s) for this Item.

END OF ITEM 439
ITEM 440

REINFORCING STEEL

440.1 Description. This Item shall govern for the furnishing and placing of reinforcing steel of the type, size and quantity designated for use in structures, as shown on the plans and in accordance with these Standard Specifications.

440.2 Materials. Unless otherwise designated on the plans, or herein, all bar reinforcement shall be deformed and shall conform to the following:

A. ASTM A615 “Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement”, Grade 40 or 60, open hearth, basic oxygen or electric furnace new billet steel. Unless noted by these Standard Specifications, rail steel or axle steel shall not be permitted.

Grade 40 reinforcing steel shall be required when specified on the contract documents.

When no specific grade is specified on the plans, the reinforcing steel shall be a minimum Grade 60.

Where bending of bar sizes #14 or #18 of Grade 60 is required, bend testing shall be performed on representative specimens as described for smaller bars in the applicable ASTM Specification. The required bend shall be 90 degrees around a pin having a diameter of 10 times the nominal diameter of the bar.

B. Spiral reinforcement shall be either smooth or deformed bars, or wire, of the minimum size or gage shown on the plans or as specified herein. Bars for spiral reinforcement shall comply with ASTM A615, ASTM A675 “Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties” or ASTM A996 “Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement.” Wire shall conform to ASTM A1064 “Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete.”

Unless otherwise shown on the plans, the minimum yield strength for spiral reinforcement shall be 40,000 psi.
Report of chemical analysis, showing the percentages of carbon, manganese, phosphorus and sulphur will be required of all reinforcing steel bars when it is to be welded.

The nominal size and area and the theoretical weight of reinforcing steel bars covered by this Item are as follows:

### TABLE 1

<table>
<thead>
<tr>
<th>BAR SIZE</th>
<th>NOMINAL DIAMETER INCH</th>
<th>NOMINAL AREA SQUARE INCH</th>
<th>WEIGHT PER LINEAR FOOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>#2</td>
<td>0.250</td>
<td>0.05</td>
<td>0.167</td>
</tr>
<tr>
<td>#3</td>
<td>0.375</td>
<td>0.11</td>
<td>0.376</td>
</tr>
<tr>
<td>#4</td>
<td>0.500</td>
<td>0.20</td>
<td>0.668</td>
</tr>
<tr>
<td>#5</td>
<td>0.625</td>
<td>0.31</td>
<td>1.043</td>
</tr>
<tr>
<td>#6</td>
<td>0.750</td>
<td>0.44</td>
<td>1.502</td>
</tr>
<tr>
<td>#7</td>
<td>0.875</td>
<td>0.60</td>
<td>2.044</td>
</tr>
<tr>
<td>#8</td>
<td>1.000</td>
<td>0.79</td>
<td>2.670</td>
</tr>
<tr>
<td>#9</td>
<td>1.128</td>
<td>1.00</td>
<td>3.400</td>
</tr>
<tr>
<td>#10</td>
<td>1.270</td>
<td>1.27</td>
<td>4.303</td>
</tr>
<tr>
<td>#11</td>
<td>1.410</td>
<td>1.56</td>
<td>5.313</td>
</tr>
<tr>
<td>#14</td>
<td>1.693</td>
<td>2.25</td>
<td>7.650</td>
</tr>
<tr>
<td>#18</td>
<td>2.257</td>
<td>4.00</td>
<td>13.60</td>
</tr>
</tbody>
</table>

C. When wire is ordered by size numbers, the following relation between size number, diameter in inches and area shall apply unless otherwise specified:

### TABLE 2

<table>
<thead>
<tr>
<th>WIRE SIZE</th>
<th>NOMINAL DIAMETER INCH</th>
<th>NOMINAL AREA SQUARE INCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>0.628</td>
<td>0.310</td>
</tr>
<tr>
<td>30</td>
<td>0.618</td>
<td>0.300</td>
</tr>
<tr>
<td>28</td>
<td>0.597</td>
<td>0.280</td>
</tr>
<tr>
<td>26</td>
<td>0.575</td>
<td>0.260</td>
</tr>
<tr>
<td>24</td>
<td>0.553</td>
<td>0.240</td>
</tr>
<tr>
<td>22</td>
<td>0.529</td>
<td>0.220</td>
</tr>
<tr>
<td>20</td>
<td>0.505</td>
<td>0.200</td>
</tr>
<tr>
<td>WIRE SIZE</td>
<td>NOMINAL DIAMETER INCH</td>
<td>NOMINAL AREA SQUARE INCH</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>18</td>
<td>0.479</td>
<td>0.180</td>
</tr>
<tr>
<td>16</td>
<td>0.451</td>
<td>0.160</td>
</tr>
<tr>
<td>14</td>
<td>0.422</td>
<td>0.140</td>
</tr>
<tr>
<td>12</td>
<td>0.391</td>
<td>0.120</td>
</tr>
<tr>
<td>10</td>
<td>0.357</td>
<td>0.100</td>
</tr>
<tr>
<td>8</td>
<td>0.319</td>
<td>0.080</td>
</tr>
<tr>
<td>7</td>
<td>0.299</td>
<td>0.070</td>
</tr>
<tr>
<td>6</td>
<td>0.276</td>
<td>0.060</td>
</tr>
<tr>
<td>5.5</td>
<td>0.265</td>
<td>0.055</td>
</tr>
<tr>
<td>5</td>
<td>0.252</td>
<td>0.050</td>
</tr>
<tr>
<td>4.5</td>
<td>0.239</td>
<td>0.045</td>
</tr>
<tr>
<td>4</td>
<td>0.226</td>
<td>0.040</td>
</tr>
<tr>
<td>3.5</td>
<td>0.211</td>
<td>0.035</td>
</tr>
<tr>
<td>3</td>
<td>0.195</td>
<td>0.030</td>
</tr>
<tr>
<td>2.5</td>
<td>0.178</td>
<td>0.025</td>
</tr>
<tr>
<td>2</td>
<td>0.160</td>
<td>0.020</td>
</tr>
</tbody>
</table>

Where deformed wire is required the size number shall be preceded by D, and for smooth wire, the prefix W will be shown.

D. Where plain steel wire is used for concrete reinforcement, it shall meet the requirements of ASTM A1064.

Fabricated deformed steel bar mats shall meet the requirements of ASTM A184 “Standard Specification for Welded Deformed Steel Bar Mats for Concrete Reinforcement”, while plain steel welded wire fabric shall meet the requirements of ASTM A1064.

Deformed steel wire for concrete reinforcement and deformed steel welded wire fabric shall meet the requirements of ASTM A1064.

440.3 Bending. The reinforcement shall be bent cold, true to the shapes indicated on the plans. Bending shall preferably be done in the shop. Irregularities in bending shall be cause for rejection. Unless otherwise shown on the plans, bends shall be made in accordance with ACI 315.
Bends of 90° and greater in stirrups, ties and other secondary bars that enclose another bar in the bend, in terms of the nominal bar diameter (d), shall be as follows:

**TABLE 3**

<table>
<thead>
<tr>
<th>BAR SIZE</th>
<th>GRADE 40</th>
<th>GRADE 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3, #4, #5</td>
<td>4d</td>
<td>4d</td>
</tr>
<tr>
<td>#6, #7, #8</td>
<td>6d</td>
<td>6d</td>
</tr>
</tbody>
</table>

All bends in main bars and in secondary bars not covered above shall be as follows:

**TABLE 4**

<table>
<thead>
<tr>
<th>BAR SIZE</th>
<th>GRADE 40</th>
<th>GRADE 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3 through #8</td>
<td>6d</td>
<td>6d</td>
</tr>
<tr>
<td>#9, #10, #11</td>
<td>8d</td>
<td>8d</td>
</tr>
<tr>
<td>#14, #18</td>
<td>10d</td>
<td>10d</td>
</tr>
</tbody>
</table>

440.4 Fabricating Tolerances. Fabricating tolerances for bars shall be as indicated in ACI 315.

440.5 Storing. Steel reinforcement shall be stored above the surface of the ground upon platforms, skids or other supports and shall be protected from mechanical injury and surface deterioration caused by exposure to conditions producing rust. When placed in the work, reinforcement shall be free from dirt, paint, grease, oil or other foreign materials. Reinforcement shall be free from injurious defects such as cracks and laminations. Rust, surface seams, surface irregularities or mill scale will not be cause for rejection, provided the minimum dimensions, cross-sectional area and tensile proportions of a hand wire brushed specimen meets the physical requirements for the size and grade of steel specified.

440.6 Lap Splices. Splicing of bars, except where shown on the plans, will not be permitted without prior approval of the Engineer.

Splices, not provided for on the plans, will be permitted in slabs not more than 15 inches in thickness, columns, walls and parapets subject to the following:

Splices will be permitted in bars 30 feet or less in plan length. For bars exceeding 30 feet in plan length, the distance center to center of splices shall not be less than 30 feet minus one splice length, with no more than
one individual bar length less than 10 feet. Splices not shown on the plans, but permitted hereby, shall be made in accordance with Table 5. The specified concrete cover shall be maintained at such splices and bars placed in contact and securely tied together. Lap bars so that both bars will be in the same plane parallel to the nearest concrete surface.

### TABLE 5

**MINIMUM LAP REQUIREMENTS**

<table>
<thead>
<tr>
<th>BAR SIZE</th>
<th>GRADE 40</th>
<th>GRADE 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3</td>
<td>1’ - 0”</td>
<td>1’ - 4”</td>
</tr>
<tr>
<td>#4</td>
<td>1’ - 2”</td>
<td>1’ - 9”</td>
</tr>
<tr>
<td>#5</td>
<td>1’ - 5”</td>
<td>2’ - 2”</td>
</tr>
<tr>
<td>#6</td>
<td>1’ – 9”</td>
<td>2’ – 7”</td>
</tr>
<tr>
<td>#7</td>
<td>2’ – 4”</td>
<td>3’ - 5”</td>
</tr>
<tr>
<td>#8</td>
<td>3’ – 0”</td>
<td>4’ – 6”</td>
</tr>
<tr>
<td>#9</td>
<td>3’ – 10”</td>
<td>5’ – 8”</td>
</tr>
<tr>
<td>#10</td>
<td>4’ – 10”</td>
<td>7’ – 3”</td>
</tr>
<tr>
<td>#11</td>
<td>5’ – 11”</td>
<td>8’ – 11”</td>
</tr>
</tbody>
</table>

Spiral steel will be lapped a minimum of one turn.

Bar sizes #14 and #18 may not be lapped.

#### 440.7 Welded Splices

Welded Splices. Where shown on the plans or required by the provisions of this Item or other pertinent specifications, welded bar splices shall be used. All welding operations, processes, equipment, materials, workmanship and inspection shall conform to the American Welding Society Specification D1.4. For bars #6 and smaller, use lap weld splices with fillet welds equal to one half bar diameter on each side, for 4 inches in length. For bars #7 and larger, use butt weld splices in accordance with AWS D1.4.

All splices whether lap, weld, mechanical or coupler, shall develop the full strength of the bar. Information on mechanical splicing devices and couplers shall be submitted for approval prior to use.

#### 440.8 Placing

Placing. Steel reinforcement shall be placed in the exact position as shown on the plans and held securely in place during the placing of the concrete. The dimensions shown are to centers of bars, unless otherwise noted. Hold bars securely in place with wire and other approved means during placement of concrete.
A. In plane of steel parallel to nearest surface of concrete, bars should not vary from plan spacing by more than one twelfth of spacing between bars.

B. In plane of steel perpendicular to nearest surface of concrete, bars shall not vary from plan placement by more than 1/4 inch.

Space steel the required distance from forms or earth by approved galvanized metal spacers, metal spacers with plastic coated tips, stainless steel spacers, plastic spacers, or approved precast mortar or concrete blocks. For approval of plastic spacers, provide samples of plastic which show no indications of deterioration after immersion in a 5 percent solution of sodium hydroxide after 120 hours.

Use galvanized metal chairs to support all reinforcing steel, except that pavement steel chairs need not be galvanized. Use a heavy bolster to support bottom layer of reinforcing in abutment caps, bent caps and other beams.

In bridge deck slabs, use two rows of supports for bottom layer of reinforcing parallel to beams for each bay. Use high chairs to support top layer.

Reinforcing steel for bridge slabs, top slabs or direct traffic culverts and the top slabs of prestressed box beams shall be tied at all intersections, except that where the spacing is less than one foot in each direction, alternate intersections only need be tied. For reinforcing steel cages or other structural members, the steel shall be tied at enough intersections to provide a rigid cage of steel. Mats or wire fabric shall overlap each other one full space as a minimum to maintain a uniform strength and shall be fastened securely at the ends and edges.

Before any concrete is placed, all mortar, mud, dirt, etc., shall be cleaned from reinforcement. No concrete shall be deposited, until the Engineer has inspected the placement of the reinforcing steel and given permission to proceed.

440.9 Submittals. The following information shall be submitted for reinforcing steel. Six sets of each item shall be submitted.

A. Product data for all materials used.

B. Shop drawings indicating locations, placement, sizes and bending. Shop drawings shall be in accordance with the ACI Manual of Practice for Detailing Reinforced Concrete Structures.
C. When welding is required, furnish report of chemical analysis, showing percentages of carbon, manganese, phosphorus and sulfur.

D. Submit certified copies of mill certificates of compliance with requirements herein specified.

E. Submit information on mechanical splicing devices, couplers, and all other reinforcing accessories.

440.10 Measurement & Payment. Reinforcing steel quantities will not be measured or paid for directly. All costs of furnishing, fabrication, placement, ties, chairs, bending, labor and equipment shall be considered subsidiary to bids for concrete structures, requiring reinforcement.

There are no line code(s), description(s), or unit(s) for this Item.

END OF ITEM 440
ITEM 441

STEEL STRUCTURES

441.1 Description. This Item shall govern for the fabrication and erection of structural steels and other metals, except reinforcing steel, which are used for steel structures or steel portions of structures.

441.2 Materials. The metal used for the various portions of the structures shall be as specified and shall conform to the requirements of the Item 442 "Metals for Structures".

Electrodes for welding shall conform to the following:

A. For manual shielded metal arc welding, AWS A5.1 or AWS A5.5.

B. For gas metal arc welding, AWS A5.18 or AWS A5.20.

441.3 Submittals. Unless otherwise provided on the plans, the Contractor shall prepare and submit detailed shop drawings for each detail of the general plans requiring the use of structural steel. Camber and erection drawings will also be required.

Preparation and submission of drawings may be either on full or half size sheets. However, drawings must be completely clear and legible.

Six copies of shop drawings and six copies of erection drawings will be required. The drawings shall reflect the use of submerged arc welding, gas metal arc welding or cored arc welding.

Erection drawings shall show the sequence of erection, the location of falsework and the location of ground and air splices, with the proposed method of support, to determine any overstress caused by the erection procedure.

Contractor shall furnish the following information for members fabricated by welding or bolting.

A. Fabricating procedures.

B. Calculated stresses.

C. List of equipment used for fabrication.

D. Sequence of assembly.
E. Details of connections.

F. Special processes such as planing, facing, etc.

Contractor shall submit certified copies of mill certificates of compliance with requirements herein specified for structural steel and other metals. Mill certificates are not required for miscellaneous hardware, bolts, nuts, washers, screws, etc.

Contractor shall submit certified copies of shop welding tests in compliance with requirements herein specified.

441.4 Welding. Welding shall be in accordance with the Item 446 "Structural Welding". Qualifications of welders may be required. If no welded splices of main stress carrying members are involved, the tests will consist of the performance of a few samples welds by the welder and the fracture and visual inspection thereof by the Engineer. If splices of main carrying members are involved, qualification procedures shall conform to the latest Specifications for Welded Highway & Railway Bridges, published by the American Welding Society. The expense of qualification shall be borne by the Contractor.

441.5 Fabrication Procedures. When structural members with calculated stress, are fabricated by welding or bolting, a fabrication procedure may be required to be submitted. A fabrication procedure shall include a list of equipment to be used, sequence of assembly, sequence and detail of connections made, special processes such as planing, facing, etc., detail of heat treating procedures, where applicable and any other information concerning fabrication, as may be required by the Engineer.

441.6 Field Erection. Spot welding for the purpose of eliminating field erection bolts or for holding steel parts together, while bolting, will not be permitted. All beams and girders over roadways or railroads shall be securely supported, with special care taken to protect the traffic below from falling objects during construction.

The Contractor shall provide the falsework and all tools, machinery and appliances, including drift pins and fitting up bolts, necessary for the expeditious handling of the work. Drift pins sufficient to fill at least one-fourth of the field holes, for main connections, shall be provided.

441.7 Paint & Painting. Shop painting shall conform to the requirements of the "American Institute of Steel Construction", except that steel shall be cleaned by buffing. Paint shall be applied at the minimum rate of one
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gallon to 450 square feet. Shop painting shall only be done if specified on the plans.

Field painting shall be in accordance with the Item 447 "Painting and Protective Coating".

441.8 Measurement & Payment. No direct compensation will be made for "Steel Structures". Measurement and payment for same shall be in accordance with the contract price bid, for work of which this is a component part.

There are no line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 442 “Metals for Structures”
Item 446 “Structural Welding”
Item 447 “Painting and Protective Coating”

END OF ITEM 441
ITEM 442

METALS FOR STRUCTURES

442.1 Description. This Item shall govern for materials such as structural steel, wrought iron, bronze, and other metals used in structures, except reinforcing steel.

442.2 Materials

A. Unless otherwise indicated by these Standard Specifications, structural steel shall be carbon steel conforming to the requirements of ASTM A36 “Standard Specification for Carbon Structural Steel.”

B. Miscellaneous Steel. Unless otherwise shown on the plans, structural steel for members such as shoes, diaphragms, stiffeners, lateral bracing, etc., shall conform to ASTM A36 or ASTM A500 “Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes”, Grade B.

C. Stud shear connectors, slab anchors and anchors on armor joints and finger joints shall conform to the requirements of ASTM A108 “Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished”, cold drawn bars or Grades 1015, 1018, or 1020, either semi or fully kilned.

Tensile properties as determined by tests of bar stock after drawing or finishing shall conform to the following:

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength (Min.)</td>
<td>60,000 psi</td>
</tr>
<tr>
<td>Yield Strength (Min.)</td>
<td>50,000 psi</td>
</tr>
<tr>
<td>Elongation (Min.)</td>
<td>20% in 2 inches</td>
</tr>
<tr>
<td>Reduction of Area (Min.)</td>
<td>50%</td>
</tr>
</tbody>
</table>

Tensile properties shall be determined in accordance with the applicable section of ASTM A370 “Standard Test Methods and Definitions for Mechanical Testing of Steel Products.”

The manufacturer shall certify that the studs or anchors, as delivered, conform to the material requirements of this section.

D. Steel piling shall conform to the following:
<table>
<thead>
<tr>
<th>TYPE</th>
<th>ASTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel H Piling</td>
<td>A36</td>
</tr>
<tr>
<td>Metal Shell Piling</td>
<td>A252, Grade 2 or A36 (heavier than 10 gauge)</td>
</tr>
<tr>
<td>Sheet Piling (Rolled)</td>
<td>A328, Grade A</td>
</tr>
<tr>
<td>Sheet Piling (Formed)</td>
<td>A1011 Grade A</td>
</tr>
</tbody>
</table>

A mill certificate shall be furnished by the manufacturer certifying to the results of the tests required by the governing specifications.

E. Galvanized sheet metal shall conform to the requirements of ASTM A653 “Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process”, coating G90.

F. Threaded fasteners shall conform to the following:


G. Plain and threaded bars used for anchorage purposes shall conform to the requirements of ASTM A36. Headed bolts and nuts shall conform to the requirements of ASTM A307, Grade A. When high strength anchor bolts are designated on the plans, they shall conform to the requirements of ASTM A193 “Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications”, B7. Nuts for high strength anchor bolts shall conform to ASTM A194 “Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both”, 2H.

Threads for anchor bolts and nuts shall be UNC Series, Class 2 fit for 1 inch diameter and smaller. Threads for anchor bolts and nuts over 1 inch diameter shall be 8UN Series, Class 2 fit.

All anchor bolts and nuts, when galvanized, shall be tapped or chased after galvanizing. Anchor bolts shall not be galvanized unless otherwise noted on the plans.
A mill test report or certification will be required indicating that the material conforms to these requirements. When heat treated material is specified or required, the test report for certification relative to the heat treating process shall be submitted.

H. Corrosion resistance (stainless steel) shall conform to the following:

1. Plate, sheet and strip fasteners where no welding is required shall conform to ASTM A167 “Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip”, Type 316 or 304.

2. Plate, sheet and strip fasteners where welding is required shall conform to ASTM A167, Type 316L or 304L.

I. Steel pipe shall conform to ASTM A53 “Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless”, Grade B.

J. Steel tubing shall conform to ASTM A500, Grade B, unless otherwise shown on the plans or herein. Tubing conforming to API Standard 5LX, Grade 52 may be used. Hydrostatic testing shall not be required on API 5LX tubing.

K. Copper products shall conform to the following:


L. Lead sheets shall be of uniform thickness, free from surface imperfections and manufactured from pig lead conforming to ASTM B29 “Standard Specification for Refined Lead.”


N. Deck plates shall conform to ASTM A242 “Standard Specification for High-Strength Low-Alloy Structural Steel.”

Galvanizing touch-up shall be by the application of zinc dust-zinc oxide paint conforming to the requirements of Federal Specification TT-P-641b, or by application of repair compounds conforming to the requirements of Federal Specification O-G-93 (stick only), in accordance with manufacturer's recommendations.

442.4 Measurement. Measurement of the quantity of structural metal furnished and placed will be based on the weight of the metal in the fabricated structures, including the quantity of bolts used in connections.

The weight of paint and all boxes, crates and other containers used for packing, together with sills, blocking and rods used for supporting or protecting members during transportation shall be excluded. Where increases in size or weights of members have been made which was not ordered by the Engineer, but approved by him, measurement will be made on the sizes or weights given on the project plans. No measurement will be made of deposited weld metal.

In determining the weight of structural metal in truss spans, I-beam spans and plate girder spans, such items as bearing plates, lead sheets, anchor bolts, drains and all other metal for which no separate measurement is specified shall be considered as structural steel.

The quantity of structural steel for concrete girder or slab spans shall include the weight of all structural shapes and plates used in drains and structural shapes and plates used in armoring roadway joints.

The weight of metal to be paid for shall be based on computed weights.

Before final payment is made, the Contractor shall furnish the Engineer four sets of shop bills showing the calculated weights of all parts of the structure. The weights shall be computed from the approved shop detail drawings.

442.5 Payment. Structural metal measured as provided above will be paid for at the unit price bid per pound for various items as set forth on the bid proposal and as called for in the specifications for the quantity shown on the plans and in the proposal, which prices shall be full compensation for furnishing all materials and for all fabrication, shop work, transportation,
erection, paint and painting and for furnishing all equipment, tools, labor
and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 442
ITEM 445

STRUCTURAL BOLTING

445.1 Description. This Item shall govern for the materials to be used, and for the method of installation of bolts used in structural connections.

445.2 Material. Unless otherwise indicated on the plans, bolts, nuts and washers shall conform to the requirements of ASTM A325 “Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength.” The length of the bolt shall be such that the point of the bolt will be flush with or outside the face of the nut when installed. Unless otherwise specified, threads for structural bolts and nuts up through 1 inch diameter shall be the UNC series and over 1 inch diameter and larger shall be the 8UN Series as specified in ANSI B1.1 and shall have Class 2A tolerance for Bolts and Class 2B tolerance for Nuts. Galvanized nuts shall be tapped or chased after galvanizing.

445.3 General. Bolted connections shall not be used unless specifically authorized. If bolted connections are permitted, the bolts shall be as specified. Bolts shall have hexagonal heads and nuts and shall be of such length that they will extent through the nut, but not more than 1/4 inch beyond.

Unfinished bolts in shear, shall have not more than one thread within the grip. The diameter of the unfinished bolt shall be not more than 1/16 inch smaller than the diameter of the hole.

The threads of turned bolts shall be entirely outside the grip. The bolts shall be given a finishing cut. Approved nut locks or flat washers 1/4 inch thick shall be furnished, as specified. The holes for turned bolts shall be reamed and their diameters shall be not more than 1/32 inch greater than the diameter of the finished bolt.

Special types of lock bolts may be used with written approval of the Engineer.

445.4 Measurement & Payment. No direct compensation will be made for the installation of bolts or fasteners. Measurement and payment for the bolts required for structural steel joints shall be in accordance with the Item 442 "Metal for Structures".

There are no line code(s), description(s), or unit(s) for this Item.
NOTE: This Item requires other Standard Specifications

Item 442 “Metals for Structures”

END OF ITEM 445
ITEM 446

STRUCTURAL WELDING

446.1 Description. This Item shall govern for the field welding of structural steel and reinforcing steel.

446.2 General. All welding operations, processes, equipment, materials, workmanship and inspection shall conform to the requirements of the latest Specifications for Welded Highway & Railway Bridges as published by the American Welding Society.

Certification of welders will be required. If no weld splices of main stress-carrying members are involved, the tests shall consist of the performance of a few sample welds by the welder and the fracture and visual inspection thereof by the Engineer. If splices of main stress-carrying members are involved, certification procedures shall conform to the latest Specifications for Welded Highway & Railway Bridges as published by the American Welding Society. The expense of certification tests shall be borne by the Contractor.

446.3 Classifications of Electrodes permitted for Field Welds:

<table>
<thead>
<tr>
<th>TYPE OF STEEL</th>
<th>MAIN MEMBERS</th>
<th>SECONDARY MEMBERS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GROOVE WELD</td>
<td>FILLET WELD</td>
</tr>
<tr>
<td>Steel Piling</td>
<td>E6010</td>
<td>E60T-8</td>
</tr>
<tr>
<td>A53 Pipe</td>
<td>E6011</td>
<td>E70S-1B</td>
</tr>
<tr>
<td>A500</td>
<td>E7016</td>
<td>ER70S-2</td>
</tr>
<tr>
<td>A501</td>
<td>E7018</td>
<td>ER70S-3</td>
</tr>
<tr>
<td>Armor Joints</td>
<td>ER70S-6</td>
<td>ER70S-7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A36</td>
<td>E7016</td>
<td>ER70S-2</td>
</tr>
<tr>
<td>A572, Grade 50</td>
<td>E7XT-1</td>
<td>ER70S-6</td>
</tr>
<tr>
<td>A588</td>
<td>E7XT-5</td>
<td>ER70S-7</td>
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<tr>
<td>A242 Deck Plate</td>
<td>E7XT-6</td>
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</tr>
<tr>
<td>TYPE OF STEEL</td>
<td>MAIN MEMBERS</td>
<td>SECONDARY MEMBERS</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------</td>
<td>------------------</td>
</tr>
<tr>
<td></td>
<td>GROOVE WELD</td>
<td>GROOVE WELD</td>
</tr>
<tr>
<td></td>
<td>FILLET WELD</td>
<td>FILLET WELD</td>
</tr>
<tr>
<td>API Pipe</td>
<td>E7XT-8</td>
<td>E7XT-8</td>
</tr>
<tr>
<td>Reinforcing Steel</td>
<td>E7016</td>
<td>E7018</td>
</tr>
</tbody>
</table>

446.4 Reinforcing Steel. Provisions made herein for the welding of reinforcing steel are by the shielded metal-arc process. Other processes may be permitted with the specific approval of the Engineer.

Splicing of reinforcing steel, by welding, shall be done only at the locations shown on the plans.

Reinforcing steel to be welded shall be new billet steel conforming to ASTM A615 “Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement” and shall also conform to the following chemical composition.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Carbon</td>
<td>0.40 Percent</td>
</tr>
<tr>
<td>Maximum Manganese</td>
<td>1.30 Percent</td>
</tr>
</tbody>
</table>

Low hydrogen electrodes, as specified in Table 1, will be required for all welding of reinforcing steel.

Butt splices will be required for all #8 bars and larger.

Lap splices will be required for #7 bars and smaller.

Lap splices shall be fillet welded a minimum of 4 inches in length on each side of the lap.

For #5 bars and smaller, welding from one side of the lap will be permitted by the Engineer, when it is impractical to weld from both sides of the lap, provided the weld is a minimum of 6 inches in length.

446.5 Measurement & Payment. No measurement or payment will be made under this Item for the work prescribed, but shall be considered subsidiary to the various other bid items called for in the contract.

There are no line code(s), description(s), or unit(s) for this Item.

END OF ITEM 446
ITEM 447

PAINTING AND PROTECTIVE COATING

447.1 Description. This Item shall govern for the finished paints, their source and for the application of paint to structures. The painting of structures shall include, unless otherwise provided in the contract, the proper preparation of the surfaces, the application, protection and drying of the paint coatings, the protection of pedestrian, vehicular or other traffic upon or underneath the structure, the protection of all parts of the structure (superstructure or substructure) against disfigurement by splatters, splashes and/or smirches of paint materials and the supplying of all tools, tackle, scaffolding, labor, workmanship, paint and materials necessary for the entire work.

Surface conditions and application requirements are specified with the intent to obtain full adhesion of coatings to clean dry surfaces and to previously applied coats. This will require careful attention to the preparation of surfaces, to prevention of contamination and moving of coatings, during and after drying and to the uniform skillful application of each coat of paint.

Surfaces receiving paint include:

A. Metal surfaces when designated by the plans, or in these Standard Specifications.

B. Concrete surface when noted on the plans.

C. Interior concrete surfaces of concrete boxes, when noted on the plans.

D. Galvanized steel surfaces when required by the plans, or in these Standard Specifications.

Do not paint the surface of stainless steel, aluminum, bronze, copper and lead.

447.2 Quality Assurance. All paints, sealers and coating shall be manufactured by those firms listed in Table 2. Products of equal quality by other manufacturers will be considered, subject to review of written submittal that includes product data and a detailed coating and painting schedule.
Contractor shall provide the manufacturer's written instructions on cleaning and coating, prior to any surface preparation or coating. Whenever possible, all coatings shall be from a single manufacturer.

447.3 Submittals. Contractor shall submit a list indicating major items to be painted, preparation, paint manufacturer, product designation and dry mil thickness.

Contractor shall also submit panels containing samples of proposed paints and coatings. Include 3 displays of each kind and color of paint used. Panel to be representative of material to be coated.

If requested by the Engineer, Contractor shall submit 1/4 pint of each kind of paint and coating proposed for use. For all paint and coatings, Contractor shall furnish Engineer with 2 sets of printed instructions and application sheets.

447.4 Products. Tables 1 and 2 of this Item include the paint, protective coatings and sealers for the project. Contractor shall furnish all such specific materials required for the manufacturer's coating systems, whether or not included in these Standard Specifications.

The Engineer shall select the colors. Contractor shall submit a list of items to be painted and the color charts.

Contractor shall follow the OSHA requirements of 29 CFR Part 1910.44 for "Safety Color Codes for Marking Physical Hazards".

The following general hazards are set forth as a guide:

A. Red-Fire protection equipment, danger signs and fire exit signs;
B. Orange-Moving parts of equipment protected by guards;
C. Yellow-Caution signs and all physical hazards;
D. Green-To designate safety;
E. Black & White-To indicate areas that must remain clear.

447.5 Surface Preparation. Prior to painting, concrete surfaces shall be free of all latent matter, burrs and fins, using one or more of the following methods:
A. Wash concrete surfaces with 10 percent solution of muriatic acid, then wash clean and free of scale, mortar, dust, moisture and other foreign matter.

B. Sandblasting may be used if adjacent equipment is adequately protected.

C. Remove oil and grease with detergent and thoroughly rinse with fresh water.

If curing compound is used, it must be removed prior to coating.

Metal surface shall be cleaned by sandblasting in the shop as required by Table 1 and leave clean, dry and ready to receive a prime coat. Contractor shall provide moisture separators to effectively remove all oil and free moisture from air supply. All dust and sand shall be removed from surface by brushing or blowing with clean dry air and removing all sand and grit around and between joints of connecting members.

Field sandblasting shall be done only if required to correct unsatisfactorily cleaned and shop primed metal.

Oil and grease shall be removed with a solvent approved by the coating manufacturer, or by steam combined with detergent. The use of gasoline, kerosene, naptha, or carbon tetrachloride shall not be permitted.

In field work, where sandblasting is not possible, scrapers, wire brushes and other suitable grinding or chipping tools may be used for the removal of existing paint coatings prior to repainting or for cleaning before applying second coat.

Surfaces which have been cleaned, but which have started to show signs of rust or dirt, are to be cleaned again prior to coating at no additional expense to Harris County. Surfaces shall be coated the same day they are cleaned.

447.6 Application of Paint & Protective Coating. Contractor shall protect floors and all other areas where work is done with suitable drop cloths and remove oil rags and waste from work area at the close of each day’s work. On completion of operations, Contractor shall remove all spots, oil and stain from all surfaces and leave the entire project in a clean condition. Remove from premises, all containers and debris resulting from this work.

Contractor shall use only those thinners and solvents specified in paint formulas of the paint being used and shall use in the proportions recommended by the paint manufacturer.
Coverage shall be as recommended by the paint manufacturer and sufficient to obtain the minimum mil thickness specified. If applicable, Contractor shall not exceed the maximum mil thickness specified by the manufacturer. After the final coat is applied, the thickness shall be checked with an elecometer or mikotest dry film thickness gauge. The drying time specified by the manufacturer, shall be allowed between coats.

For brush application, use first quality hog hair or suitable synthetic bristle brushes. The use of horsehair bristle brushes is not permitted. Brushes shall be kept clean and free from the accumulation of dried paint or dirt. When brushes for oil or varnish base paints are not in use, they shall be kept suspended in a linseed oil bath. Brushes shall be cleaned with turpentine or mineral spirits, before reuse. Brush application shall be by uniform thickness, consistent with specified coverage and with sufficient cross-brushing to ensure filling of surface irregularities. Care shall be exercised in painting around bolt heads and nuts and in corners and other restricted space.

Spray application shall be done with an adjustable air gun, equipped with suitable water trap to remove moisture from compressed air and with a paint pot having a hand agitator. Application shall be made with a width of spray not less than 12 inches, nor more than 18 inches and with a suitable pressure for the particular type of paint being used. Contractor shall make frequent checks to ensure a correct spreading rate and coating and shall apply without sags or runs.

Metal surfaces shall be shop primed prior to delivery to the job site. After delivery and prior to installation, all coated metal surfaces shall be kept clean and free from corrosion. Contractor shall clean up or repair damaged areas with additional primer.

After erection or installation of metal work, clean and touch up all rust spots and all places where primer has been rubbed or scraped off and all bolts and nuts. After previously applied paint has hardened and when surfaces to receive succeeding coats of paint have been cleaned and dried, apply finish paint in accordance with Tables 1 and 2. Allow 5 days or more, as recommended by coating manufacturer for hardening of final coat for submerged surfaces.

447.7 Special Requirements. Contractor shall provide electrical flow detection equipment, such as a Tinker Rasor Holiday Detector to test areas of coatings that are to be submerged. Tests are to be performed before structure is put into the water.
447.8 Measurement & Payment. No separate payment shall be made for work performed under this Item. Include the cost of same in the contract price bid for work of which this is a component part.

SEE ATTACHED TABLE 1 & 2

TABLE 1
SYSTEM SCHEDULE

<table>
<thead>
<tr>
<th>TYPE OF SURFACE</th>
<th>EXPOSURE</th>
<th>CLEANING</th>
<th>1st PRIMER</th>
<th>2nd COAT</th>
<th>3rd COAT</th>
<th>MIN. TOTAL MIL COAT THICKNESS</th>
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</thead>
<tbody>
<tr>
<td>Structural and Misc. Steel</td>
<td>Exterior</td>
<td>NACE #2</td>
<td>16</td>
<td>18</td>
<td>9</td>
<td>7.0</td>
</tr>
<tr>
<td>Structural and Misc. Steel</td>
<td>Interior</td>
<td>NACE #3</td>
<td>16</td>
<td>17</td>
<td>-</td>
<td>5.5</td>
</tr>
<tr>
<td>Galvanized Steel</td>
<td>Interior</td>
<td>Solvent Cleaning</td>
<td>15</td>
<td>17</td>
<td>-</td>
<td>2.9</td>
</tr>
<tr>
<td>Galvanized Steel and Galvanized Pipe Conduit Threads</td>
<td>Exterior</td>
<td>Solvent Cleaning</td>
<td>15</td>
<td>18</td>
<td>9</td>
<td>4.4</td>
</tr>
</tbody>
</table>

| Wet-Well Surfaces | Interior | Para. 3.01A | 6 | 13 | 13 | 22 |

Note: NACE - Reference to National Association of Corrosion Engineers.

TABLE 2
PAINT, SEALER, AND COATING SCHEDULE

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>MINIMUM DRY MILS PER COAT*</th>
<th>SERVICE</th>
<th>GENERIC TYPE</th>
<th>BRAND AND MANUFACTURER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>N/A</td>
<td>Primary Sealer</td>
<td>Chemical Penetrant</td>
<td>46-V-6 Silikote Water Repellent-Mobil</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>MINIMUM DRY MILS PER COAT*</td>
<td>SERVICE</td>
<td>GENERIC TYPE</td>
<td>BRAND AND MANUFACTURER</td>
</tr>
<tr>
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</tr>
<tr>
<td>2.</td>
<td>N/A</td>
<td>Weatherproof Primary Sealer</td>
<td>Acrylic Emulsion</td>
<td>600 Emulsion-Koppers Concrete and Masonry Filler</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>79-W-1 Exterior Latex Primer-Valspar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Amercoat 5625-Ameron</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>Cook Cocoryl 827 Series</td>
</tr>
<tr>
<td>3.</td>
<td>N/A</td>
<td>Primary Sealer</td>
<td>Vinyl-Acrylic Emulsion with Epoxy Esters</td>
<td>600 Emulsion-Koppers Concrete and Masonry Filler</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>79-W-8 Block Filler Valspar</td>
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<td>Amercoat 5625-Ameron</td>
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<td></td>
<td>Cook 304 Block Filler</td>
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<td>4.</td>
<td>1.5</td>
<td>Finish Coat</td>
<td>Acrylic Emulsion</td>
<td>Koppers-600-Koppers 79 Series Exterior Latex-Valspar</td>
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<td>Amercoat 5801-Ameron</td>
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<td></td>
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<td>Cook Corocryl 827 Series</td>
</tr>
<tr>
<td>5.</td>
<td>1.5</td>
<td>Metal Primer</td>
<td>Alkyd, Zinc Chromate</td>
<td>Penetrating Primer No. 622-Koppers</td>
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<td>13-R-50 Chromox Primer-Valspar</td>
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<td>Amercoat 5105-Ameron</td>
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<td>Cook 814-Y-436</td>
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<tr>
<td>SYMBOL</td>
<td>MINIMUM DRY MILS PER COAT*</td>
<td>SERVICE</td>
<td>GENERIC TYPE</td>
<td>BRAND AND MANUFACTURER</td>
</tr>
<tr>
<td>--------</td>
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<td>--------------</td>
<td>------------------------</td>
</tr>
</tbody>
</table>
| 6.     | 2.0                         | Metal Primer | Polyamide Cured Epoxy Resin | 654-Epoxy Primer-Koppers  13-R-56 Epoxy Primer-Valspar  
Amercoat 71-Ameron  
Cook Co-Poly Primer 920-Y-134  
Inorganic Coatings, Inc. P21 Epoxy |
| 7.**   | 2.0 – 4.0 (as recommended) | Metal Primer | Polyamide Cured Epoxy Resin | Epoxy Coating Hi-Gard-Koppers  
78 Series High Build Epoxy w/ 50% Valspar  
7-T-35-Valspar  
Amercoat 395 (off white)-Ameron  
Cook Epicon MW 920-W-965  
Inorganic Coatings, Inc. P21Epoxy |
| 8.     | 1.5                         | Finish Coats | Alkyd, Straight Long-Oil | Rustarmor 500 Enamel-Koppers  
12 Series Panorama Coatings Valspar  
Amercoat 5401-Ameron  
Cook 801 Enamel |
| 9.     | 2.0                         | Finish Coat  | Aliphatic Urethane | Inorganic Coatings, Inc. P35 Urethane  
Dupont Imron 326  
Devoe-Napko 369 Pruthane |
<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>MINIMUM DRY MILS PER COAT*</th>
<th>SERVICE</th>
<th>GENERIC TYPE</th>
<th>BRAND AND MANUFACTURER</th>
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</thead>
<tbody>
<tr>
<td>10.</td>
<td>1.5</td>
<td>Wood Primer</td>
<td>Oil Base</td>
<td>Thin Rustarmor 500 Koppers 400-Koppers</td>
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<td>17-W-4 Exterior First Coater Valspar</td>
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<td>Cook 307</td>
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<td>11.</td>
<td>1.5</td>
<td>Finish Coat</td>
<td>Alkyd, Straight Long-Oil</td>
<td>Rustarmor 500 Enamel-Koppers</td>
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<td>20 Series M.F. Enamel-Valspar</td>
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<td>Amercoat 5401-Ameron</td>
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<td></td>
<td></td>
<td></td>
<td>Cook 801 Enamel</td>
</tr>
<tr>
<td>12.**</td>
<td>4.0 – 6.0 (as recommended)</td>
<td>Submerged Steel, Iron and Concrete</td>
<td>Polyamide Cured Epoxy Resin</td>
<td>Epoxy Coating Hi-Gard-Koppers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>78 Series High Build Epoxy-Valspar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Amercoat 395 (white)-Ameron</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Cook Coal Tar Epoxy 920-B-950</td>
</tr>
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<td></td>
<td>Inorganic Coatings, Inc. P29 Coal Tar Epoxy</td>
</tr>
<tr>
<td>13.</td>
<td>10</td>
<td>Submerged Steel or Iron</td>
<td>Coal Tar Epoxy Two Component</td>
<td>300-M-Koppers</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>578-J-1 High Build Coal Tar Epoxy-Valspar</td>
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<tr>
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<td>Amercoat 330-Ameron</td>
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<td>Cook Coal Tar Epoxy 920-B-950</td>
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<td></td>
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<td>Inorganic Coatings, Inc. P29 Coal Tar Epoxy</td>
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<tr>
<td>SYMBOL</td>
<td>MINIMUM DRY MILS PER COAT*</td>
<td>SERVICE</td>
<td>GENERIC TYPE</td>
<td>BRAND AND MANUFACTURER</td>
</tr>
<tr>
<td>--------</td>
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<td>------------------------</td>
</tr>
<tr>
<td>14.</td>
<td>16</td>
<td>Buried Steel or Iron</td>
<td>Tar Base Pitch</td>
<td>Bitumastic No. 50-Koppers 35-J-10 High Build Bituminous Coating Valspar</td>
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<td>16.</td>
<td>3.0</td>
<td>Steel Above Ground and Above Waterline</td>
<td>High Ratio Silicate Inorganic Zinc</td>
<td>Inorganic Coatings, Inc. IC531 Dupont 347 WB Inorganic Zinc Devoe-Napko Zinc Prime 9Z</td>
</tr>
<tr>
<td>17.</td>
<td>2.5</td>
<td>Steel Interior</td>
<td>Polyamide Cured Epoxy Resin</td>
<td>Inorganic Coatings, Inc. P24 Epoxy Dupont Corlar 823 Devoe-Napko 545 Epoxy</td>
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<tr>
<td>18.</td>
<td>2.0</td>
<td>Intermediate Finish</td>
<td>Epoxy Primer</td>
<td>Inorganic Coatings, Inc. P21 Epoxy Dupont Corlar 823 Devoe-Napko Chemfast 545 Buff</td>
</tr>
</tbody>
</table>

* Or manufacturer's standard, whichever is greater. Do not exceed manufacturer's maximum standard, if applicable.

** For potable water use.
There are no line code(s), description(s), or unit(s) for this Item.

END OF ITEM 447
ITEM 448

BRIDGE PLAQUE

448.1 Description. This Item shall govern for plaque(s) to be furnished and installed on a bridge structure at the location designated on the contract drawings or as ordered by the Engineer.

448.2 Materials.

A. The plaque shall be made of solid cast aluminum and to the dimensions shown on the plaque drawing.
   1. The letter style shall be BLOCK.
   2. The background texture shall be matte.

B. The plaque shall be affixed to the bridge structure either cast-in-place or affixed utilizing methods approved by the Engineer.

448.3 The Contractor shall submit a sample of the proposed layout of the print to be used on the plaque to the Engineer for approval prior to fabrication. Harris County reserves the right to make name changes at that time.

448.4 Measurement and Payment.

The plaque shall be measured by each, installed at the location designated on the contract drawings or as ordered by the Engineer.

Payment for the plaque shall be by each at the contract unit price bid. Payment shall be full compensation for furnishing and installing the plaque in the designated place and all work associated with the plaque to include submission of the sample of the plaque for approval, prior to fabrication of the plaque.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires a Standard Civil Drawing that shall be incorporated into the contract documents.

END OF ITEM 448
ITEM 450

CONCRETE AND STEEL RAILING

450.1 Description. This Item shall govern for the construction of concrete or steel railing, or a combination of these materials on bridges, culverts, walls, or incidental structures as shown on the plans.

In general, railing shall include that portion of the structure erected on and above the roadway or along the edges of walks, curbs and/or slabs for the protection of traffic and pedestrians and shall include any tie-in anchorage to approach railing or guard fence.

Railing, including the necessary anchorage, shall be in accordance with these Standard Specifications and the details shown on the plans.

450.2 Materials. All materials shall conform to the requirements of Item 420 "Concrete Structures", Item 440 "Reinforcing Steel", Item 442 "Metals for Structures", Item 441 "Steel Structures" and Item 421 "Structural Concrete".

450.3 Quality Assurance. Bridge railings shall meet the requirements of the Texas Department of Transportation's, "Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges", Latest Edition.

450.4 Submittals. Contractor shall submit fabrication drawings for metal railing, showing construction and materials.

450.5 Steel Railing. Fabrication and erection of railing shall conform to the pertinent provisions of the Item 441 "Steel Structures" and to the requirements of these Standard Specifications.

Splicing of members will be permitted only as provided by the plans. All splice locations and details shall be shown on the shop or erection drawings. For metal railings, shop or erection drawings shall be prepared and forwarded for approval in accordance with the requirements of the Item 441 "Steel Structures".

Shop welding shall be in accordance with the Item 441 "Steel Structures" while field welding, when required, shall be in accordance with the Item 446 "Structural Welding".

Pipe rail and posts, shop fabricated into panels shall be mounted in a jig clamped in their true relative position, accurately spaced with respect to
each other and while assembled shall be completely welded or bolted, as the case may be. When required by the plans, as each rail section is completely assembled and connected, the adjacent section shall be set in its proper relative position with the ends engaged and remain in this position until completely connected. Each pair of sections shall be matchmarked so they may be erected in the same order in which they were fabricated.

The fabricated elements for deep beam railing shall conform to the dimensions and cross-section shown on the plans. The rail shall be straight and free from warp. The maximum deviation for straightness of either edge of a full length section shall be one-half of an inch. Rail elements shall be jointed and connected to the rail posts as shown on the plans. Lapped elements shall have the lap in the direction of traffic in the adjacent lane.

**Concrete Railing.** The concrete portions of railing shall conform to the provisions of the Item 420 "Concrete Structures", and to the requirements of this Item. Provisions shall be made in constructing forms to provide for checking and correction of railing lines and grades after concrete has been placed, but before initial set. The finish floating of the railing tops shall not disturb the form alignment after the final check. Particular care shall be exercised in other construction operations to avoid disturbing or vibrating the span with the newly placed railing.

Reinforcing steel for concrete railing shall conform to the pertinent provisions of the Item 440 "Reinforcing Steel".

Concrete railing may be constructed with slip-forms with equipment approved by the Engineer. Sensor control for both line and grade must be provided.

Whether slip-formed, cast-in-place or precast, the concrete must be cured with membrane curing compound.

**Protective Coating.** Unless otherwise noted on the plans, all portions of steel railing shall be galvanized.


After erection, any damaged galvanizing on steel posts and rail elements shall be thoroughly cleaned and painted with two coats of zinc dust-zinc
oxide paint conforming to the requirements of Federal Specification TT-P-641b or repaired by the application of repair compounds meeting Federal Specification 0-G-93.

When fabrication is done after galvanizing and when specifically required by the plans, the cut edges and bolt holes shall be cleaned by brushing and the cleaned area shall be treated as specified above.

450.8 Measurement. Railing, of the type designated, shall be measured by the linear foot, in accordance with the dimensions and details shown on the plans. Measurement will be made upon the face of the rail in place.

450.9 Payment. Payment will be made at the contract unit price bid per linear foot for railing of the type indicated on the plans, complete in place, measured as provided herein, which price shall be full compensation for furnishing, preparing and placing of all concrete, expansion joint material, reinforcing steel, structural steel, pipe, anchor bolts, anchorage devices and all other materials required in the finished railing and for all labor, tools, hardware, equipment, galvanizing and all other incidentals necessary to complete the work in the manner and in accordance with the plans and these Standard Specifications.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 420 “Concrete Structures”
Item 421 “Structural Concrete”
Item 440 “Reinforcing Steel”
Item 441 “Steel Structures”
Item 442 “Metals for Structures”
Item 446 “Structural Welding”

END OF ITEM 450
ITEM 451

REMOVING AND REPLACING DAMAGED RAILING

451.1 Description. This Item shall govern for the removal of existing railing, modified as indicated on the plans and replacing it on finished bridges at locations indicated on the plans and in accordance with these Standard Specifications and the details shown on the plans.

451.2 Construction Methods. Existing railing shall be removed in such a manner that it will not be damaged and shall be placed carefully on adequate blocking in a storage area approved by the Engineer, so that it will not interfere with the traffic. Any materials of the railing that are lost, damaged by repair or broken by the Contractor shall be replaced at his expense.

Damaged railing shall be replaced as shown on the plans and as directed by the Engineer. New anchor bolts and washers, and railing, etc., shall be provided as necessary to repair the railing and place it back into position.

Galvanized steel railing shall be cleaned thoroughly to an acceptably uniform color. Galvanizing damaged in removal or replacement, or galvanizing which has been damaged previously shall be cleaned thoroughly of rust or other foreign matter and the cleaned area shall be painted with two coats of zinc dust-zinc oxide paint conforming to the requirements of Federal Specification TT-P-641b, or shall be repaired by application of galvanizing repair compounds meeting Federal Specification O-G-93 in accordance with the manufacturer's recommendations.

451.3 Measurement. Removing and replacing damaged railing shall be measured by the linear foot of railing, complete in place. Measurement will be made upon the face of the rail, in place, in accordance with the dimensions shown on the plans.

Work performed under this Item shall be performed at such time and executed in such manner that will cause a minimum of inconvenience to traffic.

451.4 Payment. The work performed as prescribed by this Item, measured as provided above, will be paid for at the unit price bid for "Removing & Replacing Damaged Railing", of the type specified, which price shall be full compensation for salvaging the existing railing or rebuilding it complete in place as shown on the plans and for furnishing all additional materials, galvanizing and for all labor, tools, hardware, equipment and incidentals necessary to complete the work.
There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 451
ITEM 452

REMOVING RAILING

452.1 Description. This Item shall govern for the removal and disposal of railing which is not to be reused on the structure, but is to be completely replaced with other railing. The removal may be on one side only, or on both sides of the structure. All railing considered salvageable shall become the property of Harris County and shall be stockpiled at a location directed by the Engineer.

452.2 Construction Methods. The existing railing shall be removed to the lines and grades shown on the plans by the use of air driven equipment or other suitable means. The use of explosives will not be permitted. Care shall be taken to avoid damage to that portion of the concrete that is to remain in place. Any concrete removed beyond the neat lines, or the lines established by the Engineer, shall be replaced at the Contractor's expense.

Existing reinforcing steel, in concrete posts, that is not to be used as dowels shall be cut off a minimum of 1 inch below the surface of the concrete. The concrete removed in making the cut-off shall be replaced in a manner satisfactory to the Engineer.

The top of the concrete where railing is removed, shall be refinished in such a manner as to leave a neat surface.

Old concrete shall be removed, from the job site as directed by the Engineer.

Work performed under this Item shall be performed at such time, and executed in such a manner as to cause a minimum of inconvenience to traffic.

452.3 Measurement & Payment. Unless otherwise provided on the plans or the specifications, the furnishing of all materials, equipment and labor necessary to complete the work required by this Item will not be measured for payment under this Item, but will be included in the unit price bid for the item or items for which this work is a component part.

There are no line code(s), description(s), or unit(s) for this Item.

END OF ITEM 452
ITEM 453
TEMPORARY RAILING

453.1 Description. This Item shall govern for the installation of temporary railing, at the locations shown on the plans, in conformity with plan details and the requirements of this Item.


453.3 Materials. Use timber posts, wheel guards, rail members, and other components made from commercial grade lumber in good condition. Used timber will be acceptable, with the approval of the Engineer.

Steel components and flex beams shall be in good condition, meeting the requirements for the use intended.

Portions of the temporary railing meeting the requirements of Item 450 "Concrete and Steel Railing" are acceptable for re-use in the permanent structure.

453.4 Construction. Contractor shall construct the temporary railing from materials shown and in accordance with the details on the plans.

453.5 Installation. Temporary railing shall be as shown on the plans and in the increments required by the various phases of construction.

After erection, thoroughly clean and paint all parts not galvanized. Paint other portions of the rail with one coat of commercial grade aluminum paint, unless otherwise shown on the plans.

453.6 Removal. Upon removal of railing, materials furnished by the Contractor shall remain the property of the Contractor, unless otherwise specified. Contractor shall fill all holes drilled through or into existing concrete for erection of temporary railing with mortar and finish in an acceptable manner. Bolts cast in the slab for temporary railing are to be cut off 1/2 inch below the finished slab after removal of the rail and the resulting holes are to be filled with mortar.

453.7 Measurement & Payment. Unless otherwise shown on the plans or specifications, the furnishing of all materials, equipment and labor necessary to complete the work required by this Item will not be measured
for payment, but will be included in the unit price bid for the item or items for which this work is a component part.

There are no line code(s), description(s), or unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 450 "Concrete and Steel Railing"

END OF ITEM 453
ITEM 455

TIMBER FOR STRUCTURES

455.1 Description. This Item shall govern for the materials treated or untreated timber used in the construction of timber structures or portions of structures, as shown on the plans. This Item shall not include temporary timber construction which is not a part of the finished structure.

455.2 Materials. Unless otherwise specified, the material shall be Longleaf Southern Pine (LLSP) or Dense Southern Pine (DSP) with minimum allowable stresses (visual grading) as indicated in the following table.

<table>
<thead>
<tr>
<th>STRUCTURAL PURPOSE</th>
<th>STANDARD GRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stringers, walers, caps, flooring, posts, railing,</td>
<td>Dense Structural 65</td>
</tr>
<tr>
<td>wheel guards and fenders</td>
<td>Fb = 1,650 psi</td>
</tr>
<tr>
<td></td>
<td>Fv = 105 psi</td>
</tr>
<tr>
<td>Nailing strips, sway bracing, bulkheads, sheeting,</td>
<td>No. 1 Grade</td>
</tr>
<tr>
<td>bridging, walkways, edging strips, cleats and blocks</td>
<td>Fb = 1,650 psi</td>
</tr>
<tr>
<td></td>
<td>Fv = 95 psi</td>
</tr>
</tbody>
</table>

Stresses noted in Table 1 are based on values given in the American Institute of Timber Construction's "Timber Construction Manual", Latest Edition.

Timber to be stress graded and marked in accordance with "Grading Rules", as per the Southern Pine Inspection Bureau.

455.3 General Requirements. All timber shall be dress timber as indicated on the plans.

When not indicated, dress strip flooring (from 2" x 4" to 3" x 6" in size) shall be S1S1E, full size, hit or miss. Pieces more than 1/8" in excess of full nominal width or thickness, or more than 1/4" scant of full nominal width or thickness at any point, will be rejected.

Treated timber shall be impregnated with the kind and amount of preservative specified and by the process designated in the Item 457 "Timber Preservative and Treatment".
455.4 Measurement. The quantities of timber of the various classifications used in the completion of the structure in accordance with the plans and specifications shall be computed in board foot measure of timber in place. The measurement shall not include timber used for erection purposes such as forms, falsework and temporary bracing.

455.5 Payment. The timber quantities as measured above shall be paid for at the unit price bid per thousand board foot measure (M.B.F.M.) for "Treated Timber" or "Untreated Timber", as the case may be, which prices shall be full compensation for all materials, hardware, equipment, tools, labor, painting, preservative treatment and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 457 “Timber Preservative and Treatment”

END OF ITEM 455
ITEM 456

TIMBER STRUCTURES

456.1 Description. This Item shall govern for the construction of all bridges, bulkheads, retaining walls, piers, bents, fenders or any portion thereof which involves the use of timber materials whether treated or untreated. This Item shall not include temporary construction, which is not part of the finished work.

456.2 Materials. All materials used in the construction of timber structures shall conform to the requirements of the Item 455 "Timber for Structures".

456.3 Preservative Treatment. Lumber and piling for Timber Structures shall be "Treated" or "Untreated" as shown on the plans. "Treated" lumber and piling shall be impregnated with the quantity of preservative as shown on the plans and in the manner specified in the Item 457 "Timber Preservative and Treatment" and other pertinent specifications.

456.4 Storage of Materials. Lumber and timber at the project work site shall be stored in the following manner:

A. Untreated material shall be open-stacked at least 12 inches above the ground surface to prevent warping. It shall be protected from the weather by suitable covering.

B. Treated timber shall be close-stacked and piled to shed water and prevent warping.

456.5 Handling. Timber shall be carefully handled without sudden dropping, breaking of outer fibers or bruising. The surface of treated timbers shall not be penetrated with tools. Treated timbers shall be handled with rope slings or other approved methods. Use of cant dogs, hooks, or pike poles shall not be permitted.

456.6 Workmanship. Workmanship shall be first class throughout. Nails and spikes shall be driven with sufficient force to set the heads flush with the surface of the wood. Framing shall be true and exact. Deep hammer marks in wood surfaces shall be considered evidence of poor workmanship and sufficient cause for the removal of the workman causing them.

All lumber and timber shall be accurately cut and framed to a close fit, in such a manner that the joints will have even bearing. Mortises shall be true to size for their full depth and shall make a snug fit.
Countersinking shall be done whenever smooth faces are required.

456.7 Framed Bents. Mud sills shall be of treated or untreated timber and shall be of the material shown on the plans. Concrete pedestals for the support of framed bents shall be carefully finished so that the sills or posts will take even bearing on them.

456.8 Sills. Sills shall have true and even bearing on piling or pedestals. When possible, all earth shall be removed from around sills so that there will be free air circulation around them.

456.9 Post Covers. The tops of posts in framed bents, if untreated material, shall be given a thick coat of hot tar, hot asphaltum or hot coal tar and covered with a sheet of roofing felt weighing 55 pounds per 100 square feet or 20 gage galvanized metal as indicated on the plan. The cover shall measure at least 6 inches more in each dimension than the diameter or side of the post. The edges shall be bent down over the post and fastened with large headed galvanized nails.

For treated materials, the top shall be thoroughly saturated with hot creosote oil. They shall then be covered with a coat of hot tar pitch over which shall be placed a cover as specified for untreated material.

456.10 Caps. Timber caps shall be placed so as to secure an even and uniform bearing over the tops of the supporting posts or piling and to secure an even alignment of their ends. All caps shall be secured to the posts or piling in accordance with the details shown on the plans. No shimming on tops of piling or posts will be permitted.

456.11 Bracing. Sway bracing shall be placed diagonally on bents and connected to the cap and all piling or posts as shown on the plans.

Sash bracing and longitudinal bracing shall be placed and fastened to the piling or posts as shown on the plans.

Bracing shall be fitted to the bents in a satisfactory manner without dapping or cutting the posts or piling.

456.12 Stringers. Stringers shall be sized to uniform depth at bearings and shall be placed in a position so that knots near the edges will be in the top portions of the stringers.

Stringers may have butt joints or lapped joints as shown on the plans. The lapped ends of untreated stringers shall be separated at least 1/2 inch to permit the circulation of air. When stringers are two panels in
length, adjacent stringers shall be lapped at alternate bents. All stringers shall be securely fastened by bolts as shown on the plans.

456.13 Bridging. Diaphragms between stringers shall be given two coats of hot creosote oil before placing.

456.14 Flooring. Plank for single plank floors shall be placed with the heart side down with 1/4 inch opening between them for seasoned materials and with tight joints for unseasoned material. Unless otherwise provided, each plank shall be spiked to each stringer with not less than two spikes, the length of which shall be at least 3 inches greater than the thickness of the plank. The ends of the plank shall be cut off on a straight line parallel with the centerline of the roadway. The planks shall be carefully selected according to thickness and so laid that no two adjacent planks shall vary in thickness more than 1/8 inch.

When double plank floors are indicated on the plans, the top course shall be laid diagonal or parallel to the centerline of the roadway as shown, and unless otherwise provided, each plank shall be spiked to the lower course at intervals of not more than two feet with two spikes, the length of which shall be at least 3 inches greater than the thickness of the plank. Joints shall be staggered at least 3 feet. Where the planks are placed parallel to or diagonally with the centerline of the roadway, special care shall be exercised to securely fasten the ends, and at the ends of the bridge, the ends of the plank shall be cut to a straight line parallel to the end of the bridge.

For laminated floors, the strips shall be placed on edge and at right angles to the center line of the roadway. The strips shall be full lengths. Random lengths will not be permitted. Unless otherwise provided, each strip shall be spiked to the adjacent strip at intervals of 2 feet, the spikes being staggered 8 inches in adjacent strips. The spikes shall be of sufficient length to pass completely through two adjacent strips and approximately half way through the third strip. In addition, the strips shall be toenailed to the stringer with spikes not less than 4 inches in length. The toenailing of successive strips shall be staggered so that the spacing of spikes along each stringer shall be not less than 6 inches. For strips 3 inches in thickness, spikes driven vertically through the strips and extending into the stringer not less than 3 inches may be substituted for toenailing.

456.15 Cutting, Framing Holes for Bolts, Dowels, Rods and Lag Screws. All cutting, framing and boring of treated timbers shall be done before treatment insofar as practicable. Holes for round drift bolts and dowels shall be bored with a bit 1/16 inch less in diameter than the bolts or dowels to be used. The diameter
of holes for square drift bolts or dowels shall be equal to the least dimension of the bolt or dowel.

Holes for machine bolts shall be bored with a bit of the same diameter as the bolt.

Holes for rods shall be bored with a bit 1/16 inch greater in diameter than the rod.

Holes for lag screws shall be bored with a bit no larger than the root of the thread and shall be 1/2 inch deeper than the penetration of the lag screws.

All cuts, abrasions, holes and holes from removal of nails and spikes which penetrate the treated zone in treated lumber and timber shall be field treated in accordance with AWPA Standard M4 specified in Item 457 “Timber Preservative and Treatment”.

456.16 Painting. After completion of the structure, all bolt heads, threads, nuts, washers and exposed portions of bolts shall be given a thorough coating of hot asphalt.

For Untreated timber structures, the following surfaces shall be thoroughly coated with a thick coat of red lead and oil, hot tar, hot asphaltum or hot coal tar creosote before assembling: the ends, tops and all contact surfaces of pile caps; floor beams and stringer ends; joints and all contact surfaces of truss members; and lateral braces. The back face of bulkheads and all other timber in contact with earth, shall be thoroughly coated with one of the materials specified above.

All bolts passing through non-resinous wood shall be painted with two coats of red lead and oil.

456.17 Measurement & Payment. No direct compensation will be made for "Timber Structures". The work performed under this Item, shall be incidental to the Item 455 "Timber for Structures".

There are no line code(s), description(s), or unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 455 "Timber for Structures"
Item 457 "Timber Preservative and Treatment"

END OF ITEM 456
ITEM 457

TIMBER PRESERVATIVE & TREATMENT

457.1 Description. This Item shall govern for the preservative, and for the seasoning, preparation and treatment of piles, posts, timbers, lumber and service poles, when treatment is specified on the plans or called for in the Standard Specifications. Unless otherwise specified on the plans, the preservative and retention shall be as shown in Table 1 of this Item.

457.2 Materials. Except as otherwise provided herein, American Wood Preservers' Association (AWPA) Standard Specification shall govern for materials and methods of treatment, including seasoning, incising, preservatives, treatment and inspection for treatment. Pre-treated stock will not be accepted, except in emergencies. In such cases, special permission must be obtained from the Engineer.

Except for falsework and for temporary trestle work during construction, untreated timber piling shall be used only below permanent ground water level. Untreated timber piling shall not be used in water which is infested by marine borers.

457.3 Paintability. When painting is required by the contract documents, treated timber products shall be steam cleaned after installation.

457.4 Treatment of Cuts. When it is necessary to bore holes or to cut pressure treated material after treatment, or when any treated surface is badly scarred, the hole, cut or scarred surface shall be given a multi-application of a concentrated solution of the same type preservative as that used in the original treatment as specified in AWPA Standard M4. The supplier of the timber products shall furnish suitable liquid preservative for field treatment upon request from the Engineer. Heating of the preservative and the method of application to the damaged or cut areas shall be as specified in AWPA Standard M4.


Inspection shall be by a Commercial Laboratory, at the Contractor's expense at the site of the treatment plant to determine compliance with net penetration and retention requirements. Unsuitable materials shall be rejected.
TABLE 1
MATERIALS & APPLICATION

The Contractor shall provide the minimum net retention of preservative (lbs. per cu. ft.) for Longleaf Southern Pine or Dense Southern Pine as follows, unless otherwise specified.

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>CREOSOTE (AWPA P1)</th>
<th>CREOSOTE-COAL TAR SOLUTION (AWPA P12)</th>
<th>PENTACLORPHENOL (AWPA P8 &amp; P9)</th>
<th>WOLMANIZING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piling per AWPA C3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.60CCA-C</td>
</tr>
<tr>
<td>Land or Freshwater Use</td>
<td>12</td>
<td>-</td>
<td>0.60</td>
<td>-</td>
</tr>
<tr>
<td>Coastal Water Use</td>
<td>-</td>
<td>20</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Post per AWPA C5</td>
<td>6</td>
<td>-</td>
<td>0.30</td>
<td>-</td>
</tr>
<tr>
<td>Bridge &amp; Fender Timbers per AWPA C2</td>
<td>25</td>
<td>-</td>
<td>0.60</td>
<td>-</td>
</tr>
<tr>
<td>Lumber OTHER than Bridge &amp; Fender Timbers per AWPA C2</td>
<td>20</td>
<td>-</td>
<td>0.40</td>
<td>-</td>
</tr>
<tr>
<td>Wood in Direct Contact with the Ground</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.40CCA-C</td>
</tr>
<tr>
<td>Wood NOT in Direct Contact with the Ground</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.25CCA-C</td>
</tr>
<tr>
<td>Service Poles per AWPA C4</td>
<td>7.5</td>
<td>-</td>
<td>0.38</td>
<td>-</td>
</tr>
</tbody>
</table>
Wolmanizing material shall be manufactured by the Koppers Company, or approved equal. Prior to wolmanizing, all timber shall be air seasoned until the air content is below 20 percent. Wolmanizing shall be in accordance with applicable AWPA standards.

457.6 Identification. Each piece or bundle of treated timber products shall bear a legible brand mark or tag indicating the name of the treatment company, date of treatment and the specification symbol to which the treatment conforms.

457.7 Payment. Payment for all work prescribed herein will not be paid directly, but will be considered incidental to the wood or timber structure(s) or timber product(s).

There are no line code(s), description(s), and unit(s) for this Item.

END OF ITEM 457
ITEM 458

HARDWARE FOR HEAVY TIMBER CONSTRUCTION

458.1 Description. This Item shall govern for the furnishing of hardware for timber construction.

458.2 Materials. Machine bolts, drift bolts, dowels, etc., shall be galvanized wrought iron or galvanized steel with square heads and hex nuts. Bolts shall be the requirements of ASTM A307 “Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength.” Size shall be as shown on the plans.

Wire nails and spikes shall be galvanized steel, circular cross-section without taper with head and point and of good quality. Size shall be as shown on the plans.

Boat spikes shall be galvanized steel or galvanized wrought iron with forged heads and wedge shaped points of the size shown on the plans.

Tie rods shall meet the requirements of ASTM A36 “Standard Specification for Carbon Structural Steel.”

Cast Iron washers shall be the "O-gee" type of thickness equal to the diameter of the bolt. The diameter of the washer shall be four times the diameter of the bolt.

Plate washers shall be galvanized with square sides equal to the four times the diameter of the bolt. The thickness shall equal 1/2 the diameter of the bolt.

All hardware, with the exception of tie rods and cast iron washers shall be galvanized, in accordance with the requirements of ASTM A123 “Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products” and ASTM A153 “Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware”, as applicable.

Protective coatings for tie rods shall be as follows:

A. Remove loose rust and scale, dust or dirt prior to priming. Remove oil and grease with suitable solvent.

B. Apply TC primecoat by brush or spray at a rate of 400 square feet per gallon. Let primer dry to tacky consistency before applying finish coat. As a finish coat, apply Tapecoat-20, hot applied, in accordance with the manufacturer’s recommendations.
There are no line code(s), description(s), and unit(s) for this Item.

END OF ITEM 458
ITEM 459

TIMBER BENTS

459.1 Description. This Item shall govern for providing and installing timber bents on outfall pipes.

459.2 References.


C. AWPA U1, “Use Category System: User Specification for Treated Wood”


E. SPIB Section 300, “National Grading Rule Book for Dimensional Lumber”

459.3 Materials.

A. Timber Piles.

1. Provide southern pine wood poles for use as timber bent piles that meet the requirements of ANSI 05.01. Minimum diameter at the pile tip shall be not less than 8 inches.

2. Provide southern pine wood poles that are pressure preservative treated in accordance with the requirements of AWPA Use Category 5C.

B. Timber Members.

1. Provide southern pine timber members meeting SPIB Section 300, National Grading Rule for Dimensioned Lumber, SEL STR Grade No. 2 or better.

2. Provide pressure preservative members treated per the requirements of AWPA Use Category 5C.
C. Hardware.


2. Provide hot dipped galvanized hardware in accordance with ASTM A153.

459.4 Installation.

A. Drive piles to the depth shown on the drawings.

B. Drill holes no more than 3/16 inch larger in diameter than the bolts being used. Drill holes straight and true. Drill bolt holes in center of the pile and timber member. Use washers under bolt head and nut to prevent direct bearing of head or nut on wood.

459.5 Certification. All shipments shall include certification from the appropriate wood treatments plant. This certificate shall also state that all samples representing each lot have been tested and inspected in accordance with American Wood Preservers’ Association Standard M2, “Inspection of Treated Products” and have been found to meet the requirements of applicable American Wood Preservers’ Association standards for wood treatment for its intended use.

459.6 Measurement and Payment. Timber bents shall be measured per each of the size of pipe installed.

Payment for timber bent shall be per each per bid price. The price shall include all material, labor and equipment necessary for excavation and any incidentals necessary for complete installation.

There are line code(s), description(s) and unit(s) for this item.

END OF ITEM 459
460.1 Description. This Item shall govern for the furnishing and installing of reinforced concrete pipe.

460.2 Materials. Except as modified herein, materials, manufacture and design of pipe shall conform to ASTM C76 “Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe”, Class III, for circular pipe, ASTM C506 “Standard Specification for Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe” for arch pipe or ASTM C507 “Standard Specification for Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe” for elliptical pipe. All pipe shall be machine made or cast by a process which will provide for uniform placement of the concrete in the form and compaction by mechanical devices which will assure a dense concrete. Concrete shall be mixed in a central batch plant or other approved batching facility from which the quality and uniformity of the concrete can be assured. Transit mixed concrete will not be acceptable for use in precast concrete pipe.

In the manufacture of concrete pipe, the supplier has the option of using portland cement or portland cement plus fly ash, as defined herein. Cement plus fly ash shall be composed of portland cement and 20-30 percent fly ash, by weight. Fly ash shall be Class C or Class F, conforming to the requirements of ASTM C618 "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete."

Joint seal shall be a rubber gasket meeting the requirements of ASTM C443 “Standard Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets.” The rubber gasket shall be applied using lubricants of flax soap or equal. Mineral lubricants are not permitted.

Rubber gasket substitution shall not be permitted without written approval from the Design Engineer.

460.3 Submittals. Submit certification from the fabricator that the pipe has been tested and meets the requirements of this Item. The joint material data sheets shall be submitted for approval, by the Design Engineer.

460.4 Installation. Unless otherwise specified, the following method shall govern:

Jointing Rubber Gasket Pipe:
Lay pipe section in trench to true alignment and grade. Exceptional care shall be taken in placing pipe and making field joints. Avoid bumping the pipe in the trench. Place rubber gasket on dry spigot end of pipe. Properly lubricate spigot, with rubber gasket in place, with specified lubricants. Do not twist, roll, cut, crimp or otherwise injure gaskets or force them out of position during closure of joints. Pull or push the pipe home for closure of the joint. Correct joint rebound before backfilling the pipe. Remove foreign matter or dirt from pipe and keep clean during and after laying.

Install reinforced concrete pipe in accordance with Item 430 "Construction of Underground Utilities", and all related drawings/plans.

Unless otherwise shown on the plans, not more than two holes may be placed in the top section of the pipe for lifting and placing. The holes may be cast, cut, or drilled in the wall of the pipe. The holes shall not exceed 3 inches in diameter at the inside surface of the pipe wall. Not more than one longitudinal wire or two circumferential wires may be cut per layer of reinforcing steel when locating lift holes in the pipe wall.

All lifting holes shall be sealed to the satisfaction of the Engineer. Tapered lifting plugs shall be used, and sealed externally and internally with an acceptable cement grout. Additionally, lifting plugs shall not protrude from the pipe greater than one-half of an inch.

Quality Assurance. Concrete pipe 54 inches and smaller in diameter shall be tested in accordance with ASTM C497 “Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile” using the method outlined by Part 4. "External Load Crushing Strength Test by the Three-Edge Bearing Method". The pipe shall be tested at a frequency of three pipe joints for each 100 joints cast, for each pipe size.

Concrete pipe 60 inches and larger shall also be tested in accordance with ASTM C497 using the method outlined by Part 6. "Core Strength Test". However, where the manufacture of the pipe is witnessed by the Engineer, tests using concrete cylinders in accordance with ASTM C39 "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens", shall be acceptable. All test specimens and testing shall be done by the producer of the concrete pipe.

Pipe previously approved and stamped by a Texas Department of Transportation (TxDOT) approved fabricator with specific stamp, which must state: “Certifies Specification Compliance” (i.e. compliance with TxDOT’s DMS - 7310 “Reinforced Concrete Pipe and Machine-Made Precast Concrete Box Culvert Fabrication and Plant Qualification” requirements) will be accepted by all laboratories and by Harris County.
For pipes that are stamped by the fabricator as stated above, copies of test results (D-loads and compressive strengths) shall be submitted to the Engineer.

Random Inspection and Testing. Harris County reserves the right to inspect, sample, and test reinforced concrete pipe at any time to ensure compliance with this Item. The pipe manufacturing plant shall provide facilities, equipment, and access to allow for inspection regarding: the quality of materials, the process for manufacturing, and the finished pipe at the plant; in addition to the inspection that is done of the finished pipe at the site before and during the installation.

Acceptance Requirements. Variations in diameter, size, shape, wall thickness, reinforcement placing, laying length, and permissible underrun of length shall be in accordance with the applicable ASTM Standard for each type of pipe as referred in Section 460.2.

Pipe shall be free from fractures, all cracks and surface roughness. The ends of the pipe shall be normal to the walls and centerline of the pipe. Pipe shall be cured in accordance with the applicable ASTM Standard for each type of pipe as referred to herein.

The following information shall be clearly marked on each section of pipe:

A. The class and ASTM or D-Load of pipe.
B. The date of manufacture.
C. The name or trademark of the manufacturer and plant location.
D. Designated manufacturer’s certifying stamp.
E. One end of each elliptical section of pipe shall be clearly marked on the inside and outside to show the location of the top and bottom of pipe.
F. Clearly mark pipe to be used for jacking and boring (when applicable).
G. Pipe meeting sulfate-resistant concrete plan requirements (when applicable).

Marking shall be indented on the pipe section or painted thereon with waterproof paint.
Pipe shall be subject to rejection for failure to conform to any of the specification requirements. Individual sections of the pipe may be rejected because of any of the following:

A. Fractures or cracks passing through the shell/wall of pipe with exception of a single crack that does not exceed the depth of the joint.

B. Defects that indicate imperfect proportioning, mixing and molding.

C. Surface defects indicating honeycombed or open texture.

D. Damaged ends, when such damage would prevent making a satisfactory joint.

E. Any continuous crack having a surface width of 0.01 inch or more and extending for a length of 12 inches or more.

The painting of pipe shall not be allowed prior to delivery on the project.

460.7 Measurement & Payment. Gravity pipelines (R.C.P.) shall be measured by the linear foot of pipe actually laid, at finished grade, along pipe of size and at depth installed, in accordance with Item 430 “Construction of Underground Utilities”. Measure depth at manholes, at intervals not to exceed 50 feet between manholes, and at breaks in profile of natural ground from flow line of pipe to natural ground surface over center of pipe. Payment for gravity pipeline, furnished, installed and measured as stated shall be at the contract unit price bid for the size, type, (and depth, if shown on the proposal) measured under their respective bid line codes.

If the depth of cut is not shown on the proposal, no consideration shall be made for depth at which the pipe is installed.

Pipe installed by tunneling shall be paid for in accordance with Item 431 “Jacking, Boring and Tunneling Pipe” or Item 432 “Tunnel Construction”.

No separate payment shall be made for ordinary bedding and select backfill, unless so indicated on the bid form.

No separate payment shall be made for hauling and storing suitable excavated trench material for other uses or for disposal of excess or unsuitable materials.

No separate payment shall be made for any bedding and backfill installed in accordance with these Standard Specifications and the drawings.
Well Pointing shall be measured and paid for in accordance with the Item 436 “Well Pointing.”

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 430 “Construction of Underground Utilities”
Item 431 “Jacking, Boring or Tunneling Pipe”
Item 432 “Tunnel Construction”
Item 436 “Well Pointing”

END OF ITEM 460
ITEM 461

CORRUGATED METAL PIPE

461.1 Description. This Item shall govern for furnishing and installing corrugated metal pipe conforming to these Standard Specifications. The pipe shall be furnished to the sizes and dimensions required and shall be installed in such places as shown on the drawings or as designated by Engineer, in accordance with these Standard Specifications and in conformity with the lines and grades given.

461.2 Materials. Metal pipe shall be full circle conforming to AASHTO M36 “Standard Specification for Corrugated Steel Pipe, Metallic-Coated, for Sewers and Drains, or AASHTO M196 “Standard Specification for Corrugated Aluminum Pipe for Sewers and Drains”, Type I as specified on the plans.

Galvanized Steel coated sheets shall conform to AASHTO M218 “Standard Specification for Steel Sheet, Zinc-Coated (Galvanized), for Corrugated Steel Pipe” and structural plate material shall meet either AASHTO M167 “Standard Specification for Corrugated Steel Structural Plate, Zinc-Coated, for Field-Bolted Pipe, Pipe-Arches, and Arches” or M219 “Standard Specification for Corrugated Steel Structural Plate, Zinc-Coated, for Field-Bolted Pipe, Pipe-Arches, and Arches.” It may be fabricated with circumferential corrugations, lap joint construction with riveted or spot welded seams or it may be fabricated with helical corrugations with continuous helical lock seam or ultra high frequency resistance butt welded seams.

Pre-coated Galvanized Steel pipe shall be full circle conforming to AASHTO M246 “Standard Specification for Corrugated Steel Structural Plate, Zinc-Coated, for Field-Bolted Pipe, Pipe-Arches, and Arches”, Type I as specified on the drawings. It may be fabricated with circumferential corrugations, lap joint construction with riveted seams, or it may be fabricated with helical lock seams. Unless otherwise noted on the drawings, both the inside and outside coating shall be a minimum of 10 mils.

The shape and minimum gage for pipe shall conform to Height of Cover Tables for corrugated steel conduits as designated by the National Corrugated Steel Pipe Association (NCSPA).

Gaskets to be O ring type. Gasket material shall meet the requirements of ASTM C1619 “Standard Specification for Elastomeric Seals for Joining Concrete Structures.” Diameter to be 13/16 inch for 1/2 inch deep
Corrugations (pipe size 12 inches through 54 inches), and 1-3/8 inch for 1 inch corrugations (60 inches and larger); gasket lengths shall be in accordance with the pipe manufacturer's recommendations.

Coupling bands shall conform to the requirements of AASHTO M36. The coupling bands shall have a Minimum Width of 24 inches and shall be in accordance with Texas Department of Transportation's Specification Item 460.3.4.1 "Coupling Bands". Dimple bands will not be accepted.

Bituminous coated circular pipe shall conform to this Item both as to base metal and fabrication and in addition shall be coated inside and out with a bituminous coating which shall meet the performance requirements set forth herein and with AASHTO M190 “Standard Specification for Bituminous-Coated Corrugated Metal Culvert Pipe and Pipe Arches.” The pipe shall be uniformly coated inside and out to a minimum thickness of 0.05 inch, measured on the crests of the corrugation.

When a paved invert is specified, the pipe, in addition to the fully coated treatment described above, shall receive additional bituminous material, of the same specifications as above, applied to the bottom quarter of the circumference to form a smooth pavement with a minimum thickness of 1/8 inch above the crests of the corrugations.

Fully lined (either asphalt or concrete linings) corrugated metal pipe shall be in conformance with AASHTO M190, Type D or ASTM A849 “Standard Specification for Post-Applied Coatings, Pavings, and Linings for Corrugated Steel Sewer and Drainage Pipe.”

Field coating of pipe shall be in conformance with AASHTO M243 “Standard Specification for Field-Applied Coating of Corrugated Metal Structural Plate for Pipe, Pipe-Arches, and Arches” if specified. It shall not be allowed as an alternate to hot dip asphalt coating per AASHTO M190.

461.3 Submittals. Submit certification from the manufacturer that the pipe has been tested and meets this Item requirements. The pipe diameter, type of pipe, gauge/thickness, depth of corrugations and span of corrugations shall be submitted for approval, by the Engineer.

461.4 Construction Methods. Trench shall be excavated to the alignment, depth and width required. Brace trench and drain so that the work may be accomplished safely and efficiently. Trenches shall be excavated with suitable type equipment such as ladder type trenching machines or trench hoes or other equipment. Trench widths for pipes less than 30 inches shall as a minimum be the width of outside barrel of pipe plus 12 inches.
The maximum trench width shall be the maximum width of the outside barrel of the pipe plus 18 inches.

Where necessary, excavations shall have sheathing and bracing to prevent caving. All sheathing and bracing shall be designed to the requirements of OSHA Standard 1926, Subpart P (Latest Edition). Depth of trenches without sheathing or bracing shall comply with OSHA Regulation 1926.650.

For pipe 30 inch and larger, the minimum width of the trench shall be the width of the outside barrel of the pipe plus 16 inches and the maximum width of the outside barrel of the pipe plus 24 inches.

After the trench has been excavated to the bottom, the trench shall be fine graded to the established subgrade. Any over excavation of the subgrade shall be filled with 1.5 sack/ton of cement stabilized sand.

The Engineer will furnish and set vertical and horizontal control stakes which will establish the base line or centerline and bench marks and will furnish the Contractor with all necessary information relating to lines and grades. The Contractor shall establish the grade line in the trench from grade stakes. The Contractor shall maintain this grade control a minimum of 100 feet behind and ahead of the pipe laying operation. The Contractor shall, at his own expense, furnish and place in position as directed by the Engineer all necessary stakes, grade and batter boards for locating the work. The Contractor may, at his own expense, use a laser beam to maintain line and grade of the work as authorized by the Engineer.

The pipe shall be bedded in a foundation of cement stabilized sand conforming to Item 433 "Cement Stabilized Sand Bedding and Backfill Material", Item 430 "Construction of Underground Utilities, and the drawings. When requested by the Engineer, the Contractor shall furnish a simple template for each size and shape of pipe to be placed for use in checking the shaping of bedding.

Unless otherwise authorized by the Engineer, the laying of pipes on the prepared foundation shall be started at the outlet end, the separate sections firmly joined together, with outside laps of circumferential joints pointing upstream and with longitudinal laps on the sides. Any metal in joints which is not protected by galvanizing, shall be coated with a suitable asphaltum paint. Proper facilities shall be provided for hoisting and lowering the sections of pipe into the trench without damaging the pipe or disturbing the prepared foundation and the sides of the trench. Any pipe which is not in alignment or which shows any undue settlement after laying, or is damaged, shall be taken up and re-laid without extra compensation.
Multiple installations of corrugated metal pipe shall be laid with the center lines of individual barrels parallel. Unless otherwise indicated on the plans, the following clear distances between outer surfaces of adjacent pipes shall be maintained as shown in Table 1.

**TABLE 1**

<table>
<thead>
<tr>
<th>DIAMETER OF PIPE</th>
<th>CLEAR DISTANCE BETWEEN PIPES FULL CIRCLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>18”</td>
<td>1’ – 2”</td>
</tr>
<tr>
<td>24”</td>
<td>1’ – 5”</td>
</tr>
<tr>
<td>30”</td>
<td>1’ – 8”</td>
</tr>
<tr>
<td>36”</td>
<td>1’ – 11”</td>
</tr>
<tr>
<td>42”</td>
<td>2’ – 2”</td>
</tr>
<tr>
<td>48”</td>
<td>2’ – 5”</td>
</tr>
<tr>
<td>54”</td>
<td>2’ – 10”</td>
</tr>
<tr>
<td>60” to 84”</td>
<td>3’ – 2”</td>
</tr>
<tr>
<td>90” to 120”</td>
<td>3’ – 5”</td>
</tr>
</tbody>
</table>

Where new structures are constructed as extensions to structures in place or as jointed to existing structures, the construction shall include all work necessary to provide a proper connection between the new structure and the old as indicated on the drawings, including coating of the connection with bituminous material when required.

After the metal pipe structure has been completely assembled on the proper line and grade and headwalls constructed when required by the drawing details, selected material from excavation or borrow shall be placed along both sides of the completed structure(s) equally, in uniform layers not exceeding 6 inches in depth (loose measurement), wetted if required and thoroughly compacted between adjacent structures and between the structure(s) and between the sides of the trench, or for a distance each side of the structure equal to the diameter of the pipe. Backfill material shall be compacted to the same density requirements as specified for the adjoining section of the embankment. Above the three-fourths point of the structure, the fill shall be placed uniformly on each side of the pipe in layers not to exceed 12 inches. For backfilling, until a minimum cover of 12 inches is obtained, only hand operated tamping equipment will be allowed within vertical planes two feet beyond the horizontal projection of the outside surfaces of the structure.
Pipe damaged by the Contractor's backfilling operation shall be removed and replaced by the Contractor at no additional cost to Harris County. Unless otherwise shown on the drawings or permitted in writing by the Engineer, no heavy earth moving equipment will be permitted to haul over the structure until a minimum of 4 feet of permanent or temporary, compacted fill has been placed thereon. Pipe damaged by the Contractor's equipment shall be removed and replaced by the Contractor at no additional cost to Harris County.

During the backfilling operations, special emphasis shall be placed upon the need for obtaining uniform backfill material and uniform compacted density throughout the length of the pipe. Prior to adding each new layer of loose backfill material, until a minimum of 12 inches of cover is obtained, and inspection will be made of the inside periphery of the structure for local or unequal deformation caused by improper construction methods. Evidence of such will be reason for corrective measures as directed by the Engineer.

461.5 Measurement. Corrugated metal pipe will be measured by the linear foot. Such measurements will be made between the ends of the barrel along its flow line. Coupling bands shall be incidental to the measured pipe. Where spurs of branches or connections to existing pipe lines are involved, measurement of the spur of new connecting pipe will be made from the intersection of its flow line with the outside surface of the pipe into which it connects. Where inlets, headwalls, catch basins, manholes, junction chambers or other structures are included in lines of pipe, the length of pipe tying into the structure wall will be included for measurement but no other portion of the structure length and width will be so included.

461.6 Payment. Payment for corrugated metal pipe measured and prescribed above, will be made at the contract unit price bid per linear foot for the various sizes of "Corrugated Metal Pipe" of the material and protective coating as indicated on the plans.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 430 "Construction of Underground Utilities"
Item 433 "Cement Stabilized Sand Bedding and Backfill Material"

END OF ITEM 461
ITEM 462

CLAY PIPE

462.1 Description. This Item shall govern for furnishing and installing clay pipe of the size and strength shown on the plans.

462.2 Materials. Clay pipe shall conform to ASTM C700 “Standard Specification for Vitrified Clay Pipe, Extra Strength, Standard Strength, and Perforated.” Pipe wye, tee and bend fittings shall be of the same strength as the adjacent joint of pipe and shall also conform to ASTM C700. The clay pipe shall be free of fractures, cracks, chips and etc.

Joint closures shall be in accordance with ASTM C425 “Standard Specification for Compression Joints for Vitrified Clay Pipe and Fittings.” Joint lubricant shall be in accordance with the pipe manufacturer's recommendations.

462.3 Installation. Clay pipe shall be installed in accordance with ASTM C12 “Standard Practice for Installing Vitrified Clay Pipe Lines.” Before laying pipe, prepare pipe ends by wiping the inside surface of bell or coupling and the outside surface of the spigot until clean and dry and apply joint lubricant in accordance with the manufacturer's recommendations. Cover the entire area with joint lubricant, then complete joint immediately.

The pipe joint shall be made in the following manner. Push the spigot end into the bell of the preceding pipe until it is properly seated. Apply moderate force by using a simple lever. Two or three joints may be joined on the bank and then lowered into the trench.

462.4 Measurement and Payment. Measurement and Payment shall be made in accordance with the Item 430 "Construction of Underground Utilities."

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 430 "Construction of Underground Utilities"

END OF ITEM 462
ITEM 463

SAFETY END TREATMENT

463.1 Description. This Item shall govern for the materials to be furnished and for the construction of Safety End Treatment (S.E.T.) for drainage structures at the designated locations, in accordance with this Item and as shown on the construction drawings.

463.2 Materials. Unless otherwise shown on the drawings, materials shall conform to the following:

- Item 420 "Concrete Structures"
- Item 421 "Structural Concrete"
- Item 440 "Reinforcing Steel"
- Item 460 "Reinforced Concrete Pipe"
- Item 461 "Corrugated Metal Pipe"
- Item 480 "Precast Reinforced Concrete Box Sewers"

Pipe Runners - ASTM A53 “Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless”, Grade B or equivalent strength pipe

Plates and Angles - ASTM A36 “Standard Specification for Carbon Structural Steel”

Bolts and Nuts - ASTM A307 “Standard Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength”

Unless otherwise shown on the drawings, all metal pipe, plates, angles, nuts and bolts shall be galvanized in accordance with ASTM A123 “Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products” or ASTM A153 “Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware”, whichever is pertinent.

463.3 Types of Safety End Treatment

A. Parallel Drainage Safety Pipe Runners (PD-SPR) PD-SPR Type I S.E.T. shall be used on single or multiple reinforced concrete box culvert (RCB), either precast or cast-in-place, or Type II S.E.T. shall be used on reinforced concrete pipe (RCP) or corrugated metal pipe (CMP) with the ends tapered to the proper slope as shown in the Latest Edition of the Texas Department of Transportation (TxDOT) standard drawing, unless shown otherwise in the contract documents.
B. Cross Drainage Safety Pipe Runners (CD-SPR)

CD-SPR Type I S.E.T. shall be used on single or multiple reinforced concrete box culvert (RCB), either precast or cast-in-place, or Type II S.E.T. shall be used on reinforced concrete pipe (RCP) or corrugated metal pipe (CMP) with the ends tapered to the proper slope as shown in the Latest Edition of the Texas Department of Transportation (TxDOT) standard drawing, unless shown otherwise in the contract documents.

Unless otherwise shown on the drawings, when CMP or RCP is specified for the pipe structure, the Contractor shall have the option of providing prefabricated metal end sections or precast S.E.T. units in lieu of mitered CMP or RCP.

463.4 Construction. Construction shall be in accordance with the details shown on the drawings and in accordance with the construction and installation methods of Standard Specification Items 420, 430, 433, 461, and 480, whichever apply.

Damaged galvanizing shall be repaired by the Contractor in accordance with Item 461 “Corrugated Metal Pipe”.

When required riprap, slope paving headwall or collars are to be installed. They shall be in accordance with Item 491 "Reinforced Concrete Slope Paving".

Any required structural excavation shall be in accordance with Item 400 "Structural Excavation and Backfill". Removal of portions of in-place structures when required, shall be in accordance with Item 495 "Removing Old Structures". The extension of concrete structures, when required, will be in accordance with Item 424 "Extending Concrete Structures".

463.5 Measurement. S.E.T. will be measured by each unit of size specified with or without PD-SPR or CD-SPR.

Structural excavation and any slope paving headwalls or collars required by the drawing will not be measured but will be considered subsidiary to this Item.

463.6 Payment. Payment for S.E.T. will be paid for at the unit price bid for each for the particular size as measured herein. The following shall be specified for each S.E.T.:

S.E.T. (Type I)(Height)(Slope) or
S.E.T. (Type I)(Height)(Slope)(Pipe Runner Orientation); 
S.E.T. (Type II)(Pipe Size)(Pipe Material)(Slope) or 
S.E.T. (Type II)(Pipe Size)(Pipe Material)(Slope)(Pipe Runner Orientation)
This payment shall be full compensation for the breaking and removing of all concrete, when required, removing a portion of in-place structures and extending concrete structures, when required, for all concrete, reinforcing steel, CMP, RCP, RCB slope paving, toe wall, concrete aprons, pipe runners, collars, nuts, riprap, bolts, plates and angles as may be required, for all structural excavation, galvanizing, for all labor, tools, equipment, for construction or furnishing and installing S.E.T. units and incidentals necessary to complete the work. If the S.E.T. is specifically to be precast, it shall be noted as such.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires drawings (TxDOT Standards) that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications

Item 400 "Structural Excavation and Backfill"
Item 420 "Concrete Structures"
Item 421 "Structural Concrete"
Item 424 "Extending Concrete Structures"
Item 430 "Construction of Underground Utilities"
Item 433 "Cement Stabilized Sand Bedding and Backfill Material"
Item 440 "Reinforcing Steel" 
Item 460 "Reinforced Concrete Pipe"
Item 461 "Corrugated Metal Pipe"
Item 480 "Precast Reinforced Concrete Box Sewers"
Item 491 "Reinforced Concrete Slope Paving"
Item 495 "Removing Old Structures"

END OF ITEM 463
ITEM 464

PVC PIPE

464.1 Description. This Item shall govern for the furnishing and installation of PVC pipe, including all fittings, painting when necessary and all incidentals necessary to do the work in accordance with the plans and these Standard Specification.


The Contractor shall furnish manufacturer's certification that the pipe and fittings furnished to the project meet the ASTM requirements above.

Pipe and fittings shall be free from defects which, in the judgment of the Engineer, would hinder their ability to function as planned.

The dimensions of the PVC pipe shall be as shown on the plans. The fittings supplied shall properly fit the pipe supplied and shall be the same color as the pipe.

464.3 Construction Methods. The pipe shall be installed at the locations, lines, grades and dimensions shown on the plans or as revised by the Engineer in full accordance with ASTM D2321 “Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications.”

All fittings shown on the plans and any other fittings necessary to properly install the pipe, including splice fittings, if necessary, shall be attached to the pipe by solvent welding according to the manufacturer's recommendations.

Splicing will not be allowed unless the required length of a straight section of pipe exceeds 30 feet. This requirement may be waived by the Engineer for special conditions.
Devices required to attach the pipe to portions of structures or to other types of pipe shall be as shown on the plans or as approved by the Engineer.

**Backfill material** required for installation of the pipe, shall be performed according to the Item 430 "Construction of Underground Utilities". Bedding material for PVC pipe shall be in accordance with Item 433 "Cement Stabilized Sand Bedding and Backfill Material".

After installation of all pipe and fittings which will be exposed to view in the completed structure shall be cleaned.

**464.4 Measurement.** PVC pipe shall be measured by the linear foot along the centerline of the pipe as installed, for the various sizes required. Any excavation and backfill required will not be measured for payment, but shall be subsidiary to this Item.

**464.5 Payment.** Payment for PVC pipe measured as prescribed above will be made at the unit price bid per linear foot for "PVC Pipe" of the various sizes required. Payment shall be full compensation for furnishing and installing the PVC pipe, for all fittings, clamps, anchors, guard plates, bedding, excavation and backfill, painting labor, tools, equipment and incidentals necessary to complete the work.

There are line code(s), description(s) and unit(s) for this Item.

**NOTE:** This Item requires other Standard Specifications

- Item 430 "Construction of Underground Utilities"
- Item 433 "Cement Stabilized Sand Bedding and Backfill Material"

END OF ITEM 464
ITEM 465

REMOVE AND DISPOSE OF EXISTING CONCRETE OR METAL PIPE

465.1 Description. This Item shall govern for the removal and disposal of existing concrete or metal pipe as noted on the plans or as directed by the Engineer and shall include all excavation and backfill necessary to complete the work, as well as the removal of the pipe from the project limits.

465.2 Construction Methods. All excavation made in connection with this Item and all openings below the natural ground line caused by the removal of the pipe, shall be backfilled to the level of the original ground.

All excavation and backfilling required for the removal of the pipe, shall be performed according to the Item 430 “Construction of Underground Utilities”.

465.3 Measurement. Concrete or metal pipe to be removed and disposed of shall be measured by the linear foot along the centerline of the pipe to be removed. Any excavation and backfill required will not be measured for payment, but shall be subsidiary to this Item.

465.4 Payment. Removal and disposal of concrete or metal pipe will be made at the unit price bid per linear foot for "Remove and Dispose of Existing Concrete or Metal Pipe" of the various sizes indicated. Payment shall be full compensation for excavation and backfill and includes all labor, tools, equipment and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications.

Item 430 “Construction of Underground Utilities”

END OF ITEM 465
ITEM 471

PRECAST CONCRETE MANHOLES AND JUNCTION BOXES

471.1 Description. This Item shall govern for the manufacture and construction of precast concrete manholes, including the materials used therein and the furnishing of frames, grade rings and covers.

471.2 Design Loads. Design loads shall consist of dead load, live load, impact and in addition loads due to water table and any other loads which may be imposed on the structure. Manholes and junction boxes shall be designed in accordance with the AASHTO LRFD Bridge Design Specifications, Latest Edition.

471.3 Materials. Reinforcing steel shall conform to the Item 440 "Reinforcing Steel" and concrete shall conform to the Item 421 "Structural Concrete". The concrete mix shall contain sufficient cementitious material to produce a minimum compressive strength of 4,000 psi in 28 days.


Cast iron shall conform to ASTM A48 “Standard Specification for Gray Iron Castings”, Class 35B - Cast iron manhole frames and covers shall be heavy duty and shall be manufactured to the dimensions shown on the Standard Civil Drawing. As-cast dimensions may vary in accordance with AASHTO M306, "Drainage, Sewer, Utility and Related Castings”. Casting shall be free from sand or blow holes and other defects. Holes in cover shall be free from plugs and burrs. Frames and covers shall have machined bearing surfaces and conform to the Standard Civil Drawing.

471.4 Manufacture. Precast concrete manholes shall be manufactured in accordance with ASTM C478, "Standard Specification for Circular Precast Reinforced Concrete Manhole Sections."

471.5 Submittals.

Product Data. For standard or special precast manholes, the Contractor shall submit the manufacturer’s product data showing the dimensions, location and size of steel reinforcement and certify that the manholes and all accessories meet or exceed the applicable requirements listed in this Item. The manufacturer shall certify that such products and all accessories meet ASTM Specifications.
Shop Drawings. The Contractor shall submit shop drawings for special precast manholes for approval by the Engineer prior to fabrication of the units. These drawings shall show complete design installation including dimensions, steel reinforcement size/placement as well as supporting engineering design calculations.

471.6 Quality Assurance.

Plant Testing. The Contractor shall notify the Engineer in advance of the date and plant location so that an independent testing laboratory can monitor the manufacturing of the units.

471.7 Installation. The Contractor shall prepare a hole large enough to accommodate the outside dimensions of the manhole. Prior to setting, the Contractor shall provide a 6 inch thick base of cement stabilized sand, per Item 433 “Cement Stabilized Sand Bedding and Backfill Material” suitable to receive the manhole, unless otherwise shown on the drawings. The base material shall be compacted and graded level at proper elevation to receive the manhole in relation to the conduit grade.

Sealants used between the joints of the manhole are to be as recommended by the precast manufacturer. If grout is used, it shall be a non-shrink grout. The grout shall be poured in a water soaked groove and filled to the top of the groove in the previously set section. Grade rings where used shall have 1/2 inch thick non-shrink grout coat inside and outside, or the grade rings shall be installed with non-shrink grout to provide a sealed grade ring area. Alternately, the grade rings may be sealed from outside with Infi-Shield Uniband or approved equal.

After the installation of the precast manhole sections to the proper elevation, the cast iron manhole frame shall be set in a full mortar bed. Alternatively, the Contractor may set precast manhole cover slab in full mortar bed and adjust to the required elevation. Unless otherwise shown on the drawings, the top of cast iron frame and cover is to be flush with adjacent finished surface or to the elevation established by the Engineer. Manhole frame and cover should be located outside of the traffic wheel path.

The inverts of the sewer line or several sewer lines entering the manhole at or near the flow line elevation of the manhole shall be shaped and routed across the floor of the manhole using mortar to obtain the proper contour.

Where the main sewer (lowest line) passes straight through the manhole or the degrees of deflection of the main sewer is less than 5 degrees, and no other line or stub out is shown entering the manhole below the
centerline of the main sewer, lay the sewer continuously through the manhole. After the precast manhole sections have been installed above the top of the sewer, breakout and remove the top half of the barrel of the sewer pipe that was previously laid through the manhole. Use concrete with a 1 inch thick mortar topping and construct the invert as shown in the Standard Civil Drawing.

Where the main sewer (lowest line) alignment deflects greater than 5 degrees at manhole or where another sewer or stub out enters at or below the centerline of the main sewer, terminate main sewer pipe, by laying it in such a manner that pipe ends flush at the inside of the manhole. Construct the invert with concrete and top with 1 inch of mortar. Shape invert for smooth flow across floor of manhole and slope the sides as shown to obtain proper contour.

When installing precast square or rectangular manhole structures, construct invert channels to provide smooth flow transition waterway with no disruption of flow at pipe-manhole connections. Slope of invert bench shall be 1 inch per foot minimum, or 1-1/2 inches per foot maximum.

Before inserting the pipe into the wall opening, apply non-shrink grout on the inside curvature of the wall centered at the bottom 25 percent of the wall opening of the manhole.

Use non-shrink grout (applied per manufacturers recommendations) to attain a water tight seal at the opening of the manhole wall with the pipe. For box culverts and arch pipe (all non-circular applications) use non-shrink grout to ensure a water tight seal.

Stub outs shall be installed, where shown, to the lines and grades. Use one full joint of pipe, of the size indicated, for stub out. Seal stub out with plug. Install the plug in such a manner as to prevent seepage or leakage through stub outs. The plugs shall be installed so that they may be easily removed in the future, without damaging the end of the stub out. When inlet leads, lateral sewer pipe, stub outs and drop connections enter manholes, cut off ends of protruding pipe flush with inside of manhole wall. Point up any irregularities with mortar.

Backfill around manholes shall be placed immediately after mortar and concrete has set, and in accordance with Item 430 “Construction of Underground Utilities.” Where proposed sewer lines connect to existing manholes at grade, reshape invert of existing manhole, so that no turbulence is created in the manhole as a result of the connection.
471.8 Submittal Required. Submit certification from the foundry that the frame and cover have been tested, inspected and found to meet the requirements of this Item and the applicable ASTM Standards.

Submit certification from the manufacturer that the manhole has been tested and meets this Item requirements. Sealants used between the joints of the manhole are to be as recommended by the precast manufacturer, and approved by the Engineer.

471.9 Marking. Each individual casting shall be identified by the foundry showing the following:

A. Name of producing foundry.

B. AASHTO or ASTM number.

C. Class by a number followed by a letter indicating the minimum tensile strength and size of test bar.

D. Casting as required by the drawings.

471.10 Measurement. Manhole depths shall be measured by the linear foot of vertical distance from flow line of manhole to top of manhole casting and shall be classified per each manhole TYPE as follows:

A. Shallow manhole - a manhole with depth less than 5 feet.

B. Standard manhole - a manhole with depth equal to or greater than 5 feet and/or less than or equal to 10 feet.

C. Extra depth manhole - a manhole with a depth greater than 10 feet.

471.11 Payment. Payment for complete precast concrete manholes, as shown on the plans, will be made at the unit price bid per each TYPE of manhole at various depths, complete in place. Payment, as provided, shall be full compensation for furnishing all reinforcing steel, concrete, jointing, grade rings, frames and covers, cement stabilized sand, non-shrink grout, and all other materials, including bedding, tools, equipment, and incidentals required to complete the installation.

There are line code(s), description(s) and unit(s) for this Item.

NOTE: This Item requires Standard Civil Drawings that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications.
Item 430 “Construction of Underground Utilities”
Item 433 “Cement Stabilized Sand Bedding and Backfill Material”

END OF ITEM 471
ITEM 472

INLETS

472.1 Description. This Item shall govern for furnishing and installing inlets of the type designated on the plans including but not limited to all frames, plates, grates and covers.

472.2 Materials. Reinforcing steel shall conform to the Item 440 "Reinforcing Steel". Concrete shall conform to the Item 421 "Structural Concrete". Precast concrete inlets shall be manufactured in accordance with the Item 420 "Concrete Structures".

Cement mortar shall conform to ASTM C270 “Standard Specification for Mortar for Unit Masonry”, Type M. Aggregate for mortar shall conform to ASTM C144 “Standard Specification for Aggregate for Masonry Mortar.” Cast iron for frames, plates, covers, I-beams and grates shall be in accordance with ASTM A48 “Standard Specification for Gray Iron Castings”, Class 30 and shall be free from sand, blow holes or other defects. Frames, plates, grates and covers shall have machined bearing surfaces and conform to the Standard Civil Drawings.

472.3 Construction. All sections of the inlets will be constructed of reinforced concrete.

Prior to setting and/or casting of the inlet, the Contractor shall provide a base/bedding of 6 inch thick cement stabilized sand.

After construction/installation of the inlet, backfill with a minimum thickness of 12 inches of cement stabilized sand that completely circumvents the outside wall of the inlet, up to the elevation of the pavement. Then complete the backfill of the excavated hole, with material that’s in accordance with Item 430 “Construction of Underground Utilities”.

Inlets that are constructed/installed adjacent to and flush to the elevation of concrete pavement shall be constructed with a minimum 3/4 inch expansion joint material, that is in accordance with Item 360 “Concrete Pavement”.

Use non-shrink grout (applied per manufacturers recommendation) to attain a water tight seal at the wall opening of the inlet with the pipe.

For box culvert and arch pipe (all non-circular applications) connections, use non-shrink grout to ensure a water tight seal.
Neatly cut off inlet leads at inside face of inlet wall and point up with mortar. Shape floor with mortar as shown on the applicable Standard Civil Drawings for inlets.

472.4 Measurement. Measure depth of inlets as the vertical distance from the flow line of inlet lead to the top of curb or top of grate.

For inlets constructed with 24 inch leads, the standard depth is 6 feet deep.

Any portion of the inlet exceeding the above depth is to be measured per vertical foot of depth.

472.5 Payment.

A. Payment for Standard Type Inlets.
Payment for inlets with a standard depth shall be made at the contract unit price for each individual standard type inlet (includes non-shrink grout, cement stabilized sand backfill, & expansion joint material).

B. Payment for Inlets with an Additional Depth Greater Than 6 Feet.
When the depth of the inlet specified is greater than the standard depth by more than 6 feet, payment shall be at the contract unit price for each individual inlet (includes non-shrink grout, cement stabilized sand backfill, & expansion joint material) as follows:

“Type B Inlet with an Additional Depth Greater than 6 Feet”
“Type B-B Inlet with an Additional Depth Greater than 6 Feet”
“Type C Inlet with an Additional Depth Greater than 6 Feet”

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires Standard Civil Drawings that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications.

Item 360 “Concrete Pavement”
Item 420 “Concrete Structures”
Item 421 “Structural Concrete”
Item 430 “Construction of Underground Utilities”
Item 440 “Reinforcing Steel”

END OF ITEM 472
ITEM 473

ADJUSTING MANHOLES AND INLETS

473.1 Description. This Item shall govern for the furnishing of materials and for adjusting, abandoning or capping existing sewer manholes, inlets, or cleanouts where required by the plans. Manholes and inlets shall be adjusted to positions and/or elevations as shown on the plans or as ordered by the Engineer and in accordance with these Standard Specifications. Subject to the approval of the Engineer, pre-fabricated steel extension rings may be furnished for the adjustment of manholes.

473.2 Materials. Manholes or inlet rings, plates, grates and covers and brick in good condition, removed from the manholes and inlets in the process of abandonment, capping or adjustment, may be reused. Additional materials required shall conform to the pertinent provisions for those materials of the ASTM C55 “Standard Specification for Concrete Building Brick”, Item 471 “Precast Concrete Manholes and Junction Boxes” or the Item 472 "Inlets". When prefabricated, steel rings are furnished, the material shall conform to ASTM A36, “Standard Specification for Carbon Structural Steel.”

473.3 Construction. Manholes or inlet rings, covers, plates, and grates shall be removed carefully and the contact areas shall be cleaned of all mortar and grease. Rings, covers, plates or grates broken in the process of removal and cleaning shall be replaced in kind, by the Contractor, at his expense.

When prefabricated steel extension rings are furnished, they shall be either of the one-piece or two-piece type, as necessary, for the amount of adjustment. They shall be installed in accordance with the manufacturer's instructions.

If the adjustment involves lowering the top of the manhole or inlet, a sufficient depth of concrete or brick courses shall be removed to permit reconstruction on a batter not exceeding 1 inch horizontal to 2 inches vertical. In the case of brickwork, the mortar shall be cleaned from the top course of brick remaining in place and from all brick to be re-used and the manhole or inlet rebuilt to the original top dimensions. The manhole or inlet ring, cover, plate, or grate shall then be installed with the top conforming to the proposed new surface of street or grading as the case may be.

If the adjustment involves raising the elevation of the top of manhole or inlet, the top course of brick shall be cleaned of mortar and built up vertically to the new elevation using new brick, brick salvaged from other
manhole or inlet adjustments, or Class "A" concrete, and the ring, cover, plate or grate installed with top conforming to the proposed new surface of street or grading as the case may be. Grade rings where used shall have 1/2" thick cement mortar coat inside and outside or the grade rings shall be installed with grout or mastic joint compound e.g. Flex-Seal Utility Sealant or approved equal, to provide a sealed grade ring area. Alternately, the grade rings may be sealed from outside with Infi-Shield Uniband or approved equal.

If abandonment of an inlet or manhole is required, it shall be removed to an elevation a minimum of one foot below subgrade elevation, or as otherwise indicated on the plans and capped or backfilled from the flow line to subgrade with special sewer backfill.

Excavation and backfill shall conform to the Item 430 "Construction of Underground Utilities".

473.4 Measurement. Manholes or inlets completely adjusted, abandoned, or capped as prescribed above, will be measured by the unit of each manhole or inlet adjusted.

473.5 Payment. Each manhole or inlet adjusted, measured as prescribed above, complete in accordance with these Standard Specifications, will be paid for at the unit price bid for "Adjusting Manholes", or "Adjusting Inlets", as the case may be, which price shall be full compensation for furnishing all required materials, including backfill as required, excavation, tools, labor, equipment and incidentals required to complete the work.

There are line code(s), description(s) and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 430 "Construction of Underground Utilities"
Item 471 "Precast Concrete Manholes and Junction Boxes"
Item 472 "Inlets"

END OF ITEM 473
ITEM 476

HYDROSTATIC TESTING OF PRESSURE LINES

476.1 Description. This Item shall govern for the furnishing of all equipment and the method for performing hydrostatic testing of pressure lines.

After the pipe has been laid and backfilled and prior to the placement of paving, newly laid pressure lines shall be subjected to the hydrostatic testing described herein.

476.2 Performance and Design Requirements. For any section being tested, apply pressure such that at the highest point in any section, pressure to be 125 psi or the pressure specified by the Special Provision to this Item.

The permissible leakage shall not exceed that determined from the following formula:

\[ L = \frac{NDP}{3700} \]

Where:
- \( L \) = Allowable leakage in gallons per hour
- \( N \) = Number of rubber gasket joints or rubber seal valves
- \( D \) = Nominal diameter of pipe or valve, in inches
- \( P \) = Test pressure during leakage test, in pounds per square inch, gauge.

Leakage is defined as the quantity of water supplied into newly laid pipe, or any valved section thereto, necessary to maintain specified leakage test pressure, after pipe has been filled with water and air expelled and the specified test pressure has been applied.

Exposed joints are to be tested for not less than 2 hours with no allowable leakage. Covered joints shall be tested for a minimum of 6 hours. If leakage at the end of the 6 hour period exceeds the allowable by less than 25 percent, test to continue for not less than 18 additional hours.

476.3 Testing. To test, fill each valved section of the pipe slowly with water and apply the specified test pressure, measured at the point of highest elevation, by means of a pump connected to the pipe. Contractor shall furnish the pump, pipe connections, necessary apparatus, gauges and meters. Contractor shall furnish the necessary labor and assistance for conducting the tests. All testing shall be subject to the approval of the Engineer.
Before applying the specified test pressure, expel all air from the pipe. To accomplish this, make taps in the pipe, if necessary, at points of highest elevation. On completion of tests, taps to be tightly plugged with brass fittings.

At intervals during the test, Contractor shall inspect the route of the pipe to disclose leakage greater than that specified; locate and repair defective joints or defective pipe until testing proves that the leakage is within the specified allowance.

476.4 Measurement and Payment. No separate payment shall be made for work performed under this Item. Include the cost in the contract prices bid for items of which this work is a component.

There are no line code(s), description(s), or unit(s) for this Item.

END OF ITEM 476
ITEM 477

LOW PRESSURE AIR TEST - SANITARY SEWER LINES

477.1 Description. This Item shall govern for furnishing all labor, materials, tools and equipment and for performing low pressure air testing on completed sanitary sewer lines.

After the gravity sanitary sewer line has been laid and backfilled, but prior to replacement of pavement, the sanitary sewer line shall be subjected to a low pressure air test. Test shall be performed using equipment denoted herein and according to the outlined procedures.

The Contractor shall take such precautions as required to prevent damage to the lines and appurtenances being tested. Damage resulting from any testing shall be repaired at the Contractor's expense. All testing shall be completed in the presence of the Engineer.

477.2 Equipment. The equipment used shall meet the following requirements:

A. Pneumatic plugs shall have a sealing length equal to or greater than the diameter of the pipe being tested.

B. Pneumatic plugs shall resist the internal test pressures without requiring external bracing or blocking.

C. One of the pneumatic plugs shall have an inlet tap or other provision for connecting air supply to introduce low pressure air into the line for testing.

D. All air used shall pass through a single control panel.

E. Air supply system shall have the necessary valves and gauges to control the rate at which air enters the test section and for reading test results.

F. Pressure gauges shall have minimum gradations of 0.1 psi and an accuracy of plus or minus 0.04 psi.

477.3 Pretesting Procedures. In an area where groundwater is known to exist, prior to conducting any tests, the Contractor shall provide for determining groundwater level by installing groundwater gauges in the manholes.

Gauges shall consist of a minimum 1/2 inch diameter pipe, capped and inserted horizontally in the manhole wall as near as possible to the top of
the sewer, sealed so as to be watertight. Immediately prior to the performance of the test, groundwater back pressure shall be determined by removing pipe cap, blowing air through the pipe into the ground to clean the pipe. Clear plastic tube shall be held vertically and measurement of height (in feet) of water over invert of pipe to be taken after water has stopped rising.

Height shall be divided by 2.3 feet to establish pounds per square inch (psi) of back pressure to be added to all readings. Upon satisfactory completion of the air test, remove the groundwater gauge from the wall of manhole and neatly and permanently close opening with a non-shrinking, non-corrosive grout. Prior to testing flush and clean sewer lines of any debris, also, plug all pipe outlets to resist test pressure.

477.4 Testing Procedures. The testing procedure shall be as follows:

A. Seal-test all pneumatic plugs before using in the test installation. Lay one length of pipe on the ground and seal at both ends with the pneumatic plug. Introduce air into the pneumatic plug to 24 psig. Sealed pipe to be pressurized to 5 psig. Plugs shall hold against this pressure without external bracing.

B. Contractor shall carefully observe safety precautions during air testing; no one shall be allowed in the manholes during testing.

C. Place pneumatic plugs in the line at each manhole and inflate to 25 psig. Introduce low pressure air into sealed line until internal air pressure reaches a pressure of 4 psig plus the average groundwater back pressure. Allow two minutes for the internal air pressure to stabilize.

D. When the internal air pressure has stabilized and is at or above test pressure (3.5 psig minimum, plus groundwater back pressure), commence the test. Disconnect air hose from the control panel to the air supply. Record the pressure drop for the test period.

If the pressure drops more than 1.0 psig during the test period, line is presumed to have failed. Test may be discontinued, when the prescribed test time has been reached.

The time required for the pressure to decrease from 3.5 psig to 2.5 psig (greater than the average groundwater back to pressure over the pipe) to be not less than the time shown for the diameter given in Table 1. Times shown are based on loss of air not to exceed 0.003 cubic feet per minute per square foot of internal pipe surface
tested at an average pressure of 3.0 psi greater than the groundwater back pressure.

**TABLE 1**

**ALLOWABLE TIME TABLE**

<table>
<thead>
<tr>
<th>PIPE SIZE (INCHES)</th>
<th>TIME (MIN.)</th>
<th>TIME (SEC.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>56</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>43</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>15</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>18</td>
<td>8</td>
<td>30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PIPE SIZE (INCHES)</th>
<th>TIME (MIN.)</th>
<th>TIME (SEC.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>9</td>
<td>55</td>
</tr>
<tr>
<td>24</td>
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<td>20</td>
</tr>
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<td>0</td>
</tr>
<tr>
<td>42</td>
<td>19</td>
<td>50</td>
</tr>
</tbody>
</table>

Sanitary sewers failing to meet the requirements of the low pressure air test shall be tested again after the Contractor has located and remedied defects causing this failure. No sanitary sewer shall be accepted until the requirements of the test procedure are satisfied.


**477.5 Measurement & Payment.** No separate payment for work performed under this Item. Include the cost in the contract unit price bid for the item of which this work is a component.

There are no line code(s), description(s), or unit(s) for this Item.

**END OF ITEM 477**
ITEM 480

PRECAST REINFORCED CONCRETE BOX SECTIONS

480.1 Description. This Item shall govern for the furnishing and installing of precast reinforced concrete box sections of the size, type and configuration installed to the lines and grades established by the drawings.

Precast reinforced concrete box sections (RCB) shall be one of the following:

A. Conventional tongue and groove joints with preformed flexible butyl rubber (FBR) sealant. Conventional RCB has squared shoulders on both the tongue and groove ends of the section at the corners.

B. Rubber gasketed tongue and groove joints with rubber gasket seals. The rubber gasketed RCB has rounded shoulders on both the tongue and groove ends of the section at the corners. Please note, when rubber gasket RCB is selected, no external seal strip shall be required.

It is permissible to use both types of box sections within the same project as may be needed due to product supply issues, but any continuous run of RCB between structures must have the same joint type for that entire run.

480.2 Material. Precast reinforced concrete box sections shall be manufactured in accordance with the ASTM C1433 “Standard Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers.”

In the manufacture of concrete box sections, the supplier has the option of using portland cement or portland cement plus fly ash, as defined herein. Cement plus fly ash shall be composed of portland cement and 20-30 percent fly ash, by weight. Fly ash shall be Class C or Class F, conforming to the requirements of ASTM C618 "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete."

Conventional Joints with Flexible Butyl Rubber Joint Sealant

The sealant for conventional tongue and groove joints shall be preformed flexible butyl rubber meeting the requirements of ASTM C990 “Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box
Sections Using Preformed Flexible Joint Sealants” Section 6.2 “Butyl Rubber Sealant.” The sealant shall be one of the following:

A. “RU106 - RUBR-NEK”, manufactured by Henry Company, or

B. “CS-102” manufactured by ConSeal Concrete Sealants, Inc., or

C. an approved equal.

The sealant width and thickness shall conform to its manufacturer's recommendations, and be large enough to properly seal the entire perimeter of the tongue and groove joint.

In addition, joints shall be sealed externally with a continuous 12” wide minimum seal strip along and over the entire joint. The seal strip shall be centered on the joint and wrapped around all four sides completely covering the exposed surface of the joint. The seal strip shall conform to ASTM C877 “Standard Specification for External Sealing Bands for Concrete Pipe, Manholes, and Precast Box Sections”, Types II or III. It shall have a rubberized mastic sealer with woven polypropylene reinforcing, and heavy polyethylene backing. The seal strip shall be one of the following:

A. “MacWrap”, which is manufactured by Mar-Mac Construction Products, Co.; or

B. “ConWrap CS-212”, which is manufactured by Concrete Sealants, Inc.; or

C. an approved equal.

The external seal strip shall be installed per its manufacturer's recommendations.

Rubber Gasketed Joints

Joint seal shall be a rubber gasket meeting the requirements of ASTM C1677 “Standard Specification for Joints for Concrete Box, Using Rubber Gaskets” for the design of the gaskets and permissible variations in dimensions.

The rubber profile gaskets are glued in place by the manufacturer against the offset on the tongue end of the box sections. The rubber gasket is pre-lubricated on its inner surface. DO NOT LUBRICATE THE JOINT OR GASKET.
480.3 Submittals.

For Box Sections with Flexible Butyl Rubber Sealants –

A. Provide dimensional data for the box section barrel and joint by size.

B. Provide sealant composition data, sealant material width and thickness by box section size, and manufacturer’s installation instructions.

C. If used, joint primer type, manufacturer and installation instructions.

D. External joint seal strip manufacturer, model/type and installation instructions.

For Box Sections utilizing Rubber Gasket Joints –

A. Provide dimensional data for the box section barrel and joint by size.

B. Provide gasket composition data and dimensional data by box section size.

C. Provide joint assembly instructions.

480.4 Installation. Trenches shall be excavated with suitable type equipment such as ladder type trenching machines or trench hoes or other equipment that may be approved by the Engineer. Trenches for precast box sections shall have a width below the top of the box of not less than the outside width of the box plus 18 inches clear on both sides and shall be wide enough to permit making up the joints.

No box sewer shall be laid in a trench in the presence of water. All water shall be removed from the trench sufficiently ahead of the sewer placing operation to insure a dry, firm bed on which to place the sewer, and if necessary, the trench will continue to be dewatered until after the sewer is bedded and backfilled as directed by the Engineer. Removal of water may be accomplished by pumping, or pumping in connection with the well point installation as the particular situation may warrant. The well point installation shall be in accordance with the Item 436 “Well Pointing”. When well pointing is used for dewatering, then the seal slab shall be installed. Where available, Harris County will provide the Contractor with soils data; however, Harris County does not guarantee the adequacy or accuracy of the information as compared to actual field conditions at the time of construction. The Contractor may elect to do soil borings on his own, if he so desires.
Where necessary, to comply with OSHA Regulation 1926.650, the side of the trench or other excavation shall be braced and rendered secure. The bracing shall be in accordance with the Item 429 "Trench Safety System".

In the event that excavation cannot be dewatered to the point where the precast box sewer trench bottom elevation is free of mud, excessive wet soil, sandy silt or clay with water, a seal slab shall be used in the trench bottom. Such seal slab shall be in accordance with Item 421 “Structural Concrete”. The 7 inch thick cast-in-place seal slab shall be Class “D”, 5 sacks of cement per cubic yard with a minimum compressive strength of 1,750 P.S.I. at 7 days and 2,500 P.S.I. at 28 days. The seal slab shall have minimum #4 rebar at 18 inch on centers, in each direction. A precast seal slab, minimum 6 inch thick, may be used, provided that the joints of the seal slab do not occur at the joint of the precast box sewer. Contractor shall have an option of using a three day cylinder test break at no expense to Harris County.

All surplus excavated material shall be disposed of by the Contractor outside the limits of the right of way, in a legal manner.

After the trench has been excavated to its bottom, the trench shall be fine graded to the required trench bottom elevations. Any over-excavation of the subgrade shall be filled with 1.5 sack per ton of cement stabilized sand. Cement stabilized sand shall be in accordance with the Item 433 "Cement Stabilized Sand Bedding and Backfill Material", at the Contractor’s expense. The Contractor shall establish the grade line in the trench from either grade stakes or by use of lasers. The Contractor shall maintain this grade control for a minimum of 100 feet behind and ahead of the box laying operation. The Contractor shall, at his expense, furnish and place in position all necessary stakes, grade and batter boards for establishing and maintaining correct elevation and alignment.

Following trench excavation, the Contractor shall place cement stabilized sand bedding a minimum of 6 inches thick in such a manner that once the box sections are laid, the invert elevation of the box section shall conform to the drawing elevations. Cement stabilized sand shall be installed in accordance with Item 433 "Cement Stabilized Sand Bedding and Backfill Material". Laboratory tests will be performed as the backfill proceeds.

The precast box sections shall be so laid in the trench that, after the storm sewer is completely installed, the interior surface shall conform accurately to the grade and alignment as shown on the drawings or as established and given by the Engineer. All box sections must be laid in a straight line with the tongue end of the box section pointed downstream and pulled fully home into the grooved end of the previously laid box section.
Caution shall be taken to not drag cement stabilized sand or earth into the
annular space. Box sections shall be fitted together so that the finished
storm sewer has a smooth and uniform invert.

All lifting holes shall be sealed to the satisfaction of the Engineer. Tapered lift hole plugs shall be used, and sealed both externally and internally with non-shrink grout. Additionally, lift hole plugs shall not protrude above the top exterior surface of the box nor below the soffit of the box by more than one-half inch.

Conventional Joints with Flexible Butyl Rubber Joint Sealant

A. If required, tongue and groove ends shall be primed immediately before installation of sealant. Primer shall be used as recommended by the sealant manufacturer. When the atmospheric temperature is below 40ºF, priming the concrete joint will improve the bonding action with the joint sealant. Primer should be applied both to the tongue end of the upstream box and the groove end of the downstream box, so that both sides of the flexible butyl rubber sealant are in contact with the primer when the joint is pulled home. The sealant shall then be applied to box section joints.

B. If required by the sealant manufacturer, lubricant shall be applied by the Contractor immediately prior to placing each box section in the trench, and then followed by joining with the previously laid box section.

C. The flexible butyl rubber sealant will come in either coils or strips with paper on both sides of the sealant.

D. Before laying the box section in the trench, the paper wrapper shall be removed from one side only of the sealant. The sealant shall then be pressed firmly to the clean, dry box section joint surface. The sealant material shall be placed around the entire perimeter of the tapered tongue near the shoulder of each box section joint in accordance with the sealant manufacturer’s instructions.

E. The paper wrapper on the other side of the sealant shall not be removed until immediately before pulling each box section into its final position.

F. When the tongue is correctly aligned with the flare of the groove, the remaining paper wrapper on the joint sealant shall be removed and the box section shall be pulled (do not push box home with backhoe bucket) with sufficient force and power (using tuggers) to cause evidence of squeeze-out of the sealant on either the inside
or outside around the complete box section joint perimeter. In no case shall a joint be wider than one inch, after having been pulled home. Any sealant that extends into the interior of the box section shall be removed. Each box section shall be pulled home in a straight line with all parts of the box section on line and grade at all times.

G. The external joint seal wrap, as previously described in the materials section, shall be placed around the complete external surface of the joint, with a twelve inch overlap, and installed per the seal strip manufacturer’s instructions.

Rubber Gasketed Joints:

A. When the tongue is correctly aligned with the flare of the groove, the box section shall be pulled home (using tuggers) with sufficient force to fully home the tongue into the groove. Each box section shall be pulled home in a straight line with all parts of the box section on line and grade at all times.

When installing concrete box sections in a trench condition, backfill shall consist of material in the “Storm Sewer Construction Detail” shown on the Standard Civil Drawing. All backfill not meeting the requirements of the detail shall be removed and recompacted at no cost to Harris County.

When installing concrete box culverts in an existing channel, ditch, or gully, all bedding and backfill material shall be placed in accordance with the drawing details provided by the design Consultant.

Final backfill over box sections will be permitted as installation proceeds. Final backfill shall conform to the requirements of Item 132 “Embankment”. Prior to backfilling, the Contractor shall remove all steel sheeting and/or cut off all timber sheeting a minimum of 3 feet below finished grade or as shown by the plans. Backfill shall consist of material excavated on the site and deemed adequate by the Engineer or suitable materials obtained from a borrow site.

480.5 Quality Assurance.

If production of box sections is not witnessed by the Engineer, selected box sections shall be cored in accordance with ASTM C1433, Section 10.3 and tested in accordance with ASTM C42 “Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete”, (wet method). All test specimens and testing shall be done by the producer of the concrete box sewer.
Box sections previously approved and stamped by a Texas Department of Transportation (TxDOT) approved fabricator with specific stamp, which must state: “Certifies Specification Compliance” (i.e. compliance with TxDOT’s DMS - 7310 “Reinforced Concrete Pipe and Machine-Made Precast Concrete Box Culvert Fabrication and Plant Qualification” requirements) will be accepted by all laboratories and by Harris County.

The Testing Laboratory’s representative will determine the moisture density relationship in accordance with ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³ (600 kN-m/m³))” on material secured from the trench excavation.

The Testing Laboratory’s representative will determine the in-place density in accordance with ASTM D6938 “Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)” or ASTM D1556 “Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method.” The minimum level of testing will consist of at least one test for each 50 linear feet of trench for bedding and per lift of backfill, or as directed by the Engineer.

480.6 Acceptance Requirements. The average compressive strength of all cylinders tested shall be equal to or greater than the design concrete strength and no cylinder tested shall have a compressive strength less than eighty percent of the design concrete strength. Any lot which complies with all of these requirements will be considered acceptable with regard to concrete strength. Any lot which does not meet all of these requirements will be subject to further testing by cores of hardened concrete in accordance with ASTM C1433.

Box sections which meet all the dimensional tolerances given in ASTM C1433 or further defined in this Item will be considered acceptable provided that the box sections have met the compressive strength requirement outlined above. Repaired box sections will only be acceptable if the repaired portions are visible and areas repaired were within the limitations given in this Item and ASTM C1433.

480.7 Measurement. All box sections installed in accordance with the above specifications and accepted by the Engineer shall be measured by the linear foot of the size installed. Longitudinal measurements shall be made along the centerline of the box sewer from the interior wall face of the downstream junction box to the interior wall face of the upstream junction box.

Seal slabs shall be measured by the square yard installed, along the
centerline of the RCB sewer.

480.8 Payment. All box sections installed in accordance with this Item and accepted by the Engineer shall be paid for at the unit price bid by the Contractor, complete in place, for the type, size and depth constructed. The unit price bid shall be full compensation for furnishing all material, including joint materials, equipment and labor for all excavation, shaping of trench bottom, jointing, laying, normal dewatering, sheeting, bracing, bedding, backfilling, and specials necessary to install the box sections in accordance with this Item.

Payment for seal slab shall be made at the unit price bid per square yard for class “D” concrete seal slab and shall include the price of all labor, materials and equipment necessary to complete this Item.

Payment for a well point system, when used for dewatering, shall be made in accordance with the Item 436 “Well Pointing”.

There are line code(s), description(s), and unit(s), for this Item.

NOTE: This Item requires other Standard Specifications:

Item 132 “Embankment”
Item 421 “Structural Concrete”
Item 429 "Trench Safety System" 
Item 433 "Cement Stabilized Sand Bedding and Backfill Material"
Item 436 "Well Pointing"

END OF ITEM 480
481.1 Description. This Item shall govern for the construction of monolithic, reinforced concrete box sewers of the size, type and configuration and constructed to the lines and grades established by the plans, including all excavation, sheeting, bracing, dewatering, bedding, backfill and disposal of surplus excavation.

481.2 Materials. Concrete for monolithic box sewers shall be Class B concrete as described in the Item 421 "Structural Concrete". The mixing and placing of concrete shall be in accordance with that item.

The Contractor shall provide reinforcing steel in accordance with the Item 440 "Reinforcing Steel". The steel shall be placed and tied in accordance with the details shown on the plans.

481.3 Construction Methods. Trenches shall be excavated with suitable type equipment, such as ladder type trenching machines or trenching hoes as approved by the Engineer. Trenches for monolithic box sewers shall have a width adjacent to the sewer section equal to the outside width of the sewer, plus the thickness of any steel or wood sheeting extending below the top of the concrete. Above the top of the monolithic box sewer, the trench width may be greater than specified above by an amount sufficient only to place sheeting and bracing and permit installation of well point headers or manifolds and pumps where the depth of the trench is such that it would be uneconomical to pump from a surface installation. For monolithic box sewers constructed within existing channels, ditches and bayous, the trench width shall only be wide enough at the flowline grade of the box sewer to permit placement of forms. Side slopes may be laid back on the sufficient grade to permit placement of outside forms without causing slope failures or as directed by the Engineer, or as shown on the plans. "Step cutting or benching", will not be permitted without the written approval of the Engineer.

After the trench has been excavated to the bottom, the trench shall be fine graded to the established subgrade. The Contractor shall establish the grade line in the trench from grade stakes. The Contractor shall maintain this grade control a minimum of 100 feet behind and ahead of the construction operations. The Contractor shall, at his own expense, furnish and place in position as directed by the Engineer, all necessary stakes, grade and batter boards for locating the work. The Contractor may, at his own expense, use a laser beam to maintain line and grade.
No box sewer shall be constructed in a trench in the presence of water. All water shall be removed from the trench sufficiently ahead of the construction operation to insure a dry firm bed on which to place the sewer and if necessary, the trench will continue to be dewatered until after the sewer is constructed and backfilled as directed by the Engineer. Removal of water may be accomplished by pumping or pumping in connection with well point installation as the particular situation may warrant. The Contractor shall satisfy himself as to the soil conditions to be encountered. Where available, the Engineer will provide the Contractor with soil data; however, the Engineer does not guarantee the adequacy or accuracy of the information as compared to actual field conditions to be encountered at the time of construction. The Contractor may elect to do soil borings on his own, if he so desires.

Where necessary to comply with the requirements of OSHA Regulation 1926.650, the side of the trench or other excavation shall be braced and rendered secure to the satisfaction of the Engineer. Board sheeting and/or steel sheeting may be utilized as directed by the Engineer. For vertical trenches where board sheeting is utilized, the floor shall be installed as bracing to support the bottom of the vertical sheeting. Flooring shall be set solidly against the vertical sheeting and undisturbed earth in the bottom of the trench. Where voids are left below the flooring, the board shall be spaced apart adequately to allow concrete to flow between the boards and fill the voids. Bracing and sheeting shall be installed in accordance with the Item 435 "Timber Ordered Left in Trench".

The Contractor shall construct a concrete seal slab in the trench bottom when excavation cannot be dewatered to the point where the construction of a monolithic reinforced concrete box sewer subgrade is free of mud, excessive wet soil, sandy silt or clay with water. Excavation shall be made below the bottom of the monolithic box sewer to a depth equal to the thickness of the seal slab. Concrete for seal slab shall be in accordance with Item 421 "Structural Concrete". The 7 inch thick cast-in-place seal slab shall be Class "D", 5 sacks of cement per cubic yard with a minimum compressive strength of 1,750 P.S.I. at 7 days and 2,500 P.S.I. at 28 days. A precast seal slab minimum 6 inch thick may be used, provided that the joints of the seal slab do not occur at the joint of the monolithic box sewer. Contractor shall have an option of a three day cylinder break test at no expense to Harris County. The Contractor may, at his option and expense, place seal slabs other than as shown on the drawings or as ordered by the Engineer. The seal slab cannot be substituted for the floor or "bottom slab" of the monolithic concrete box.

The Contractor shall provide forms having smooth surfaces and ample strength that shall be rigidly braced. The bracing shall be adequate to prevent deviations from the correct lines. All steel forms shall be neatly
and accurately made with all similar parts in each longitudinal section being interchangeable with other sections. All wooden forms shall be built of clean sound lumber, reasonably free from knots, dressed on all sides and neatly fitted. The form surface shall be watertight and shall be securely fastened to the ribs or supports. No form shall be used that is not of proper shape and strength, and in every way suitable to the Engineer.

Before placing reinforcing steel and concrete, the forms shall be coated with lubricants to prevent adherence of the concrete.

Where construction of the box sewer permits construction of the bottom slab with a starter wall and construction joints, the Contractor shall not erect wall forms or wall and top forms on the slab prior to 24 hours following placement of the concrete. Wall forms must remain in place until the concrete has attained a compressive strength of 1,000 psi, but in no event shall they be removed prior to 24 hours following placement of the concrete.

Forms and center supports shall not be disturbed until the concrete has attained a compressive strength of 2,000 psi, but in no event shall they be removed prior to 72 hours following placement of concrete, without the prior written authorization of the Engineer. In certain instances, a "stiffback" system may be utilized to remove top forms prior to this time, provided they adequately support the top slab at its midpoint while being supported themselves by only the side walls.

In cases of vertical trench excavations, the trench sheeting may be used as the outside form for box sewers. During the trench excavation, rangers and struts shall be placed as necessary to adequately brace the sheeting and permit placement of forms. Rangers and struts placed immediately above the permissible construction joint in the walls shall not be removed until the concrete in the bottom slab has attained a compressive strength of 2,000 psi. Rangers and struts placed immediately above the top slab shall not be removed until the concrete has attained a compressive strength of 2,500 psi. Strength of the concrete shall be determined by test cylinder breaks. Cylinders for these tests shall be kept at job temperature and under job conditions and shall be made and broken by the laboratory designated by the Engineer at the Engineer's expense.

Backfill over monolithic box sewers shall not be started until the concrete has attained a compressive strength of 3,600 psi. Prior to backfilling, the Contractor shall remove all steel sheeting and/or cut-off all timber sheeting a minimum of 3 feet below finished grade, as shown on the plans. Backfill shall consist of material excavated on the site and deemed
adequate by the Engineer or materials obtained from a suitable borrow site. Suitable materials shall be CL/CH materials as determined by the Uniform Soil Classification System (ASTM D2487 “Standard Practice for Classification of Soils for Engineering Purposes – Unified Soil Classification System”) and are cohesive in nature, free of debris and organic material and acceptable to the Engineer. Backfill shall be placed in maximum 8 inch lifts, sprinkled as required and compacted to a density of 90 percent standard proctor density (ASTM D698 “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort – 12,400 ft-lbf/ft$^3$”), except under the roadway. Moisture content shall be controlled so that the required density is achieved from optimum moisture content to 3 percent above optimum moisture content.

Where backfill occurs beneath a road surface, the material from 2 feet below subgrade to the established base material shall be compacted to a density of 95 percent standard proctor density (ASTM D698).

Laboratory tests will be performed as the backfill proceeds. All backfill not meeting this Item shall be removed and recompacted to the satisfaction of the Engineer at no cost to the County.

All surplus excavated material shall be disposed of by the Contractor. If the material is suitable, it can be used in the construction of the roadway.

The angles in box type sewers shall be built in accordance with the plans and specifications. The cost of making these angles and all cost incidental to them shall be included in the unit price bid for box sewer.

Where junctions with sewers are to be made, openings may be left in the walls the size of which shall be the outside dimensions of the connecting sewer. A bond length of each reinforcing bar shall be left in the opening for connecting with future sewer. Where a future stub sewer is to be built, the end of the concrete of the stub sewer at the box sewer shall be at the inside face of the sewer box wall. All openings shall be closed with an 8 inch brick plug.

The cost of providing these openings and the brick bulkheads shall be included in the unit price of the box sewer.

481.4 Quality Assurance. The concrete for the box sewer and seal slab will be tested in accordance with the Item 421 "Structural Concrete".

The Testing Laboratory’s representative will determine the moisture density relationship in accordance with ASTM D698, on material secured from the trench excavation or from the supplier of cement stabilized sand. Samples secured from the cement stabilized sand supplier shall be
blended with portland cement in accordance with Item 433 "Cement Stabilized Sand Bedding and Backfill Material", and in accordance with ASTM D558 "Standard Test Methods for Moisture-Density (Unit Weight) Relations of Soil-Cement Mixtures" on material from the supplier of cement stabilized sand.

The Testing Laboratory's representative will determine the in-place density in accordance with ASTM D6938 "Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods" or ASTM D1556 "Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method." The minimum level of testing will consist of at least one test for each 50 linear feet of trench per lift of backfill.

Method of Measurement. All box sewers installed in accordance with the above specification and accepted by the Engineer, shall be measured by the linear foot of the size installed. Longitudinal measurements shall be made along the centerline of the box sewer from face of headwall or outfall structure to a point of change in size or termination of the line.

Seal slabs shall be measured by the square yard installed, along the centerline of the structure.

Basis of Payment. All box sewers installed in accordance with this Item and accepted by the Engineer shall be paid for at the unit price bid by the Contractor, complete in place, of the type, size and depth constructed. The unit price bid shall be full compensation for furnishing all material, equipment and labor for all excavation, shaping of trench bottom, reinforcing, concrete, dewatering, sheeting, bracing, forming, backfilling and specials necessary to install the box sewers in accordance with this Item and of the size, type, and depth as shown on the plans.

Payment for seal slab shall be made at the unit price bid per square yard for Class "D" Concrete Seal Slab and shall include all costs for labor, materials and equipment necessary to install this Item complete in place. When timber is ordered left in place, it shall be paid for in accordance with the Item 435 "Timber Ordered Left in Trench".

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications.

Item 421 "Structural Concrete"
Item 433 "Cement Stabilized Sand Bedding and Backfill"
Item 435 "Timber Ordered Left in Trench"
Item 481
Page -6-

FOR PROJECTS INITIATED
AFTER MAY 1, 2014
REVISION 6

Item 440 "Reinforcing Steel"

END OF ITEM 481
ITEM 491

REINFORCED CONCRETE SLOPE PAVING

491.1 Description. This Item shall govern for furnishing and placing reinforced concrete slope paving to the lines, grades, and depths shown on the plans.

491.2 Materials. Concrete shall be Class D concrete, in accordance with the Item 421 "Structural Concrete". Reinforcing steel shall conform to the requirements of Item 440 "Reinforcing Steel."

With prior approval of the engineer, fly ash may be used with the cement. Cement plus fly ash shall be composed of portland cement and 20-30 percent fly ash, by weight. Fly ash shall be Class C or Class F, conforming to the requirements of ASTM C618 “Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.”

Curing materials shall be in accordance with the Item 526 "Membrane Curing”.

491.3 Construction Methods. Prior to placing material, the subgrade shall be prepared to the proper section for the width and depth of slope paving as shown on the Plans. Construction joints shall be located as shown on the plans, or as otherwise indicated.

Place as a minimum requirement: 3/4 inch expansion joint material at the location where slope paving is to be placed against walls, or around columns or piling, and at maximum intervals of 80 feet throughout the length of slope paving. Nail a 3/4 inch by 1 inch deep redwood board to the top of the joint material and after the slope paving has set and cured, remove the redwood board and fill the area with joint sealant.

Unless otherwise indicated on the plans, use a minimum No. 4 reinforcing bar conforming to ASTM A615 “Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement”, Grade 60, at a maximum spacing of 12 inches in each direction. The distance from the first parallel bar to the edge of the concrete shall not exceed 3 inches.

When welded wire fabric reinforcing is substituted, it shall be equivalent to the No. 4 rebar at 12 inch on centers, at a minimum. The welded wire shall conform to ASTM A1064 “Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete.” Only flat sheets shall be used. Use a minimum of 6 inch lap at all splices, with not less than 1 inch, nor more than 3 inches clearance.
from fabric to the edge of concrete, and no wires projecting to last member parallel to the edge of concrete.

The reinforcing steel shall be supported throughout the placing of the slope paving to maintain its position approximately equidistant from top and bottom surface of the concrete.

The minimum thickness of the reinforced concrete slope paving shall be 5 inches.

After the concrete has been placed, compacted and shaped to conform to the dimensions shown on the plans, and after it has cured sufficiently to avoid slumping, the concrete shall be finished with a wooden float to secure a reasonably smooth finish.

The concrete shall be cured in accordance with the Item 526 "Membrane Curing".

Weep holes shall be installed in the bottoms and walls of the low flow section and in the slope paving at the locations and spacing and in accordance with the details shown on the plans.

491.4 Measurement. Concrete slope protection shall be measured by the square yard of surface area, complete in place. All edge beams and/or toe walls, as well as weep holes, shall be incidental to the reinforced concrete slope paving.

491.5 Payment. Concrete slope protection shall be paid for at the contract unit price, measured as provided above. Price shall be full compensation for furnishing and placing all materials, including expansion joint material, joint sealant and reinforcing steel, surface finishing, and curing.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 421 “Structural Concrete”
Item 526 “Membrane Curing”

END OF ITEM 491
ITEM 493

RIPRAP

493.1 Description. This Item shall govern for furnishing and installing of concrete or stone riprap for common erosion protection applications in open channels.

493.2 Materials. The storage area shall be kept clean, firm, and smooth and well drained in order that the riprap can be recovered free from dirt and other foreign matter.

The riprap shall be stockpiled and handled so as not to cause undue segregation of particle sizes either in the stockpile, or while loading, hauling and handling.

The riprap shall consist of broken concrete or stone blocks and shall be dense, durable and hard material free from cracks, seams and other defects which would tend to increase deterioration from handling and natural causes.

Where broken concrete is used, all exposed metal, including rebar and wire mesh, shall be cut off flush with the surface of the block prior to placing.

Spalls, fragments and chips shall not exceed 5 percent by weight. The dimension and shape limitations do not apply to this portion of the riprap.

Riprap blocks shall be provided in cubic form, rather than elongated (flat) shapes.

The minimum thickness of each block shall be 6 inches.

No more than 25 percent of the blocks may have a length greater than 2-1/2 times the width or thickness. No length of block shall exceed 3 times the width or thickness.

The riprap shall be well graded and shall conform to the following tables unless specifically noted otherwise on the drawings:
## TABLE 1 - RIPRAPP GRADATION NO. 1

<table>
<thead>
<tr>
<th>PERCENT LIGHTER BY WEIGHT</th>
<th>STONE WEIGHT (Lbs.)</th>
<th>VOLUME CUBIC FOOT (2)</th>
<th>CUBICAL SHAPE (Ea. Side, ft.)</th>
<th>SPHERICAL SHAPE (Dia., ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower Limit</td>
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<tr>
<td>100</td>
<td>180</td>
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<td>50</td>
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<td>0.73</td>
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<td>15</td>
<td>40</td>
<td>60</td>
<td>0.27</td>
<td>0.40</td>
</tr>
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</table>

**NOTES:** The theoretical cube and sphere size is presented in the table for guidance only. The previous size and shape specifications shall govern.

Volume is based on 150 pcf, unit weight.

This gradation is to be used in normal applications, and may be noted on the drawings as standard riprap, riprap, 18 inch thick riprap mats, or other similar designations.

## TABLE 2 - RIPRAPP GRADATION NO. 2

<table>
<thead>
<tr>
<th>PERCENT LIGHTER BY WEIGHT</th>
<th>STONE WEIGHT (Lbs.)</th>
<th>VOLUME CUBIC FOOT (2)</th>
<th>CUBICAL SHAPE (Ea. Side, ft.)</th>
<th>SPHERICAL SHAPE (Dia., ft.)</th>
</tr>
</thead>
<tbody>
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<td>Upper Limit</td>
<td>Lower Limit</td>
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<tr>
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</table>

**NOTES:** Provide a 24 inch thick mat, minimum, for Riprap Gradation No. 2.

The theoretical cube and sphere size is presented in the table for guidance only. The previous size and shape specifications shall govern.

Volume is based on 150 pcf, unit weight.
The gradation is to be used only where specifically noted on the drawings as “Riprap Gradation No. 2”.

For special applications, gradation, thickness, and other special requirements shall be as shown in the plans.

493.3 Construction Methods. The riprap shall meet the gradation and quality requirements prior to placing.

The riprap shall be placed to the slopes, lines, and grades as shown on the drawings, to provide a well-graded mass of riprap without voids.

Thickness of the riprap mat shall be as shown on the drawings, with a minimum mat thickness as shown on the gradation tables.

The riprap shall be placed in one course (lift) across the channel bottom, then up the channel side slopes. Place the riprap carefully in such a manner to avoid displacement or damage to the prepared surface or geotextile and in such a manner to avoid segregation of particle sizes. Place riprap as close to final position as feasible.

The riprap blocks are to be in close contact, well-graded, and free from pockets of small stones or clusters of large stones. Elongated riprap blocks shall be well distributed throughout the riprap mat. Individual oversized blocks will not be permitted. These shall be broken to acceptable size or removed and replaced with riprap within the gradation limits. Surface irregularities shall be minimal.

Do not drop riprap from such a height to cause breakage or to damage the geotextile (if used).

Prevent mixture or incorporation of dirt or other materials with the riprap during placing operation.

Placing of riprap by any method, machine or hand, will be permitted as long as specified requirements are obtained.

Fill spaces between larger riprap blocks with spalls and smaller blocks of the largest feasible size to form a compact mass. Do not place spalls and small blocks in place of larger size blocks.

493.4 Measurement. Riprap shall be measured by the square yard or by the ton of riprap material, as noted on the bid sheets. Riprap Gradation No. 1 when measured by the square yard shall be for a minimum specified thickness of 18 inches, complete in place. Riprap Gradation No. 2 when
measured by the square yard shall be for a minimum specified thickness of 24 inches, complete in place.

Channel excavation to the top of riprap (finish grade) is measured as shown on the bid sheets.

Excavation for the placement of Riprap Gradation No. 1 to 18 inches beyond the finish grade shall be considered incidental to placement of riprap.

Excavation for the placement of Riprap Gradation No. 2 to 24 inches beyond the finish grade shall be considered incidental to placement of riprap.

Channel fill to the top of riprap (finish grade) is measured as shown on the Bid Sheets. Channel fill, not approved by the Engineer, shall not be measured.

Geotextile under the riprap, where required (as shown on the drawings), shall not be measured and shall be considered incidental to riprap.

493.5 Payment. Payment for riprap shall be based on the unit price per square yard or the price per ton for riprap placed, as shown on the plans. Payment shall be full compensation for providing all labor, materials, geotextile, excavation and equipment necessary to complete the riprap installation.

Excavation for the placement of riprap is considered incidental.

Payment for Channel Excavation to the top of riprap (finish grade) is paid for as shown on the Bid Sheets.

Fill, as approved by the Engineer, to the top of riprap (finish grade) is paid for as shown on the Bid Sheets.

There are line code(s), description(s) and unit(s) for this Item.

NOTE: This Item requires other Standard Specification

Item 494 “Geotextiles”

END OF ITEM 493
ITEM 494

GEOTEXTILES

494.1 Description. This Item shall govern for geotextile fabric to be used in pavements or erosion control as herein specified or as called for on the drawings or as directed by the Engineer.

494.2 Material. The Geotextile fabric and the threads used in joining Geotextiles by sewing shall be manmade long-chain synthetic polymer fibers, composed of at least 95 percent by weight of polyolefins or polyesters that form a durable woven or non-woven mat of uniform quality such that the filaments or yarns retain their dimensional stability relative to each other, including selvages. They provide separation, water proofing and stress relieving membrane within the pavement structure.

There are three classes of geotextile fabric:

A. Class 1 is specified for more severe or harsh installation conditions where there is a greater potential damage

B. Class 2 and 3 are specified for less severe conditions

General Requirements:

A. Fabric fibers are continuous and randomly oriented throughout the fabric.

B. The fabric is mildew resistant and rot-proof and it is satisfactory for use in a wet soil and aggregate environment.

Geotextiles used for separation, stabilization, subsurface drainage, temporary silt fence, paving fabric and permanent erosion control shall satisfy AASHTO M288-00 “Geotextile Specification for Highway Applications” requirements, and shall meet the following minimum physical property values:

<table>
<thead>
<tr>
<th>PROPERTIES</th>
<th>TEST METHOD</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
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<td>Class 1</td>
<td>Class 2</td>
</tr>
<tr>
<td></td>
<td>Elongation</td>
<td>Elongation</td>
</tr>
<tr>
<td>Ultra-Violet Stability (Strength</td>
<td>ASTM D4355</td>
<td>50% after 500 h of exposure</td>
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<tr>
<td>Retained)</td>
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<td>PROPERTIES</td>
<td>TEST METHOD</td>
<td>VALUE</td>
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<td>Puncture Resistant (N)</td>
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<td>Sewn Seam Strength (N)</td>
<td>ASTM D4884</td>
<td>1260</td>
</tr>
<tr>
<td>Permittivity (sec(^{-1}))</td>
<td>ASTM D4491</td>
<td>0.05</td>
</tr>
<tr>
<td>Melting Point***</td>
<td>ASTM D276</td>
<td></td>
</tr>
<tr>
<td>Ultimate Elongation ***</td>
<td>ASTM D4632</td>
<td></td>
</tr>
<tr>
<td>Apparent Opening Size**</td>
<td>ASTM D4751</td>
<td></td>
</tr>
<tr>
<td>Mass per Unit Area***</td>
<td>ASTM D5261</td>
<td></td>
</tr>
<tr>
<td>Asphalt Retention***</td>
<td>ASTM D6140</td>
<td></td>
</tr>
</tbody>
</table>

* Permittivity shall be as specified in the bid documents in accordance with tables 2, 3, 4, 5 and 6 of AASHTO M288-00 as per the requirements of various applications.

** Opening size shall be as specified in the bid documents in accordance with tables 2, 3, 4, 5 and 6 of AASHTO M288-00 as per the requirements of various applications.

*** These shall be as specified in the bid documents/construction notes in accordance with tables 1 and 7 of AASHTO M288-00 as per the requirements of various applications.

NOTES:

1. Conformance to specification property requirements shall be based on ASTM D4759 Standard Practice for Determining the Specification Conformance of Geosynthetics.”

2. All numeric values represent the minimum average roll values (i.e. the average of test results from any sample roll in a lot shall equal or exceed the minimum values). Lots shall be sampled according to ASTM D4354 “Standard Practice for Sampling of Geosynthetics and Rolled Erosion Control Products(RECPs) for Testing.”

494.3 Packaging Requirements:
A. Provide fabric in the length and width specified on the plans or in the bid documents.

B. Wind fabric onto suitable cylindrical forms or cores to aid in handling and unrolling.

C. Package fabric individually in a suitable container to protect the geotextile from damage due to ultraviolet light and moisture during normal storage and handling.

D. Identify each roll with a tag or label affixed to the outside or the roll on one end the following information: unique roll number, serially designated; manufacturer’s lot number or control numbers, if any; name of fabric manufacturer; brand name of the product; manufacturer’s style or catalog designation of the fabric, if any; roll width (inches); roll length (feet).

494.4 Submittal Requirement. When requested by the Engineer, the Contractor shall provide samples of the geosynthetics for testing. The test results will be used to verify that the physical properties specified in this Item have been met. The cost of the testing will be paid for by Harris County. The Contractor shall also submit manufacturer’s recommended installation method for geotextile installation based on its designated application.

494.5 Quality Assurance/Quality Control. Should any individual sample selected at random from 100 rolls, or fraction thereof, fail to meet any specification requirement, then that roll will be rejected. Two additional samples will be taken, one from each of two other rolls selected at random from the same 100 roll lot, or fraction thereof. If either of these two additional samples fails to comply with any portion of the specification, then the entire quantity of rolls selected by that sample will be rejected.

494.6 Placing. The geotextile shall be placed in accordance with the specifications of the various applications.

494.7 Measurement. The geotextile fabric shall be measured in place by the square yard of material, furnished and placed as shown in the plans. Waste and overlap shall not be included in this measurement.

494.8 Payment.

A. Payment for geotextile, complete in place shall be made at the contract unit price of the specified class per square yard, which price shall include all costs of materials, and labor to place it in position.
B. Where the bid sheet specifies FOB the job, the materials shall be transported to the job site specified on the bid sheet and paid for by the square yard.

C. When the Project Manual, plans or other specifications indicate the use of geotextile as incidental to another pay item, no direct payment for the material will be made.

There are line code(s), description(s) and unit(s) for this Item.

END OF ITEM 494
ITEM 495

REMOVING OLD STRUCTURES

495.1 Description. This Item shall govern for the removal and disposal of old structures or portions of structures such as bridges, headwalls, box culverts, pipes, timber structures, and other structures, as noted on the plans. This Item shall include all excavation and backfill necessary to complete the removal.

495.2 Method of Removal. Culvert or sewer pipe for reuse shall be removed by careful excavation of all material on the top and sides so that the pipe will not be damaged. Removal of sewer appurtenances shall be included for removal with the pipe. Those pipe which are deemed unsatisfactory for reuse, by the Engineer, will be removed and disposed of, off the job site, in any manner the Contractor may select.

When an existing concrete structure is to remain in use, the removal of any portions thereof shall be in accordance with the Item 424 "Extending Concrete Structures".

Concrete portions of structures below the permanent groundline shall be neatly squared off. Reinforcement shall be cut off close to the concrete.

Steel structures or steel portions of structures shall be dismantled in sections determined by the Engineer. The sections shall be of such weight and dimensions which permit convenient handling, hauling and storing. Rivets and bolts connecting steel rail members, steel beams or girder spans and steel stringers of truss spans will be removed by cutting the heads with a cold cut then punched or drilled by a method that will not injure the member for reuse and will meet the approval of the Engineer. The removal of rivets and bolts, from connections, will not be required unless specifically called for. Unless otherwise specified, the Contractor shall have the option of dismantling these members by flame cutting immediately adjacent to the connection. Flame-cutting will not be permitted when plans call for the structural unit to be salvaged in such a manner as to permit re-erection. In such case, all members shall be carefully dismantled without damage and match marked with paint in accordance with the plans and all rivets and belts shall be removed from the connections in the manner specified in this section.

Timber structures or timber portions of structures to be reused shall be removed with as little damage to the timber as possible. All bolts and nails shall be removed from such lumber as deemed salvageable by the Engineer.
Unless otherwise specified on the plans, timber piles shall be either pulled or cut off at a point not less than two feet below the groundline, or to final grade, with the choice between these two methods resting with the Engineer.

Brick or stone structures shall be removed by sledging the masonry into removal sizes. Portions of such structures below the permanent groundline, which will not in any manner interfere with the proposed construction, may be left in place, but removal shall be carried at least two feet below the permanent groundline and neatly squared off.

All material such as pipe, timbers, railing, etc. which the Engineer deems as salvageable for reuse and all structural steel shall be carefully placed in neat piles along the right-of-way at convenient loading points. All of these materials shall be the property of Harris County.

All timber structural members which are deemed unsatisfactory for reuse, by the Engineer, will be removed and properly disposed of at a permitted landfill. If the timber is treated wood, such as creosote, then the timber shall be disposed of as a hazardous waste, and a copy of the waste manifest shall be provided to the Engineer. The transportation and disposal cost for unsalvageable timber structural members shall be the responsibility of the Contractor. If temporarily stored on site until final disposition, all reusable timber members and waste timber members shall be blocked up off the ground and covered with a tarp.

The I-beams, girders, stringers, etc. which are to be put in storage or specified for reuse, shall be blocked up off the ground to protect the members against damage.

Materials which are not deemed salvageable by the Engineer, shall become the property of the Contractor and shall be removed and disposed of off the site by the Contractor. The Contractor is responsible for the proper protection of all materials that are salvageable.

All excavation made in connection with this Item and all openings below the natural groundline caused by the removal of old structures or portions thereof shall be back filled to the level of the original groundline, unless otherwise provided on the plans. No separate payment shall be made for backfill and it shall be considered subsidiary to this Item.

That portion of the backfill which will support any portion of the roadbed or embankment shall be placed in layers of the same thickness as those required for placing embankment. Material in each layer shall be wetted uniformly, if required, and shall be compacted to the density required in the adjoining embankment. In places inaccessible to blading and rolling
equipment, mechanical or hand tampers shall be used to obtain the required compaction.

That portion of the backfill which will not support any portion of the roadbed or embankment shall be placed as directed by the Engineer in such manner and to such state of compaction as will preclude objectionable amounts of settling.

495.3 Measurement. The work as provided for by this Item shall be measured as each individual structure to be removed, except that box culverts, pipes and water lines shall be measured by the linear foot. The removal shall include all appurtenances thereto.

495.4 Payment. The work as prescribed for in this Item shall be paid for at the unit price bid for "Removing Old Structures" per each or "Removing Old Box Culverts, Pipes or Water Lines" per linear foot, which price shall be full compensation for all work, labor, tools, equipment, excavation, backfilling, materials, disposal costs and incidentals necessary to complete the work.

There are line code(s), description(s) and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 424 “Extending Concrete Structures.”

END OF ITEM 495
500 ITEMS

- 500 – Remove and Relocate or Dispose of Traffic Signs, Mail Boxes and Roadway Signs
- 501 – Tree Protection and Trimming
- 510 – Planing and/or Texturing Pavement
- 516 – Installation of Flex Beam Guardrail
- 520 – Weighing and Measuring Equipment
- 526 – Membrane Curing
- 530 – Concrete Curb, Concrete Curb and Gutter, Sidewalks and Driveways
- 531 – Coloring Concrete for ADA Ramps
- 535 – Medians and Directional Islands
- 536 – Coloring Concrete for Median Noses
- 537 – Wheel Stops
- 540 – Removing and Disposing of Existing Asphalitic Surface and Base Material
- 550 – Existing Fencing and Gates
- 554 – Wood Fencing
- 555 – Chain Link Fencing
- 556 – Four Strand Barbed Wire Fence
- 559 – Construction Safety Fence
- 560 – Maintenance and Cleanup of the Project Site
- 561 – Video Recording Construction
- 562 – Preparing the Right-of-Way
- 563 – CCTV Inspection of As-Built Storm Sewer Systems
ITEM 500

REMOVE AND RELOCATE OR DISPOSE OF TRAFFIC SIGNS, MAIL BOXES AND ROADWAY SIGNS

500.1 Description. This Item shall govern for the removal and relocation or disposal of traffic signs, mail boxes and roadway signs. Traffic signs shall be relocated in accordance with the "Texas Manual on Uniform Traffic Control Devices" (TMUTCD), Latest Edition.

500.2 Construction Methods. The Contractor shall relocate those traffic signs, roadway signs, and mail boxes that are indicated on the plans to be relocated. They shall be reinstalled with the foundation standard required by the applicable jurisdictional agencies.

All concrete for foundations shall be Class C Concrete in accordance with the Item 421 "Structural Concrete", with $f'c = 3000$ psi.

For any location on the job site that is to remain open to traffic, the Contractor is required to furnish and install temporary poles, fittings, fixtures, signals, signs or other incidentals necessary to construct permanent traffic control systems. Such temporary installation shall remain in place until such time as the relocated systems are operational, or until required by the Engineer.

500.3 Measurement & Payment. The basis of payment for this item shall be the lump sum, or per each as provided in the bid proposal which price shall be full compensation for all materials, equipment and labor and all other incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 421 "Structural Concrete"

END OF ITEM 500
ITEM 501

TREE PROTECTION AND TRIMMING

501.1 Description. This Item shall govern for the protection and trimming of trees indicated to be preserved. Trees located a clear distance of 3 feet or more from the tree’s dripline to the proposed face of curb are to be preserved unless field conditions determine otherwise.

501.2 Quality Assurance. All tree removing, trimming and work within the tree’s dripline shall be performed by or under the supervision of an arborist certified by the International Society of Arboriculture (ISA). The arborist shall indicate the trees that need to be removed, but no removal will be done without prior approval of the Engineer.

The Latest Edition of reference standards applicable to this Item are:


B. AWPA Standard U1 “Use Category System: User Specification for Treated Wood”

501.3 Job Conditions. The Contractor shall protect each tree designated to be preserved with a tree protection fence, installed in accordance with Item 559 “Construction Safety Fence” along the outside edge of the tree’s dripline. The fencing shall be continuous between posts, shall be pulled taut prior to securing to posts, and shall be firmly attached to the posts with a minimum of 4 ties.

All tree protection fencing shall be installed prior to site work or construction activity. The fence shall be placed in a continuous alignment as shown on the tree protection plan or as approved by the Engineer.

Tree protection fencing shall be removed by the Contractor unless otherwise directed by the Engineer, at no additional costs, upon completion of all construction activity in each work zone area. Tree protection fencing materials used in the first work zone area(s) shall be removed and utilized in subsequent work zone areas. Materials and labor shall be paid for each linear foot of fencing installed in first two work areas. All fencing installed in subsequent work zone areas shall be paid for labor only.
Contractor shall not allow any vehicular traffic, parking of vehicles or stockpiling of excavated material or construction materials within 3 feet of the dripline of trees indicated to be preserved.

Construction equipment may operate within 3 feet of the dripline of a tree when necessary for the performance of indicated work; such operations shall be conducted with special care to avoid damaging the tree.

Water trees indicated to be preserved, as required to maintain their healthy growth during the course of construction operations (per Arborist recommendation).

501.4 Materials. Tree pruning compound shall be waterproof, antiseptic, elastic, and free of kerosene, coal tar, creosote, and other substances harmful to trees.

Topsoil shall be material free of clay, rock or gravel larger than 2 inches in any dimension, debris, waste, vegetation, and other deleterious matter.

Drainage fill shall be selected stone or gravel, graded to pass a 3 inch sieve and retained on a 1 inch sieve.

Physical barriers, if required, shall be constructed from the following material:

A. Wood Components: Number 2 Pine, pressure treated to prevent decay for 1 year in accordance with the requirements AWPA Standard U1, suitable for Use Category 4B.

B. Fence Material: Fence shall be comprised of extruded, high density polypropylene, 4 foot tall minimum and orange in color. The mesh openings shall be no larger than 3-1/2 inches x 1-1/2 inches. T-posts shall be made of fiberglass or steel and shall be 6 feet long (minimum).

C. Banding: Stainless steel or varnish coated carbon steel, 3/4 inch wide x 26 gauge.

D. PVC pipe shall conform to ASTM D2665 and be 4 inch O.D., nominal.

501.5 Execution. The Contractor shall protect tree root systems from damage due to noxious materials in solution caused by run-off or spillage during mixing and placement of construction materials, or drainage from stored materials.
The Contractor and/or any of the Contractor’s workers shall not park vehicles under trees, nor perform vehicle maintenance under trees.

If required, remove branches from trees indicated to be preserved to clear for new construction. All cuts should be made sufficiently close to the parent limb or trunk without cutting into the branch collar or leaving a protruding stub, so that closure can readily start under normal conditions. All lateral cuts shall be made back to a lateral that is at least 1/3 the diameter of the parent limb. Clean cuts shall be made at all times. Where directed by the Engineer, extend the pruning operation to restore the natural shape of the entire tree.

Cut branches and roots with sharp pruning instruments. Do not break or chop branches and roots. Paint cuts over 1/2 inch in size with tree pruning compound. Apply black latex paint to all fresh wounds on Oak (Quercus) species immediately after each cut is made.

**501.6 Pruning.** Pruning shall be completed by ISA (International Society of Arboriculture) certified arborist who has received training in proper pruning techniques. Prior to construction, all deciduous trees indicated to be preserved shall be pruned of new or recent growth to maintain the basic branching form of the trees. Extent of pruning shall be based upon the proximity of pavement to the trunk and the size of tree blockouts and the requirements for construction adjacent to the tree.

Trees having branches which extend to the ground at their outermost limit shall have such branches pruned to a height equal to the height of all vehicles requiring access below or around such trees. Provide minimum of 14 feet and maximum of 18 feet of vertical clearance over proposed street construction. The Contractor shall notify property owner in writing 48 hours prior to trimming or pruning any trees on private property for privately owned trees extended into County right-of-way.

Pruning shall be limited as much as possible to young branches. Care shall be taken to maintain older branches which provide the basic form of the tree.

**501.7 Excavation Around Trees.** Excavate within the dripline of trees only where indicated. Where trenching for utilities is required within dripline, tunnel under or around roots by hand digging. Do not cut main lateral roots or tap roots. Smaller roots which interfere with the installation of new work may be cut.

Where excavating for new construction is required within the dripline of trees, hand excavate to minimize damage to the root system. Provide
sheeting at excavations if required. Use narrow spading forks and comb soil to expose roots.

Relocate roots in backfill areas wherever possible. If large main lateral roots are encountered, expose beyond excavating limits as required to bend and relocate without breaking. If roots are immediately adjacent to location of new construction and relocation is not practical, cut roots approximately 3 inches back from new construction.

Do not allow exposed roots to dry before permanent backfill is placed. Provide temporary earth cover, or pack with peat moss and wrap with burlap. Water and maintain exposed roots in moist condition and temporarily support and protect from damage until permanently relocated and covered with earth.

Prune branches to balance loss to root system caused by damage or cutting, per arborist recommendations.

501.8 Grading and Filling Around Trees. Maintain the existing grade within the dripline of trees, unless otherwise indicated.

Where the existing grade is above the new finish grade around trees, carefully hand excavate within the dripline to new finish grade. Cut roots exposed by excavation and provide permanent protection as recommended by the certified arborist.

Where the existing grade is 3 inches or less below new finish grade, use a topsoil fill material. Place the topsoil in a single layer and do not compact. Hand grade to the required elevation.

Where existing grade is more than 6 inches below new finish grade, provide 1 inch, schedule 40 PVC pipe, 6 feet on centers around tree perimeter, at dripline for aeration of the root system.

501.9 Repair of Trees. When trees indicated to be preserved are damaged by construction operations, remove the damaged portions as soon as possible to prevent progressive deterioration. Repair work shall be subject to the approval of the Engineer.

Remove and replace dead or damaged trees designated to be preserved which are determined by the certified arborist to be incapable of restoration to normal growth status.

501.10 Submittal Requirement. The Contractor shall submit the qualifications of ISA certified arborist for Engineer’s approval.
501.11 Measurement and Payment. Measurement and payment for tree protection and trimming shall be by the lump sum or by each in accordance with the bid proposal.

Removal of trees shall be paid for as provided in the bid proposal in accordance with Item 102 “Clearing and Grubbing”.

Tree protection with barrier (orange fence) shall be measured and paid per each or per linear feet in accordance with bid proposal.

There are line code(s), description(s), and unit(s), for this Item.

NOTE: This Item does require other Standard Specifications.

Item 102 “Clearing and Grubbing”
Item 559 “Construction Safety Fence”
Item 725 “General Source Control (SWPPP)”

END OF ITEM 501
ITEM 510

PLANING AND/OR TEXTURING PAVEMENT

510.1 Description. This Item shall govern for the planing or the planing and texturing of existing asphaltic concrete pavement, asphalt stabilized base and/or Portland cement concrete pavement and bridge deck surfaces at the locations shown on the drawings, or as directed by the Engineer.

When shown on the drawings, salvaged asphaltic concrete pavement and/or asphalt stabilized base, including any accompanying surface treatment, or plant mix, may be allowed or required for use in other construction items for this project. If not used in the construction of this project, these materials shall be stockpiled or disposed of in compliance with current local, State and Federal Regulations, by the Contractor, at a location approved of by the Engineer.

510.2 Equipment. The equipment for removing the pavement surface shall be a power operated planing machine with a minimum six foot cutting width. For detail work, equipment with less than six foot cutting widths will be allowed. The equipment shall be self-propelled with sufficient power, traction and stability to maintain an accurate depth of cut and slope. The equipment shall be capable of cutting a four inch depth of asphaltic concrete pavement, or a combination of two inches of asphaltic concrete pavement and one half inch Portland concrete pavement, in one continuous operation.

The equipment shall be equipped with an approved automatic dual longitudinal grade control system and a transverse control system, unless otherwise directed by the Engineer. The longitudinal controls shall be capable of operating from any longitudinal grade reference. The transverse controls shall have an automatic system for controlling cross slope at a given rate.

The machine shall have a manual system providing for uniformly varying the depth of cut while the machine is in motion, thereby making it possible to cut flush to all inlets, manholes, curbs and gutters or other obstructions within the paved area. The speed of the machine shall be variable in order to leave the desired grid pattern.

The machine shall be equipped with integral loading and reclaiming devices to immediately remove material being cut from the surface of the roadway and discharge the cuttings into a truck, all in one operation. The machine shall be equipped with devices to control dust created by the cutting action.
A street sweeper shall be provided for removing cuttings and debris from the planed or textured pavement. Other sweeping equipment may be provided in lieu of a street sweeper, when approved by the Engineer. The Contractor shall provide any other equipment and personnel necessary for the proper operation of the planing machine, to minimize dust and remove cuttings.

510.3 Construction Methods. The pavement surface shall be removed for the length, depth and width and to the typical section shown on the drawings, and to the lines and grades established by the Engineer. The planed surface shall provide a satisfactory riding surface free from gouges, continuous longitudinal grooves, ridges, oil film and other imperfections of workmanship and shall have a uniform textured appearance. Any damage inflicted to water valves, water meters or manholes caused by the planing machine shall be repaired by the Contractor, at his expense.

When removing the asphaltic concrete pavement from an underlying Portland cement concrete pavement, all of the asphaltic concrete pavement shall be removed leaving a uniform surface of Portland cement concrete.

Any vertical or near vertical longitudinal face exceeding 1-1/4 inches in height, in the pavement surface open to traffic at the end of a work period shall be sloped a minimum of 10:1. Transverse faces that are present at the end of a work period, shall be tapered in a manner acceptable to the Engineer.

Loose concrete material resulting from the operation shall be stockpiled at locations indicated, or shall be disposed of at sites obtained by the Contractor and approved by the Engineer. Loose asphaltic material resulting from the planing operation, which is not used in the other construction items for this project, shall be disposed of per local, state and Federal requirements by the Contractor at his expense. Salvaged asphaltic paving to be used for the construction of other items for this project, shall be kept as free as possible from contamination by non-asphaltic materials during its removal, transportation and storage. The stockpile areas shall be cleaned of trash, weeds and grass. The Engineer may require separate stockpiling of salvaged asphaltic paving materials of differing type or quality.

Pavement that is not removed by the planing machine, adjacent to steep curbs and gutters, inlets, manholes or other obstructions shall be removed by other methods acceptable to the Engineer.
The pavement surfaces shall be swept with a street sweeper or other sweeping equipment, approved by the Engineer, to remove all debris leaving a clean and presentable condition.

510.4 Surface Texture and Tests. In areas where traffic will be permitted, the texture shall be a grid pattern or any other pattern with discontinuous longitudinal striations that will provide, in the opinion of the Engineer, a satisfactory riding surface.

When the planed pavement is not to be overlaid, the minimum texture depth shall be not less than 0.05 inches. When these texture requirements are not met, the Contractor shall cease operations until the Engineer is satisfied that changes in the texturing procedures will produce an acceptable texture. In no case shall the texture depth on bridge deck structures exceed 3/16 inch. Additionally, care shall be taken to prevent damage to armor joints, sealed expansion joints and/or other appurtenances.

The surface of the pavement, after planing, shall have a smooth riding quality and shall be true to the established line, grade and cross-section. The pavement surface, when tested with a 10 foot straight edge placed parallel to the centerline of the roadway, shall not have any deviation greater than 1/8 inch in 10 feet. The deviations shall be measured from the top of the texture. Any point in the surface not meeting this requirement shall be corrected, as directed by the Engineer, at the Contractor's expense.

510.5 Measurement. Planing, or planing and texturing pavement, will be measured by the square yard of surface area for the various depths shown on the drawings for each pavement type. Pavement types are asphaltic concrete pavement and Portland cement concrete pavement. Square yard calculations will be based on the neat dimensions shown on the drawings, or as adjusted by the Engineer.

Measurement will be based on the depth shown for each bid item, within the limits shown on the drawings regardless of the actual thickness removed, or the number of passes required. Only one bid item for each pavement type will be applicable to any one location.

When planing asphaltic concrete pavement from an underlying Portland cement concrete pavement, the planing of any Portland cement concrete pavement to remove all asphaltic concrete pavement as required under Section 510.3 of this Item, will be considered subsidiary to the planing of asphaltic concrete pavement, to the depth shown on the drawings, and will not be paid for directly.
Payment. The work performed in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Planing and Texturing Asphaltic Concrete Pavement", "Planing and Texturing Portland Cement Concrete Pavement", "Planing Asphaltic Concrete Pavement", or "Planing Portland Cement Concrete Pavement", of the various depths shown by the drawings. This price shall be full compensation for removing all material to the depth shown, texturing the pavement surface (when texturing is shown on the bid item description), loading, hauling, unloading and satisfactory storing or disposing of the material, for all sweeping, and for all labor, tools, equipment, manipulation and incidentals necessary to complete the work.

Tapering or sloping of the longitudinal or transverse joints as described under Section 510.3, will be considered subsidiary to this Item and will not be paid for directly.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 510
ITEM 516

INSTALLATION OF FLEX BEAM GUARDRAIL

516.1 Description. This Item shall govern for the following:

A. Furnishing and Installing

B. Removing and Replacing

C. Removing and Disposing

D. Removing and Salvaging

of 10 or 12 gauge galvanized flex beam guardrail, terminal sections, terminal anchor sections complete with timber or steel posts as stated in the contract documents or shown on the contract drawings. Treated timber shall be properly disposed of in compliance with current local, State and Federal Regulations.

516.2 Materials. The rail elements shall be of the deep beam type, fabricated to develop continuous beam strength and shall consist of metal plate or sheet formed into a beam not less than 12 inches wide and 3 inches deep as shown on the plans. The beam shall be free from warp. When tested with a straight edge or string along either edge of a 12-1/2 foot sectional length of beam, the maximum deviation of the beam edges from the straight edge shall not exceed 1/2 inch at any point.

The steel for the rail elements shall conform to the requirements of the Latest Edition of AASHTO M-180, “Standard Specification for Corrugated Sheet Steel Beams for Highway Guardrail.” The rail shall be 10 gauge nominal thickness (0.1345 + 0.008 inch), or 12 gauge (0.1046 + 0.008 inch) as shown on the drawings. The rail element may be galvanized before or after fabrication in accordance with the requirements of ASTM A123, “Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products” or ASTM A653, “Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process” whichever is applicable, except that the galvanized coating shall be not less than 2.0 ounces per square foot of double exposed surface (single spot test).

Rail elements shall not contain more than 0.04 percent phosphorous nor more than 0.05 percent sulfur.

516.3 Posts. The posts shall be either timber or steel as indicated on the plans and shall meet one of the following requirements.
Timber Posts:

Timber posts and spacers shall be Southern Yellow Pine. All posts shall be round. Posts shall not be less, in any place, than 7 inches in diameter. The average diameter at the base of the dome shall not exceed the specified diameter by more than 1 inch. The diameter at the butt of any post shall not exceed the diameter at the base of the dome of that post by more than 2 inches. The length of the posts shall not vary more than 1 inch from the specified length. All timber posts shall be in accordance with ASTM D1165 “Standard Nomenclature of Commercial Hardwoods and Softwoods.”

For domed posts, the dome shall be approximately hemispherical in shape and the radius of the dome of each post shall be 1/2 the diameter of the posts at the base of the domed portion. The dome shall be smooth and the distance from the top of the dome to the base of the dome shall not vary more than 1 inch at any length. The posts shall be machine tooled and trimmed of all knots and knobs and shall be straight and smooth. For posts that are not domed, the tops shall be sloped.

The posts shall be sound and free from defects such as injurious ring shakes, unsound or loose knots, or other defects that might impair their strength and durability. A line drawn from the center of each end of the post, shall not fall outside the center of the post at any point more than 1-1/4 inch.

Timber posts, where spacers are required, shall be bored and cut to the dimensions shown on the plans before being treated. Posts shall be given a creosote treatment or shall be wolmanized meeting the requirements of AWPA Standard U1, “Use Category system: User Specification for Treated Wood”, suitable for Use Category 4A. Wolmanizing material shall be manufactured by the Koppers Company, or approved equal.

Steel Posts:

Steel posts and spacers shall be of the rolled sections shown on the plans. The posts and spacers shall be structural steel conforming to the requirements of ASTM A36, “Standard Specification for Carbon Structural Steel”. All posts shall be beveled and drilled or punched for bolts for rail attachments. Steel posts and spacers shall be galvanized and shall conform to the requirements of ASTM A123.

Fittings shall consist of bolts, nuts and washers and shall conform with the requirements as specified herein. All bolts and nuts shall conform to the requirements of ASTM A307 “Standard Specification for Carbon Steel
Bolts and Studs, 60,000 PSI Tensile Strength.” They shall be hot-dip galvanized to conform to ASTM A153, “Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware”, Class C or D.

516.4 Construction Methods. The posts shall be set plumb and firm to the line and grade shown on the plans. The post holes shall be backfilled by thoroughly tamping the material in 4 inch layers. The rail elements shall be erected to produce a smooth continuous rail, paralleling the line and grade of the roadway surface.

The rail elements shall be overlapped in the direction of traffic by bolts and lapped in the direction of traffic in the lane adjoining the guard fence. When designated, any deformed or curved piece shall be shop fabricated prior to delivery to the project site.

After erection, all parts of galvanized steel posts, spacers, washers, bolts, nuts and rail elements on which galvanizing has become scratched, chipped or otherwise damaged shall be thoroughly cleaned by wire brushing the damaged area to remove all loose, cracked or bruised spelter coating. The cleaned area shall be painted with two coats of zinc dust-zinc oxide paint conforming to the requirements of Federal Specification TT-P-641b or shall be repaired by application of galvanizing repair compounds meeting Federal Specification 0-G-93, applied in accordance with the manufacturer’s recommendations.

Re-use of old flex beam guard rail shall be allowed if found satisfactory in good condition and shall be subject to approval by the Engineer.

516.5 Certification. All shipments shall include certification from the appropriate wood treatment plant. This certificate shall also state that all samples representing each lot have been tested and inspected in accordance with American Wood Preservers’ Association Standard M2, “Inspection of Treated Products” and have been found to meet the requirements of applicable American Wood Preservers’ Association standards for wood treatment for its intended use.

The Contractor shall submit manufacturer’s descriptive literature for flex beam guardrail for Engineer’s approval.

516.6 Measurement. Flex beam guardrail, except for terminal sections and terminal anchor sections, will be measured by the linear foot of rail, complete in place. Measurement shall be made upon the face of the rail in place, or prior to removal, from center to center of end posts. Terminal sections and terminal anchor sections shall be measured by each unit. Flex beam guardrail shall be measured by the linear foot. Mowing strips
within the limits of the guardrail and terminal anchor section are incidental to the guardrail.

516.7 Payment. The work performed and the material furnished as prescribed by this Item, measured as provided under measurement, will be paid for at the unit price bid for "Flex Beam Guardrail", or "Flex Beam Guardrail Including Mowing Strip", which price shall be full compensation for furnishing and installing all materials, for all preparation, hauling and erection and painting of same, and for all labor, tools, equipment and incidentals necessary to complete the work, including excavation, backfilling and disposing of surplus material. Terminal sections and terminal anchor sections shall be paid for per each, complete in place.

There are line code(s), description(s) and unit(s) for this Item.

NOTE: This Item requires Standard Civil Drawings that shall be incorporated into the contract documents.

END OF ITEM 516
ITEM 520

WEIGHING AND MEASURING EQUIPMENT

520.1 Description. This Item shall govern for the weighing and measuring equipment utilized where materials are specified to be measured or proportioned by weight or volume.

520.2 General Requirements. Except as modified herein, all scales and scale installations shall meet the requirements of the Latest Edition of the National Bureau of Standards Handbooks 44 and 112 (published by the U.S. Department of Commerce and available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402), except that the required accuracy shall be 0.4 percent of the load being weighed or 1 graduation on the dial of the scale. The Contractor shall provide personnel, facilities and equipment for checking the scales to the satisfaction of the Engineer.

All scales shall be checked prior to beginning of operations, after each move and at such other times, when in the opinion of the Engineer there is a question as to their accuracy or adequacy, and at least once each 6 months. Plant operations shall cease during the checking operation. When inaccuracy or inadequacy is discovered, scale use will not be resumed until corrective measures have been completed and/or the scales calibrated as provided by this Item. Whenever equipment is adjusted, the adjustments shall be so made as to bring performance errors as close as practicable to zero value.

For use of County inspection forces in checking the scales during operation, the Contractor shall furnish four 50 pound weights. In addition, the Contractor shall furnish four 5 pound weights and four 2 pound weights to be used in checking cement, asphalt and small platform scales. All weights shall be checked and certified by the Texas Department of Agriculture, Weights and Measures Section as meeting the Maintenance Tolerances for Avoirdupois Weights specified in the National Bureau of Standards Handbook 44. All scales shall be satisfactorily insulated against shock, vibrations or movement of other operating equipment in the plant.

In lieu of the above specified weights for checking the scales, the Contractor may furnish a report of calibration from a commercial scale company, approved by the Engineer, certifying that the scales meet the requirements of this Item. This report of calibration will be required at least once each 6 months.
The weighing containers shall be sufficiently tight to prevent leakage of the contents and shall be of sufficient capacity to hold a complete batch without wasting or leveling by hand and shall be so designed that the entire batch will discharge quickly into the mixer. The weighing containers shall be so constructed that if in charging, an excess is introduced into the weighing containers, it may be removed by the operator. The weighing containers shall be provided with a close fitting and quick operating cut-off gate, so that there will be no leakage of the contents into the mixer, and shall be satisfactorily attached to the batching scales.

520.3 Equipment. Any electronic device which has been adapted for weighing that meets the calibration requirements of Section 520.2 will be acceptable. This type of scale may be substituted for any of the equipment described in this Section.

A. Truck Scales. Truck scales shall consist of a set of standard platform truck scales capable of weighing the load as a single draft; that is, the total weight of the truck or truck-trailer combination shall not be determined by adding together the weights obtained by separately weighing each end of such truck or by weighing individual elements of such truck or coupled combination. The Contractor shall provide a weathertight building of sufficient size to house the Contractor's weigher and the State's checker.

B. Aggregate Batching Scales. The scales used for weighing aggregate shall be equipped with a quick adjustment at zero to provide for any change in tare. The scales shall be provided with pointers or "tell-tale" indicators of the springless dial type to indicate full load for each aggregate. The dial or "tell-tale" device shall be in full view of the operator while charging the weigh box and he/she shall have convenient access to all controls.

C. Portable Platform Scales. Portable platform scales shall conform to the general requirements of this Item, except that they will no be required to be checked after each move or set up within a given project, unless directed by the Engineer.

1. Type A. This type shall consist of a portable platform scale having a container fastened securely to the platform.

The capacity of this type of scale shall be not less than 500 pounds. The weighing capacity may be obtained by means of a weigh beam and loose weights.

When this type of scale is used, the Contractor shall provide a container of approximately the same size as the platform
for weighing the aggregate, or he/she may provide an elevated hopper, the base of which is approximately the size of the platform from which the aggregates may be discharged.

If the hopper is provided, it shall be of such design that the aggregates will be completely and quickly discharged and shall be of such construction that the position of the aggregates while being weighed will not affect the accuracy of the weights.

The Contractor will not be permitted to increase the size of the original platform by constructing another platform on top of the original unless provision is made to set the tare weight of the container or hopper separately from the batch weight. Separate scales for fine and coarse aggregate will be required.

2. Type B. This type shall consist of a portable platform scale having a platform sufficiently large to permit the weighing of loaded wheelbarrows or carts.

The capacity of this type of scale shall be not less than 800 pounds. The weighing capacity may be obtained by means of a weigh beam and loose weights. The scale shall preferably be equipped with a double weigh beam, in order that the tare weight of the wheelbarrow or other vehicle for transporting the aggregates may be set off on the weigh beam separately from the batch weights. When the scale is equipped with a single beam or a single beam and a tare beam, separate scales shall be provided for fine and coarse aggregates.

When this type of equipment is designed to weigh more than one kind of material on the same scale, it shall be equipped with separate charging beams and a tare beam. Each charging beam shall be equipped with a release lever to throw the beam in and out of service. This type of scale may also be equipped with a "tell-tale" dial meeting the requirements of this Item.

D. Suspended Hopper. This type shall consist of a weighing container or hopper completely suspended from the scale equipment. Suitable provisions shall be made for leveling the scale equipment.
The appliances used for placing materials within or upon the weighing equipment shall so regulate and control the quantity supply that accurate adjustment to the weights required can be secured with little expenditure of time and labor. A convenient means shall be provided for the addition or the removal of small amounts of material to adjust the quantity to the exact weight per batch.

E. Cement Weighing Equipment. Where bulk cement is used it shall be batched by weight. The scales shall be of rugged construction. Provision shall be made for indicating to the operator that the required load in the weigh box or container is being approached, which device shall indicate at least 50 pounds of load. Where a closed type cement weigh box is used, the cement weighing scales shall be provided with a springless dial to indicate when the weigh box is empty. This indicator for the empty condition of the weigh box shall be in continuous operation. The weigh box shall be fitted with an approved vent, a tightly covered inspection opening of not less than 12 inches by 12 inches. The box and scales shall be maintained in a condition to meet the requirements for accuracy of weight.

Where Portland cement to be mixed with subgrade, subbase or base material is not batched by weight and bulk cement is furnished, each truck shall have the weight of cement certified by a bonded public weigher or the Contractor shall place a set of standard platform truck scales or hopper scales at a location approved by the Engineer.

F. Belt Scales. Belt scales used for proportioning aggregate into asphaltic mixtures shall be accurate to within 1.0 percent, average of 3 test runs, where no individual test run shall exceed 2.0 percent when checked as outlined in TxDOT's Test Procedure Tex-920-K. Material tests shall be performed at least once each six months. Simulated belt loading tests may be used as expeditious checks of scale accuracy between material tests. The manufacturer's operation and maintenance manual shall be made available to the Engineer.

G. Automatic Proportioning Devices.

1. Portland Cement Concrete. When required by the plans or special provisions, batching plants shall be equipped to proportion by weight, aggregates and bulk cement, by means of automatic proportioning devices of an approved type.
The scales shall be automatic to the extent that the only manual operation required for proportioning the aggregates for one batch shall be a single operation of a switch or a starter.

The bulk cement batcher and aggregate batcher shall be so interlocked that a new batch cannot be started until all weigh hoppers are empty, the scale at zero and the discharge gates closed. The interlock shall permit no part of the batch to be discharged until all aggregate hoppers and the cement hopper have been filled with the correct charge. The discharge gate on the cement hopper shall be so designed as to permit regulating the flow of the cement into the aggregate as directed by the Engineer.

Material discharged from the bins shall be controlled by gates or by mechanical conveyors. The means of withdrawal from the bins and the discharge from the weigh box shall be so interlocked that not more than one bin can discharge at a time; that the order of discharge can be changed as directed by the Engineer; and that the weigh box cannot be tripped until the required quantity from each of the bins has been deposited therein. Should a separate weigh box be used for each size aggregate, all may be operated and discharged simultaneously.

When the discharge from the bin is controlled by gates, each gate shall be actuated automatically so that the required weight is discharged into the weigh box after which the gate shall automatically close and lock.

The automatic weighing device shall be so designed that the number of proportions required may be set at the same time and that proportions and the sequence of weighing individual sizes may be changed without delay. The locking mechanisms or devices shall be so arranged that they may be locked at the direction of the Engineer.

When shown on the plans, automatic scales shall be equipped with a recorder capable of printing the weight of each proportion and the total batch weight.

Automatic proportioning devices shall comply with the general requirements for scales. In order to check the accuracy of batch weights, the gross weight and tare weight
of batch trucks, truck mixers and truck agitators shall be determined when directed by the Engineer. The equipment shall be weighed on truck scales conforming to the requirements of Subsection 520.3.(A) of this Item.

2. Asphaltic Mixtures.

a. Weigh-Batch Plant. When specifically indicated on the plans, asphaltic mixture mixing plants used in the production of asphaltic base and surface mixtures shall be equipped with approved fully automatic devices for the batching and cycling operations. There shall be interlock cut-off circuits to interrupt and stop all operations at any time there is a malfunctioning of any part of the control system.

The automatic proportioning controls shall include the necessary equipment of accurately proportioning batches of the various components of the mixture into each batch. The mixture shall be proportioned by weight except that an asphalt meter, measuring by volume, may be used in lieu of an asphalt scale. Visible dial scales shall be provided to show the weights of each batch ingredient. If an asphalt meter is used, a suitable digital readout shall be provided to show the amount of asphalt used.

Over and under asphalt and aggregate weight check sensors shall be included in the proportioning system to check the accuracy of the asphalt and aggregate bin weights. The over-under tolerance limits for aggregate shall be selected by the Engineer after the amounts of the various ingredients have been determined for a batch of mixture. The equipment shall be capable of a tolerance range of ±0.5 percent to ±2 percent as applied to the material being weighed. The tolerance limits for asphalt shall be ±1 percent of the total asphalt being weighed. The tolerance limits for the no-load condition shall be ±1 scale graduation for the aggregate scales and ±3 graduations for the asphalt scales. The tolerances shall be locked in such manner that the settings for the over and under sensors cannot be altered or bypassed without the written approval of the Engineer. The system shall incorporate provisions for
a manual check which the operator would perform periodically as requested by the Engineer.

At least one set of scale dials shall be provided, one dial for aggregate and one dial for asphalt. The scale dials shall be divided into increments not to exceed 1/1000 of the total dial capacity. The scale dials may be located either in the dust proof control room or on the plant near the weighing hopper. In either location, the scale dials shall accurately indicate the weight in the weighing hopper from zero load to the maximum batch weights.

If the scale dials are located on the plant outside the control room, there shall be provided either an identical set of scale dials inside the control room or digital weight indicators which for either type shall duplicate within a tolerance of \( \pm \) one graduation for aggregate scales and \( \pm \) one graduation for asphalt scales any reading of the scale dial indicators located outside on the plant. Wherever located, the scale dials shall be so positioned that the dial and indicators are in full view of the operator in the electronic control room. The normal weight of a batch of aggregate shall be not less than \( \frac{1}{2} \) the aggregate scale dial capacity.

The automatic proportioning system shall be provided with low bin indicators arranged in such manner that under normal working operations the batching operation will be automatically stopped when the level of material in any supply bin is not sufficient to complete the weighing of a complete batch of the asphaltic mixture.

The system shall include a batch counter which can be preset for determining the number of batches which may be desired in one uninterrupted production sequence, and a counter to show the number of batches for the day's run.

The mixer shall have an accurate timelocking device to control the operation of a complete mixing cycle by locking the weigh box gate(s) after charging the mixer. It shall remain locked until the mixing cycle is complete, the mixture has been dumped, and the
mixer discharge gate is closed. The timing device shall automatically control the dry and wet mixing period in accordance with the governing specification.

The control of the timing shall be adjustable and capable of being preset at the time intervals directed by the Engineer. Changes in mixing time shall be made only when approved in writing by the Engineer.

The aggregate dryer and asphalt tank heaters shall be equipped with burners that are automatically controlled by thermostats. This automatic equipment shall control the heat of the materials within the specified tolerances. Manual controls shall be used only as directed by the Engineer.

Temperature recording devices shall be supplied to record the temperatures of the aggregate prior to the mixing operation and the asphalt near the discharge valve into the mixer unit.

The automatic heat control panel and the temperature recording devices shall be located inside the dust-proof control room.

Automatic controls shall be housed in a dust-proof room located in such manner that the mixer discharge chute is in full view of the operator.

If at any time the automatic control devices become inoperative, the plant operations will be allowed to continue under manual controls for not more than two days of operation, at which time all plant operations shall cease until the necessary repairs are made. Continuous and frequent breakdowns of the automatic control devices shall be cause for suspending operations until the devices are properly repaired.

When specifically provided for in the plans, the proportioning system shall be equipped with an automatic digital record printer and will record batch weights and print out the required information on a continuous tape or ticket through the use of a printing calculator. When requested by the Engineer, the Contractor shall demonstrate the accuracy of the
printout device, within a tolerance of ± one graduation for asphalt scales. The printout accuracy shall also apply to the no-load condition.

In the event of a breakdown of the recording equipment, the pay weights shall be determined by weighing the mix in the trucks on approved platform and recording scales or by calculated batch weights for a maximum period of not more than two working days. Continuous and frequent breakdowns of the recording equipment shall be cause for suspending operations until the recorder is properly repaired.

Each individual ticket or continuous tape shall contain the following readable information printed automatically by the digital record printer:

Project Job Number.

Time of day to the nearest minute at intervals not greater than for each truck load, or at intervals not greater than 10 batches when material is being deposited into a storage bin.

The gross weight, tare weight and net weight of the truck load.

Mix Design Number.

Zero scale record for aggregate and asphalt to be printed at intervals not greater than before each truck loading or at intervals not greater than 10 batches when material is being deposited in a storage bin.

Weight of each aggregate for each batch recorded accumulatively or separately.

Total weight of all aggregate in each batch.

Weight of asphalt in batch.

Total of batch weights (combined mixture of asphalt and aggregate) for the day and/or any part of a day as required by the Engineer. This printing will be required on the tape or ticket at
the times specified herein during each day of operation.

Total of either the aggregate or the asphalt for the day and/or any part of a day as requested by the Engineer. This printing will be required on the tape or ticket at the times specified herein during each day of operation.

One copy of the tape shall be provided the Engineer at the end of each day's run. If tickets are used, the Engineer shall be furnished three tickets with each truck load.

The recording unit shall be in the same room as the automatic batching console unit. The recording unit may be separate from the console.

b. Continuous Mixing Plant. Continuous mixing plants shall provide satisfactory means to afford positive interlocking or mechanical control between the flow of aggregate through the gates and flow of asphaltic material through the asphalt meter. Means shall be provided to check the rate of flow of the asphaltic material by scale weight per revolution.

When shown on the plans, devices capable of automatically sampling and weighing the quantity of each hot bin aggregate size and sampling, weighing, or metering the asphaltic material fed to the pugmill during either a known number of revolutions of the plant or a known interval of time shall be installed as part of the plant equipment. In addition, each aggregate hot bin, mineral filler bin, and the asphaltic material feed line shall have interlock circuits such that the plant operations will be stopped if either aggregate or asphaltic material flow is discontinued or reduced.

The plant shall proportion size of aggregate to the pugmill with such accuracy that the weight of material from each hot bin shall not deviate from the design value by an amount more than 1.5 percent of the total weight of asphaltic concrete delivered per revolution or interval of time. Where the separate addition of mineral filler is required, it shall be added so as not to
deviate more than 0.5 percent on the basis stated above for aggregates. The asphaltic material shall be added so as not to deviate more than 0.1 percent on the basis stated above for aggregates. In no case shall the total weight of asphaltic concrete vary from the design weight by more than ± 2 percent of the design weight.

c. Drum Mix Plant. Drum mix plants shall provide satisfactory means to assure positive interlock between dry weight of aggregate flow and the flow of asphaltic material to the drum mixer.

The total aggregate feed shall be weighed continuously by a belt scale meeting the requirements of this Item. Provisions shall be made for introducing the moisture content of the total aggregate feed into the belt scale weighing signal and correcting wet aggregate weight to dry aggregate weight. The proportioning system shall be capable of adjusting the flow of asphaltic material to compensate for any variation in the dry weight of aggregate flowing into the drum mixer. Automatic digital readings of both the dry weight of aggregate flow and asphaltic material flow shall be displayed and totaled in appropriate units of weight and time.

The automatic proportioning system shall be provided with bin flow indicators arranged in such manner that under normal working conditions a signal will automatically be given when flow of aggregate from any cold aggregate bin is interrupted.

The drum mixer burner and asphalt tank heaters shall be automatically controlled by thermostats. This automatic equipment shall control the heat of the materials within the specified limits. Plants shall be equipped to record mixture temperature as it leaves the drum mixer.

H. Asphaltic Material Bucket. The asphaltic material bucket shall be of sufficient size to hold the necessary asphaltic material for one batch. If the material is measured by weight, the bucket shall be properly attached to the scales. If the proportioning is by volume based on weight, the measuring bucket used shall be of the overflow type and shall meet the requirements of the Engineer.
The valves at the asphaltic material bucket shall be of a quick cut-off type that do not leak.

I. Asphalt Meter.

1. Weigh-Batch Plant. Pressure type flow meters for volumetric measurement of asphalt shall automatically measure the asphaltic material within an accuracy of 1.0 percent when tested in accordance with TxDOT’s Test Procedure Tex-921-K. The meter shall be so constructed that any setting may be locked and the meter will automatically reset itself to this setting after the discharge of the asphaltic material to the batch. A thermometer shall be installed in the asphalt line to accurately measure the temperature within plus or minus 5°F over a range from 50°F to 400°F. Provisions of a permanent nature shall be made for checking the accuracy of meter output, including scales and container of such size that a full batch of asphaltic material may be weighed.

2. Continuous and Drum Mix Plants. Asphalt flow meters shall provide an automatic digital display of the volume or weight of asphaltic material which has passed through the line leading to the spray bar. The meter shall register within an accuracy of 1.0 percent when checked in accordance with TxDOT’s Test Procedure Tex-921-K. Accuracy of asphalt flow meters shall be checked at least once each six months.

J. Water. The measuring device for measuring water by volume shall indicate the quantity in gallons and fractions thereof for asphaltic mixtures. The quantity shall be measured in gallons for Portland cement concrete. When a volumetric tank or bucket is used for measuring the water, the supply inlet shall cut off automatically and remain off until the container has emptied completely and the discharge line to the mixer is closed. When water is measured by weight, the weigh bucket shall be properly attached to scales meeting the general requirements of this Item. When a pressure type flow meter for volumetric measurement of the water is used, it shall be so constructed that any setting may be locked and the meter shall be capable of being manually or automatically reset to the locked setting after the addition of water to each batch.

Regardless of the method of water measurement used, the operating mechanism shall regulate the quantity of water required for any given batch to within plus or minus 0.2 percent of the total batch for bituminous mixtures and to within plus or minus 1 gallon of the specified quantity of water required for Portland cement.
concrete mixes. Provisions of a permanent nature shall be made for checking the accuracy herein specified.

520.4 Measurement and Payment. The furnishing, erection, checking, calibration and operation of items listed under this Item will not be measured and paid for directly but shall be considered subsidiary to other bid items.

There are no line code(s), description(s), or unit(s) for this Item.

END OF ITEM 520
ITEM 526

MEMBRANE CURING

526.1 Description. This Item shall govern for curing concrete pavement, concrete base, curbs, curb and gutters, sidewalks, driveways, medians, islands, mowing strips, ADA ramps, concrete structures and slope paving, by the impervious membrane method.

526.2 Materials. The membrane curing compound shall comply with ASTM C309 "Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete", Type 2. White pigmentation shall be used on concrete paving. Red or clear pigmentation shall be used on structures. The material shall not have a flash point less than 50°F when tested by ASTM D56, “Standard Test Method for Flash Point by Tag Closed Cup Tester.”

The material shall be of such consistency that it can be satisfactorily applied as a fine mist through an atomizing nozzle by means of approved pressure spraying equipment at atmospheric temperatures above 40°F. The material shall be of such nature that it will not produce permanent discoloration of concrete surfaces nor react deleteriously with the concrete, or its components.

The compound shall not settle out excessively or cake in the container and shall be capable of being mixed to a uniform consistency by moderate stirring and shall exhibit a daylight reflectance of not less than 60% of that of magnesium oxide, when tested in accordance with ASTM E1347 “Standard Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry.

The compound shall produce a firm, continuous, uniform moisture-impermeable film, free from pinholes and shall adhere satisfactorily to the surfaces of damp concrete. It shall, when applied to the damp concrete at the rate specified by the manufacturer, dry to touch in not more than 4 hours and shall not be tacky or track off concrete after 12 hours. It shall be a tenacious film without running off or appreciably sagging. The compound shall not disintegrate, check, peel, or crack during the required curing period. The compound shall not peel or pickup under traffic and shall disappear from the surface of the concrete by gradual disintegration.

The compound shall be delivered to the job only in the manufacturer's original containers, which shall be clearly labeled with the manufacturer's name, the trade name of the material and a batch number or symbol with which test samples may be correlated.
The permissible percentage moisture loss when tested for water retention by ASTM C156 “Standard Test Method for Water Loss Through Liquid Membrane-Forming Curing Compounds for Concrete” shall not exceed:

<table>
<thead>
<tr>
<th>Time After Application</th>
<th>Moisture Loss</th>
</tr>
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<tbody>
<tr>
<td>24 hours</td>
<td>2 percent</td>
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<tr>
<td>72 hours</td>
<td>4 percent</td>
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526.3 Construction Methods. Keep the concrete pavement surface from drying until the curing material has been applied. The membrane curing compound shall be applied after the surface finishing has been completed and immediately after the free surface moisture has disappeared. The surface shall be sealed with two uniform coatings of the specified type of curing compound applied at an individual application rate of 1 gallon per 180 square feet of area or as specified by the manufacturer. The Contractor shall provide satisfactory means and facilities to properly control and check the rate of application of the compound. Use a towel or absorbptive fabric to remove any standing water that may be present on the surface before applying the curing compound. Apply the first coat within 10 minutes after completing texturing operations. Apply the second coat within 30 minutes after completing texturing operations.

The compound shall be thoroughly agitated during its use and shall be applied by means of approved mechanically powered pressure sprayers. The sprayers used to apply the membrane to concrete pavement shall travel at a uniform speed and be mechanically driven. The equipment will be of such design that it will ensure uniform and even application of the membrane material. The sprayers shall be equipped with satisfactory atomizing nozzles.

Hand powered straying equipment will be permitted only on small miscellaneous items.

For all spraying equipment, the Contractor shall provide facilities to prevent the loss of the compound between the nozzle and the concrete surface during the spraying operations.

The compounds shall not be applied to a dry surface and if the concrete has become dry, it shall be thoroughly moistened prior to application of membrane by fogging or moist application. Sprinkling or coarse spraying will not be allowed.

At locations where the coating shows discontinuities, pinholes or other defects, or if rain falls on the newly coated surface before the film has dried sufficiently to resist damage, an additional coat of the compound
shall be applied immediately at the same rate of coverage specified herein.

To insure proper coverage, the Engineer shall inspect all treated areas after application of the compounds for the period of time designated in the governing specification for curing, either for membrane curing or for other methods. Dry areas are identifiable because of the lighter color of dry concrete as compared to damp concrete. All suspected areas shall be tested by placing a few drops of water on the suspected areas. If the water stands in rounded beads of small pools which can be blown along the surface of the concrete without wetting the surface, the water impervious film is present. If the water wets the surface of the concrete as determined by obvious darkening of the surface, or by visible soaking into the surface, no water impervious film is present. Should the foregoing test indicate that any area, during the curing period is not protected by the required water impervious film, an additional coat or coats of the compound shall be applied immediately, and the rate of application of the membrane compound shall be increased until all areas are uniformly covered by the required water impervious film.

When temperatures are such as to warrant protection against freezing, curing by this method shall be supplemented with an approved insulating material capable of protecting the concrete for the specified curing period.

If at any time there is a reason to believe that this method of curing is unsatisfactory or is detrimental to the work, the Contractor, when notified, shall immediately cease the use of this method and shall change to curing by one of the other methods specified e.g. use of burlap polyethylene material or cotton mats or burlap mats with polyethylene sheeting, in close contact with the concrete surfaces as approved by the Engineer.

526.4 Submittal Required. The Contractor shall submit the vendor’s data for the curing compound to be used for Engineer’s approval. He/she shall also submit the manufacturer’s recommended method of application.

526.5 Measurement & Payment. Work and materials prescribed herein will not be paid for directly but shall be included in the unit price bid for the items of construction in which those materials are used.

There are no line codes for this Item.

NOTE: This Item requires other Standard Specifications

Item 420 “Concrete Structures”
Item 360 “Concrete Pavement”

END OF ITEM 526
ITEM 530

CONCRETE CURB, CONCRETE CURB & GUTTER, SIDEWALKS AND DRIVEWAYS

530.1 Description. This Item shall govern for curb, monolithic curb and gutter, sidewalks and/or driveways, with or without reinforcing steel, composed of portland cement concrete constructed on approved subgrade, foundation material, or finished surface in accordance with the lines and grades established by the Engineer and in conformance with the details shown on the plans. ADA compliance is required for sidewalks and ramps.

As used in this Item the word "curb" refers to standard 6 inch, doweled, and mountable concrete curbs, and monolithic curb and gutter.

530.2 Materials. Concrete used in conventionally formed construction shall be minimum Class D2 concrete, meeting the requirements of Item 421 “Structural Concrete”. Concrete for extruded construction shall also be minimum Class D2.


In construction of concrete curb, concrete curb and gutter, sidewalks and driveways, the Contractor has the option of using portland cement or portland cement plus fly ash, as defined herein. Cement plus fly ash shall be composed of portland cement and 20-30 percent fly ash, by weight. Fly ash shall be Class C or Class F, conforming to the requirements of ASTM C618 “Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.”

Reinforcing steel shall conform to the requirements of Item 440 "Reinforcing Steel".

Membrane curing materials shall meet the requirements of the Item 526 "Membrane Curing".

Bank sand, used as bedding material for concrete sidewalks, shall meet the requirements of Item 402 “Bank Sand Backfill”.

530.3 Construction Methods. Any required excavation and backfill shall be completed in accordance with Item 400 “Structural Excavation and Backfill”, except for measurement and payment, and/or in accordance with Item 110 “Roadway Excavation” and Item 132 “Embankment”.
For conventionally formed concrete, the subgrade, foundation, or pavement surface shall be shaped to the line, grade and cross-section and if considered necessary by the Engineer, hand tamped and sprinkled. If dry, the subgrade or foundation material shall be sprinkled lightly immediately before concrete is deposited thereon.

Outside forms shall be of wood or metal, of a section satisfactory to the Engineer, straight, free of warp and of a depth equal to the depth required. They shall be securely staked to line and grade, and maintained in a true position during the depositing of concrete. Inside forms for curbs shall be of approved material, shall be of such design as to provide the curb required and shall be rigidly attached to the outside forms.

The reinforcing steel and/or dowels, if required, shall be placed in the position shown by the plans. Care shall be exercised to keep all steel in its proper location.

After the concrete has been struck off and after it has become sufficiently set, the exposed surfaces shall be thoroughly worked with a wooden float. The exposed edges shall be rounded by the use of an edging tool to the radius indicated on the plans. Unless otherwise specified on the plans, when the concrete has become sufficiently set, the inside form for curbs shall be carefully removed and the surface shall be plastered with a mortar consisting of one part of portland cement and two parts of fine aggregate. The mortar shall be applied with a template made to conform to the dimensions as shown on the plans. All exposed surfaces shall be brushed to a smooth and uniform surface.

Sidewalks shall be constructed in sections of the lengths shown on the plans. Unless otherwise provided by the plans, no section shall be of a length less than 8 feet and any section less than 8 feet shall be removed by the Contractor at his own expense. The different sections shall be separated by a premolded or board joint of the thickness shown on the plans, placed vertically and at right angles to the longitudinal axis of the sidewalk. Where the sidewalks or driveways abut a curb or retaining wall, approved expansion material shall be placed along their entire length. Similar expansion material shall be placed around all obstructions protruding through sidewalks or driveways. Sidewalks shall be marked into separate sections, each 4 feet in length, by the use of approved jointing tools. The reinforced concrete sidewalk shall be placed on a bedding material of bank sand, at a minimum of 2" thick.

Curbs, gutters and curb and gutters shall be placed in sections of 80 foot maximum length unless otherwise shown on the plans. Joints shall be
constructed at such locations and of the type as directed and specified on the plans.

All concrete placed under this Item shall contain 4 percent ± 1-1/2 percent entrained air. The completed work shall be cured for a period of not less than 72 hours in accordance with the requirements of the Item 526 "Membrane Curing". Color of concrete shall be in accordance with Item 531 "Coloring Concrete for ADA Ramps".

**Extruded Concrete Curbs:**
For extruded concrete construction, the concrete shall be placed by an extrusion machine approved by the Engineer. When placement is directly on subgrade or foundation materials the foundation shall be hand-tamped and sprinkled if considered necessary by the Engineer. If the concrete is placed directly on the surface material or pavement, such surface shall be thoroughly cleaned. If required by plan details, the cleaned surface shall then be coated with an approved or other coating as specified at the rate of application per vendor recommendations.

The horizontal alignment shall be maintained from a “guide” line set by the Contractor. The alignment shall strictly conform to the details shown on the plans. The forming tube of the extrusion machine shall be readily adjustable vertically, during the forward motion of the machine to provide variable heights necessary to conform to the established grade line. To provide a continuous check on the grade, a pointer or gauge shall be attached to the machine in such a manner that a comparison can be made between the extruded work and the grade line. Other methods may be used if approved by the Engineer.

The mix shall be fed into the machine in such a manner and at such consistency that the finished work will present a well compacted mass with a surface free from voids and honeycomb and true to the established shape, line and grade.

Any additional surface finishing specified and/or required, shall be performed immediately after extrusion. Joints shall be constructed at such location as directed by the Engineer and to the details shown on the plans.

All concrete placed under this item shall contain 4 percent ± 1-1/2 percent entrained air. The completed work shall be cured for a period of not less than 72 hours in accordance with the requirements of the Item 526, "Membrane Curing".

**Measurement.** Work and accepted material as prescribed by this Item for concrete curb, will be measured by the linear foot, complete in place.
Work and accepted material as prescribed by this Item for concrete sidewalks shall be measured by the square yard of surface area, complete in place including bank sand bedding material, as indicated on the plans.

Work and accepted material as prescribed by this Item for ADA curb ramps shall be measured by units of each, or square yard of surface area at specified depth, complete in place. When required, the Contractor’s coordination of a TDLR inspection shall be an integral part of each ADA compliant sidewalk construction site.

Work and accepted material as prescribed by this Item for concrete driveways, shall be measured by the square yard of surface area, at specified depth complete in place.

530.5 Payment. The work performed and the materials furnished as prescribed by this Item and measured as provided under measurement will be paid for at the unit price bid for:

A. "Concrete Curb" of the type indicated on the plans
B. "Concrete Sidewalks" of the width, and type indicated on the plans.
C. “ADA Curb Ramps”
D. "Concrete Driveways"

The price for each item shall be full compensation for:

A. Cleaning and coating the base
B. Furnishing and applying all water, mortar, adhesives or other material, including reinforcing steel and dowel bars, if required
C. For furnishing, loading and unloading, storing, hauling and handling all ingredients, including all freight and royalty involved
D. For mixing, placing, finishing, sawing, cleaning and sealing joints and curing all concrete
E. For furnishing all materials for sealing joints and placing joints and joint filler material in proper position
F. For all manipulations, labor, equipment, appliances, tools, traffic provisions and incidentals necessary to complete the work.
There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires Standard Civil Drawings that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications.

Item 110 "Roadway Excavation"
Item 132 "Embankment"
Item 360 "Concrete Pavement"
Item 400 "Structural Excavation and Backfill"
Item 402 "Bank Sand Backfill"
Item 440 "Reinforcing Steel"
Item 526 "Membrane Curing"
Item 531 "Coloring Concrete for ADA Ramps"

END OF ITEM 530
COLORING CONCRETE FOR ADA RAMPS

531.1 Description. This Item shall govern for the coloring of concrete ADA ramps in accordance with the details shown on the plans and the requirements of these Standard Specifications.

531.2 Materials. All materials shall conform to the requirements of Item 530 “Concrete Curb, Concrete Curb and Gutter, Sidewalks and Driveways” with the following exceptions:

A. Color Hardener. Bomanite or Lithochrome color hardeners, or approved equal is to be used. The color shall be as shown on the plans.

B. Colored Wax. Color wax complying with ASTM C309 “Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete” as a curing membrane and with all applicable air pollution regulations is to be used.

531.3 Construction Methods. After the concrete mix is placed and finished in accordance with Item 530 “Concrete Curb, Concrete Curb and Gutter, Sidewalks and Driveways”:

A. The colored hardener shall be applied evenly to the plastic surface by the dry-shake method using a minimum of 65 pounds per 12 square yards. It shall be applied in two separate applications, wood floated after each application and troweled only after the final floating.

B. While the concrete is still in the plastic stage of set, using forming tools approved by the Engineer, the concrete shall be patterned to create the surface as shown on the plans and as approved by the Engineer.

C. The colored curing and finishing compound shall be applied in accordance with the manufacturers’ recommendations.

531.4 Measurement and Payment. This Item shall not be paid for directly, but shall be considered incidental to Item 530 “Concrete Curb, Concrete Curb and Gutter, Sidewalks and Driveways”.

There are no line code(s), description(s), and unit(s) for this Item.
NOTE: This Item requires other Standard Specifications.

Item 530 “Concrete Curb, Concrete Curb and Gutter, Sidewalks and Driveways”

END OF ITEM 531
ITEM 535

MEDIANS AND DIRECTIONAL ISLANDS

535.1 Description. This Item shall govern for cast-in-place concrete medians and/or concrete directional islands, constructed in conformity with the lines and grades established by the Engineer, and to the details shown on the plans and in accordance with these Standard Specifications.

535.2 Materials. All concrete and concrete materials shall conform to the requirements of Item 421 “Structural Concrete” or Item 360 "Concrete Pavement". Joint materials shall conform to the requirements of the Item 420 "Concrete Structures". Reinforcing steel shall conform to the requirements of the Item 440 "Reinforcing Steel".

535.3 Construction Methods. The median and/or directional island shall be placed on the prepared foundation to the grade and dimensions specified. Forms, where required, shall be of wood or metal, straight, free of warp and of a depth equal to the depth of the required section. They shall be securely held in place, true to line and grade, during the concrete placing operations. Reinforcing steel and/or dowels if specified, shall be securely held in position.

Concrete shall be placed and cured in accordance with Item 421 “Structural Concrete” and Item 526 “Membrane Curing”. Each section shall be placed to the dimensions indicated on the plans. When required by the plans, the section shall be separated from adjacent curbs or adjoining sections by expansion or construction joints of the type and size specified. When permitted by the Engineer, an extrusion machine may be used to form curbs or sections of the median or islands.

After the concrete has been struck off and has set sufficiently, the exposed surface shall be thoroughly worked with a wooden float. Exposed edges shall be rounded to the required radius by the use of edging tools.

Color of concrete shall be in accordance with the Item 536, "Coloring Concrete for Median Noses".

Immediately after finishing operations are completed, the surface shall be cured in accordance with the Item 526, "Membrane Curing".

535.4 Measurement. Medians and directional islands will be measured by the square yard, complete in place.
535.5 Payment. "Medians and Directional Islands" constructed as prescribed above and measured as provided under measurement shall be paid for at the contract unit price bid for "Medians and Directional Islands", which price shall be full compensation for furnishing, hauling and installing all materials; for furnishing and installing reinforcing steel; for furnishing and installing joint materials; for curing and for all manipulations, labor, equipment, tools and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications.

Item 360 "Concrete Pavement"
Item 420 "Concrete Structures"
Item 421 “Structural Concrete”
Item 440 "Reinforcing Steel"
Item 526 “Membrane Curing”
Item 536, "Coloring Concrete for Median Noses"

END OF ITEM 535
ITEM 536

COLORING CONCRETE FOR MEDIAN NOSES

536.1 Description. This Item shall govern for the coloring of concrete median noses, at the locations shown on the plans.

536.2 Materials. The pigment used for the coloring agent, shall be a crystalline pigment known as black magnetic oxide of iron, or ferroso-ferric oxide, or an approved equal, made by a process of chemical precipitation so as to form a pigment of uniformly small particle size.

536.3 Construction Methods. Locations to be colored shall be as shown on the plans. The specified pigment (coloring agent), shall be applied on the newly finished concrete surface as soon as job conditions will permit, but in no event later than 2 hours after the concrete is placed. The pigment shall be applied dry, then lightly sprinkled with water and worked into the surface of the fresh concrete by wooden floats, steel trowels or other approved methods to secure a penetration of 1/8 to 1/4 inch, over the entire surface to be colored. The pigment shall be applied at the rate directed by the Engineer, but not less than three nor more than four pounds of oxide per fifty square feet of area.

536.4 Measurement and Payment. Coloring concrete median noses shall be paid for at the contract unit price bid per square yard for this Item. This price shall be full compensation for furnishing all materials, equipment and labor necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 536
ITEM 537

WHEEL STOPS

537.1 Description. This Item shall govern for the construction, furnishing and installing of precast reinforced concrete wheel stops.

537.2 Materials. Concrete shall be Class “C1” concrete and conform to Item 421 “Structural Concrete”, while reinforcement shall conform to Item 440 “Reinforcing Steel”.

537.3 Construction. Wheel stops shall be constructed in accordance with the Standard Civil Drawing.

537.4 Measurement. Wheel stops shall be measured by each unit, which shall include attachment pins (No.4 Grade 60 reinforcing bars, 12 inches in length with 7 inch embedment depth), furnished and installed.

537.5 Payment. Wheel stop shall be paid for at the contract unit price for each unit, furnished and installed in place. This price shall be full compensation for all materials, equipment and labor necessary to furnish and install the wheel stop.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires a Standard Civil Drawing that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications.

421 “Structural Concrete”
440 “Reinforcing Steel”

END OF ITEM 537
ITEM 540

REMOVING AND DISPOSING OF EXISTING ASPHALTIC SURFACE
AND BASE MATERIAL

540.1 Description. This Item governs for the removing and disposing of existing asphaltic surface and all types of base material outside the project limits in compliance with current local, State and Federal Regulations.

540.2 Construction Methods. The existing asphaltic surface and all base materials (rigid and flexible base courses) shall be removed to its full depth and to the width directed by the Engineer. The surface and base material (all depths) shall be removed in such a manner as not to disturb the subgrade.

540.3 Measurement. The basis of measurement shall be by the square yard of surface removed, regardless of depth.

540.4 Payment. The basis of payment shall be at the unit price bid per square yard, which price shall be full compensation for the cutting back of shoulders at the location of construction, stripping, scarifying, removal and disposal of material, including all labor, materials, tools, equipment and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 540
ITEM 550

EXISTING FENCING AND GATES

550.1 Description. This Item shall govern for the removal of existing fencing and gates and their disposal, salvaging or reinstallation at a location as shown on the drawings or directed by the Engineer.

550.2 Construction Methods. Fencing which is designated to be removed but not reinstalled shall be removed from the site and disposed of by the Contractor in compliance with current local, State and Federal Regulations unless salvaged as directed by the Engineer. All holes left as a result of post removal, if in an area not to receive roadway construction, excavation or fill, shall be filled and tamped with dirt to the elevation of natural ground. The Contractor shall provide the dirt.

At such locations where new fencing is to be installed and existing fencing removed, the existing fence shall not be removed until after new fencing has been installed.

When a chain link fence is to be reinstalled it shall be installed in accordance with the Item 555 "Chain Link Fencing". When barbed wire fence is to be reinstalled, it shall be installed in accordance with the Item 556 "Four Strand Barbed Wire Fence". When wood fencing is to be reinstalled, it shall be installed in accordance with the Item 554 "Wood Fencing". When an existing fence is to be reinstalled, it shall be installed with the same material, post spacing as the original, and design, or as otherwise directed by the Engineer.

If a chain link fence is to be reinstalled, the reinstallation of pig rings and wire clips shall be accomplished with new galvanized or aluminum rings and clips.

All new gates shall be as shown on the plans, or as directed by the Engineer. New gates shall be paid for under Items 554, 555 and 556, as appropriate.

550.3 Measurement. Measurement for the:

A. Removal and Disposal
B. Removal and Salvage
C. Removal and Reinstallation
of existing fencing shall be made by the linear foot, including gates.

550.4 Payment. Payment shall be made at the contract unit price bid per linear foot by type of fencing, including gates:

A. To be removed and disposed of;

B. To be removed and salvaged;

C. To be removed and reinstalled;

and this unit price shall include furnishing and installing, all labor, equipment, and any new materials necessary for; removal and disposal, removal and salvaging and/or reinstallation, necessary to complete the work.

There are line code(s), description(s) and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications.

Item 554 “Wood Fencing”
Item 555 “Chain Link Fencing”
Item 556 “Four Strand Barbed Wire Fence”

END OF ITEM 550
ITEM 554
WOOD FENCING

554.1 Description. This Item shall govern for furnishing the necessary materials and installing a solid picket wood fence, with gates, to the lines and grades shown on the plans.

554.2 Materials. Wood shall be western red cedar meeting the requirements of AWPA Standard U1, suitable for Use Category 4A. All members shall be straight, sound and with tight knots. Concrete for post embedment shall be Class “D2”, in accordance with the Item 421 “Structural Concrete”.

Hardware for gate hinges, drop rods (one in each gate section) and other gate hardware shall be hot-dip galvanized with 2.0 ounces minimum per square foot. All gate hardware shall be the heavy duty type. Nails for fence pickets shall all be aluminum alloy screw type. All other nails shall be new galvanized nails. Bolts, nuts and washers shall be galvanized.

Pickets shall be 1 inch x 8 inches or 1 inch x 10 inches.

Posts to be 4 inches x 4 inches, S4S, meeting the requirements of AWPA Standard U1, suitable for Use Category 4A. Bottom 3 feet of posts shall be set in Class “D2” concrete, with a minimum concrete cover of 4 inches. The top of posts shall extend above the top of pickets as required, for bolted attachment of 2 inches x 4 inches, 45 degree guard arms (extending out). The spacing of posts shall be 6 foot on centers, maximum. Concrete shall be crowned one inch at the top to shed water.

Guard arms shall be 2 inches x 4 inches, S4S, at 45 degrees, extending out, proper length for 3 barbed wire guard, top wire approximately 12 inches above top and 12 inches outside of pickets. Arms to be bolted to top of posts, with two 3/8 inch galvanized carriage bolts.

Gate shall be double swing, 14 foot clear opening, all bolted construction. Frames to be 2 inches x 6 inches minimum, S4S, well braced, with metal straps and hardware as required for sturdy construction. Each gate section shall have a drop rod with receptacle in concrete, at ground level; gate shall be heavy bolted on hinged hasp and staple for lock.

554.3 Submittal Required. All shipments shall include certification from the appropriate wood treatment plant. This certificate shall also state that all samples representing each lot have been tested and inspected in accordance with American Wood Preservers’ Association Standard M2, “Inspection of Treated Products” and have been found to meet the requirements of the Latest Edition of American Wood Preservers’ Association standards for wood treatment for its intended use.

The Contractor shall submit certification that the concrete that will be used meets the requirements of this Item.
554.4 Measurement. Wood fencing will be measured by the linear foot, including gates. When noted in the bid documents, gates may be measured as a separate item.

554.5 Payment. The work performed and the material furnished and installed as prescribed by this Item and measured as provided under measurement will be paid for at the contract unit price bid for “Wood Fencing”. Which price shall be full compensation for furnishing and installing all fence materials, including gates; for all preparation, hauling and installing of same; and for all labor, tools, equipment and incidentals necessary to complete the work, including excavation, backfilling and disposal of surplus material.

There are line code(s), description(s) and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications.

Item 421 “Structural Concrete”
Item 550 “Existing Fencing and Gates”

END OF ITEM 554
ITEM 555

CHAIN LINK FENCING

555.1 Description. This Item shall govern for furnishing and installing the quantities of chain link fencing and gates as shown on the plans, including all posts, bracing and accessories as called for herein and the installation of all items, complete in every respect at the locations shown on the plans.

555.2 Materials. Wire fabric for fencing shall be 9 gauge steel with a minimum tensile strength of 80,000 psi. Mesh size shall be 2 inch + 1/16 inch between parallel wires. Top edge of fabric shall be twisted and barbed on 5 and 6 foot height fencing and shall be knuckled selvage on 4 foot fencing. Bottom edge of all fencing shall be twisted and barbed.

Fabric ties of the same material as fabric shall be furnished in sufficient quantity to fasten fabric to top tension wire or to top rail at 18 inch intervals. Ties shall be furnished to fasten the fabric to bottom tension wire at 18 inch intervals. The fabric shall be tied to the line posts at 15 inch intervals.

Line posts shall be furnished in sufficient quantity to provide a maximum spacing between posts of 10 feet.

### TABLE 1

LINE POST REQUIREMENTS

<table>
<thead>
<tr>
<th>FABRIC HEIGHT</th>
<th>PIPE SECTION</th>
<th>H-BEAM SECTION</th>
<th>EMBEDMENT LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size</td>
<td>Wt./Ft.</td>
<td>Wt./Ft.</td>
</tr>
<tr>
<td>4 Feet</td>
<td>1.90&quot; O.D.</td>
<td>2.72 lbs.</td>
<td>2.70 lbs.</td>
</tr>
<tr>
<td>5 Feet</td>
<td>2.375&quot; O.D.</td>
<td>3.65 lbs.</td>
<td>2.70 lbs.</td>
</tr>
<tr>
<td>6 Feet</td>
<td>2.375&quot; O.D.</td>
<td>3.65 lbs.</td>
<td>4.10 lbs.</td>
</tr>
</tbody>
</table>

### TABLE 2

CORNER POST, PULL POST AND ENDPOST REQUIREMENTS

<table>
<thead>
<tr>
<th>FABRIC HEIGHT</th>
<th>PIPE SECTION</th>
<th>EMBEDMENT LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size</td>
<td></td>
</tr>
<tr>
<td>4 Feet</td>
<td>2.375&quot; O.D.</td>
<td>3.65 lbs.</td>
</tr>
</tbody>
</table>
Post caps for pipe sections shall be designed to exclude all moisture. Where barbed wire is specified, extension arms shall be integral with post caps. Where top rail is specified, post caps shall have an opening for top rail. All post caps shall have a 2 inch skirt for rigidity.

Top rail, where called for, shall be 1.625 inch O.D. steel pipe weighing 2.27 lbs./ft. Top rail shall be furnished in random lengths not less than 18-feet per section and shall be joined with outside sleeve, steel couplings not less than 6 inches long and having a wall thickness of not less than 0.07 inch. Couplings shall be designed to allow for expansion movement of the top rail.

Tension wire shall be 7 gauge galvanized carbon steel wire with a minimum breaking strength of 1,950 lb. Tension wire shall be furnished for the bottom edge of all fence fabric, and for the top edge when a top rail is not specified.

Trussed bracing shall be furnished for each panel adjacent to a terminal, pull, corner or gate post. Compression member shall be 1.625 inch O.D. pipe, as specified for top rail material. Tension members shall be 3/8 inch diameter galvanized steel rods with turnbuckles.

For 5 and 6 foot fences with top tension wire, braced panels shall consist of horizontal pipe brace, located approximately 4 inches below top of fabric, a diagonal pipe brace, attached at the midpoint of the terminal post and at the bottom of the adjacent line post, and a truss rod, attached to the top of the adjacent line post, extending diagonally to the bottom of the terminal post.
For 5 and 6 foot fences with top rail, braced panels shall consist of a horizontal pipe brace, midway between top and bottom of fence fabric, with a truss rod extending from the mid point of the line post diagonally to the bottom of the terminal post.

For 4 foot fences with top rail shall be braced with a truss rod connected to the bottom of the terminal post and extending to the top of adjacent line posts.

For 4 foot fences without top rail shall have a horizontal brace pipe at the top of the fabric and a diagonal truss rod installed as described above.

Pedestrian and vehicular gates shall be fabricated from 1.90 inch O.D. pipe weighing 2.72 lbs./ft. The fabric on the gates shall be the same as that specified for fencing. The following accessories shall be furnished for each gate:

A. Corner and tee fittings of malleable iron or pressed steel having means for attaching diagonal members. Hinges of malleable iron providing for full 180 degree swing with bottom hinges to be ball and socket type.

B. Diagonal braces consisting of 3/8 inch diameter truss rods with turn-buckles, two for each gate frame. Vehicular gates shall have vertical 1.90 inch O.D. pipe brace at center of each gate leaf.

C. Latches for single gates shall have a single fork latch with padlock eye; double leaf gates shall have two fork latches mounted on center plunger rod with padlock eye.

D. Hold backs shall be provided for each leaf of vehicular gates, employing a semi-automatic hold back catch to be anchored at least 12 inches into a 12 inch diameter by 24 inch deep concrete footing.

E. A malleable iron center rest, designed to receive the plunger rod, to be anchored at least 12 inches into a 12 inch diameter by 24 inch deep concrete footing, shall be provided for all double leaf gates.

The top of all gate frames shall align with the fencing top rail. Vehicular gates shall be 4 inches greater in overall height than the adjacent fencing so as to extend to within 2 inches of pavement between 6 inch curbs, if curbs are designated on the plans.
Rolling gates shall be fabricated from 1.90 inch O.D. vertical pipe weighing 2.72 lbs./ft. and 2.375 inch horizontal pipe weighing 3.65 lbs./ft. The fabric on the gates shall be the same as that specified for fencing. The following accessories shall be furnished for each rolling gate:

A. Diagonal braces consisting of 1.625 inch O.D. pipes, one for each gate bay(s) and two for counterbalance bay(s).

B. Single rolling gate application shall have one 4 inch post latch and one 2 inch cantilever latch with padlock; double rolling gate application shall have one 2 inch cantilever latch on each gate with padlock.

C. Single rolling gate application shall have 5 galvanized 4 inch cantilever gate roller assemblies; double rolling gates application shall have 10 galvanized 4 inch cantilever gate roller assemblies.

Barbed wire support arms shall be at an angle of 45 degrees from vertical and shall have clips for attaching three strands of barbed wire. Each support arm shall be of sufficient strength to support a 200 lb. weight applied at the outer strand of barbed wire.

Barbed wire, where specified, shall be twisted 12-1/2 gauge wire, with 14 gauge 2 point barbs spaced approximately 5 inches apart conforming to ASTM A121 “Standard Specification for Metallic-Coated Carbon Steel Barbed Wire.” Three strands of barbed wire will be required where barbed wire top is specified.

Stretcher bars shall be not less than 3/16 inch by 3/4 inch flat steel and not more than 2 inches shorter than the fabric height. One stretcher bar shall be provided for each gate and end post. Two stretcher bars shall be provided for each corner and pull post. Stretcher bars shall be attached to terminal posts with 1 inch by 1/8 inch flat steel bands, with 3/8 inch carriage bolts at intervals not exceeding 15 inches. Steel band diameter shall match the adjoining post.

Miscellaneous fittings and fasteners shall be furnished in sufficient quantities to erect all fencing materials in a proper manner.

All fencing materials shall be approved by the Engineer to be in accordance with this Item before they are erected. When requested by the Engineer, samples of any fencing component shall be furnished by the Contractor for testing.

555.3 Galvanizing. All material used in chain link fencing shall be hot dip zinc coated as specified by the following:
All Posts and Pipe: ASTM A53 “Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless” (1.8 oz/sf)

All H-Beam Sections: ASTM A123 “Standard Specification for Zinc (Hot- Dip Galvanized) Coatings on Iron and Steel Products” (2.0 oz/sf)

Fence Fabric: ASTM A392 “Standard Specification for Zinc-Coated Steel Chain-Link Fence Fabric” Class I (1.2 oz/sf)

Tension Wire, Barbed Wire: ASTM A121, Class III (0.80 oz/sf)

Post Caps, stretcher Bars and Miscellaneous Fittings, ASTM A153 “Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware”

The weight of zinc coating for all items shall be determined in accordance with ASTM A90 “Standard Test Method for Weight of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings”.

555.4 Construction Methods. The Contractor shall perform all clearing of brush and debris, which may be necessary for the installation of this fencing. The fencing panels between corner and terminal posts shall generally follow the finished ground elevations. However, the Contractor shall grade off minor irregularities in the path of the fencing as necessary to limit the variation of grade under the bottom edge of fence fabric to a distance of not more than 6 inches and not less than 2 inches to the ground.

The maximum spacing for line posts shall be 10 feet. Pull posts shall not be located more than 500 feet apart and at each change in direction exceeding 20 degrees, both horizontally and vertically. Runs of fencing over 500 feet but less than 1,000 feet shall have a pull post in the center of the run.

Holes for concrete footings, for all posts, shall be drilled to the dimensions listed in the following tables.

<table>
<thead>
<tr>
<th>TABLE 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOLES FOR LINE AND END POSTS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TYPE POST</th>
<th>FABRIC HEIGHT</th>
<th>MIN. HOLE DIAMETER</th>
<th>MIN. HOLE DEPTH</th>
<th>POST EMBEDMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line</td>
<td>4 Feet</td>
<td>9”</td>
<td>30”</td>
<td>24”</td>
</tr>
<tr>
<td>Line</td>
<td>5 Feet - 6 Inches</td>
<td>9”</td>
<td>30”</td>
<td>24”</td>
</tr>
<tr>
<td>End</td>
<td>4 Feet</td>
<td>12”</td>
<td>36”</td>
<td>30”</td>
</tr>
</tbody>
</table>
Concrete for footings shall be Class B and shall be in accordance with the Item 421 "Structural Concrete". All concrete footings shall be cast up to finish grade and crowned one inch to shed water. Excess concrete not used in the footings, and any other construction debris shall be removed from the site.

The fence fabric shall be erected by securing one end and applying sufficient tension to the other end to remove all slack before making attachments. The fabric shall be cut and each span shall be attached independently at all corner posts and pull posts.

Fastening to end, pull, corner and gate posts shall be with stretcher bars which shall be secured to the posts with stretcher bar bands at intervals not exceeding 15 inches.

Fence fabric shall generally follow the finished contour of the site with the bottom edge of the fabric located 2 inches above the grade.

### TABLE 5

**HOLES FOR GATE POSTS**

<table>
<thead>
<tr>
<th>GATE POST SIZE</th>
<th>MIN. HOLE DIAMETER</th>
<th>MIN. HOLE DEPTH</th>
<th>POST EMBEDMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.875&quot; O.D. x 5.79 lbs.</td>
<td>12&quot;</td>
<td>42&quot;</td>
<td>36&quot;</td>
</tr>
<tr>
<td>4.00&quot; O.D. x 9.10 lbs.</td>
<td>18&quot;</td>
<td>42&quot;</td>
<td>36&quot;</td>
</tr>
<tr>
<td>6.625&quot; O.D. x 18.97 lbs.</td>
<td>18&quot;</td>
<td>48&quot;</td>
<td>42&quot;</td>
</tr>
</tbody>
</table>

555.5 Submittal Required. The Contractor shall submit manufacturer's certification that materials meet the requirements of this Item.

555.6 Measurement. Chain link fencing of the height specified, will be measured by the linear foot of fence measured at the bottom of the fabric along the centerline of fence from center to center of end posts, excluding gates. Gates will be measured as each gate, complete in place.

555.7 Payment. The work performed and the material furnished as prescribed by this Item, measured as provided under measurement, will be paid for at the unit price bid for "Chain Link Fencing", of the height specified, which price shall be full compensation for furnishing and installing all fencing.
materials, except gates, including all miscellaneous fittings, braces, all post caps, line wires, connection clips or wires; digging all post holes; furnishing and placing concrete for setting all posts; all hauling; and for all manipulations, labor, tools, equipment and incidentals necessary to complete the work, including excavation, backfilling and disposal of surplus material.

Gates measured as provided under measurement will be paid for at the unit price bid for "Pedestrian Gate", "Vehicular Gate" or "Rolling Gate", of the type, height and opening specified, which price shall be full compensation for furnishing and installing all materials; fabricating, preparation, hauling and erecting all miscellaneous fittings, braces, latches, gate hinges, stops and center anchorages; and for all manipulations, labor, tools, equipment and incidentals necessary for a complete installation.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires Standard Civil Drawings that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications

Item 421 “Structural Concrete”
Item 550 “Existing Fencing and Gates”

END OF ITEM 555
ITEM 556

FOUR STRAND BARBED WIRE FENCE

556.1 Description. This Item shall govern for furnishing and installing the materials for one line of 48 inch, four strand barbed wire fence in accordance with the details and at the locations shown on the plans.

556.2 Materials. Barbed wire shall be fine coated (galvanized) steel, meeting the requirements of ASTM A121 “Standard Specification for Metallic-Coated Carbon Steel Barbed Wire”, 2 twisted strands of 12-1/2 gauge wire with 2-point 14 gauge barbs at 5 inch maximum spacing. Zinc coating shall be to Class 1 requirements.

Staples shall be new 9 gauge galvanized hard wire. All staples shall be a minimum of 1-1/2 inches long. Staples shall be driven diagonally with the wood grain to avoid splitting. Space should be left between the staple and the post, to permit movement of wire.

Treated wood posts and braces shall be pine, or fir timber, meeting the requirements of AWPA Standard U1, suitable for Use Category 4A. Line posts shall have a maximum spacing of 12 feet and have 3 inch to 4 inch tops. Line posts shall be a minimum of 6 feet long and shall be set 24 inches in the ground.

All corner, pull and gate posts shall be 7 feet long and a minimum of 6 inches round and be set in the ground 36 inches.

The timber shall be sound and free from all decay, shakes, splits or any other defects which would weaken the posts or braces or otherwise make them structurally unsuitable for the purposes intended.

All posts and braces shall be round. A line drawn from the center of each end of the post shall not fall outside the center of the post at any point more than 2 inches. All posts and braces shall be penta-treated and shall have pentachlorophenol wood treatment of a minimum of 8 pounds per cubic foot of 5 percent penta solution.

Posts shall be inspected at time of treatment. Round posts and braces shall be peeled to remove all outer bark and all inner combium bark, except that occasional strips of bark may remain if not over 1/2 inch wide or over 3 inches long. All knots shall be trimmed flush with the sides, spurs and splinters removed. The allowable taper from end to end of round posts and braces shall not exceed 1-1/2 inches.
Contractor shall provide and install gates at the locations shown on the plans. Gates shall be 14' wide, and the same dimension as the height of the fence, Hog Gate by Farmaster or approved equal, installed as per manufacturer's recommendations.

556.3

Construction Methods. Fence posts shall be spaced at the intervals required by this Item. All posts shall be set in a vertical position. Corner and pull posts shall be braced in two directions. End and gate posts shall be braced in one direction. Where alignment changes 15 degrees or more, a corner post shall be installed. The spacing of pull post assemblies shall be approximately 500 feet, unless otherwise shown on the plans. All posts shall be placed the minimum depth below ground as shown on the Standard Civil Drawings or as required by these Standard Specifications. Posts shall be set plumb and firm to the lines and grades shown on the plans. Backfilling shall be thoroughly tamped in 4 inch layers. The timber post braces shall be notched as shown on the plans.

The corner, end or angle post assembly shall be installed before stretching the barbed wire between line posts. The barbed wire shall be installed inside (cattle side) of the posts. At all grade depressions where stresses tend to pull the posts out of the ground, the fencing shall be snubbed or guyed at the critical points by means of a twisted double loop of 9 gauge galvanized wire connected to each horizontal line of barbed wire and then to a deadman, or screw type anchor, buried in the ground as shown on the Standard Civil Drawing. The fencing shall be stretched before being snubbed and guyed. Existing crossing fences shall be connected to the new fences and corner posts with braces which shall be placed at junctions with existing fences. The barbed wire shall be drawn taut and fastened to posts with staples.

556.4

Submittal Required. All shipments shall include certification from the appropriate wood treatments plant. This certificate shall also state that all samples representing each lot have been tested and inspected in accordance with American Wood Preservers' Association Standard M2, “Inspection of Treated Products“ and have been found to meet the requirements of the Latest Edition of applicable American Wood Preservers' Association standards for wood treatment for its intended use.

The Contractor shall submit manufacturer's certification that materials meet the requirements of this Item.

556.5

Measurement. Fencing will be measured by the linear foot, in-place, including gates. When noted in the bid documents, gates may be measured separately.
556.6 Payment. The work performed and the material furnished and installed as prescribed by this Item and measured as provided under measurement will be paid for at the contract unit price bid for "Four Strand Barbed Wire Fence", which prices shall be full compensation for furnishing and installing all fence material, including gates; for all preparation, hauling and installing of same; and for all labor, tools, equipment and incidentals necessary to complete the work, including excavation, back filling and disposal of surplus material. When noted in the bid documents, gates may be paid for separately.

There are line code(s), description(s) and unit(s) for this Item.

NOTE: This Item requires a Civil Standard Drawing that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications.

Item 421 “Structural Concrete”
Item 457 “Timber Preservative and Treatment”
Item 550 “Existing Fencing and Gates”

END OF ITEM 556
ITEM 559

CONSTRUCTION SAFETY FENCE

559.1 Description. This Item shall govern for furnishing, installing, maintaining, and removing “Construction Safety Fence”; to provide a temporary barrier to prevent pedestrians or members of the General Public from entering the designated work areas and/or protected areas. The four foot high orange color polypropylene construction safety fence shall be installed at the locations designated by the Engineer.

559.2 Materials. Construction safety fence shall be comprised of extruded, high density polypropylene, 4 foot tall minimum and orange in color. The mesh openings shall be no larger than 3-1/2 inches by 1-1/2 inches.

Plastic fence ties (zip ties), 7 inches long by 0.187 inches wide minimum, shall be used for attaching safety fence to posts for a tight secure installation.

Line/Support posts shall be steel T-posts, any color, shall be furnished in sufficient quantity to provide a maximum spacing between posts of 8 feet (See Table 1). Reinforcing steel bars shall not be used as posts.

<table>
<thead>
<tr>
<th>T-POST FENCE HEIGHT</th>
<th>SECTION</th>
<th>T-POST OVERALL LENGTH</th>
<th>T-POST WEIGHT</th>
<th>EMBEDMENT LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Feet</td>
<td>5 Feet – 6 Inches</td>
<td>1.25 lbs./lf</td>
<td>±18”</td>
<td></td>
</tr>
</tbody>
</table>

All fencing materials shall be approved by the Engineer to be in accordance with the specification before they are erected. When requested by the Engineer, samples of any fencing component shall be furnished by the Contractor for testing and/or examination.

559.3 Construction Methods. The Contractor shall perform all clearing of brush and debris, which may be necessary for the installation of this fencing.

The fencing sections between T-posts shall generally follow the finished ground elevations. However, the Contractor shall grade off minor irregularities in the path of the fencing as necessary to limit the variation of
grade under the bottom rung of fencing to a distance of not more than 2 inches and not less than 1 inch to the ground.

559.4 Installation. Place T-posts no more than 8 feet apart, center to center. Posts shall be located to allow movement of machinery and job related maneuvers in the designated work areas.

Pull the construction safety fence taut and secure to the posts with plastic fence ties (zip ties). Loop the ties through the available holes or “teeth” in/on the T-posts at the top and bottom of the fence, with two additional ties evenly spaced in the middle section of the fence. (Minimum of 4 ties per post).

To connect fence sections, overlap ends of adjacent strands by at least 6 inches and join the two strands by weaving a wood slat vertically through the mesh openings. Then secure the joined area to a T-post.

Ingress/Egress - The Contractor shall provide gates, capable of being secured, or other means as required to allow machinery and equipment to enter the work areas during normal working hours. These areas shall be secured when work is not in progress.

For special construction applications of the construction safety fence, as example: installed over an existing paved area (parking lot, etc.), the Contractor shall provide an alternate method of installation, approved by the Field Engineer, so not to damage any existing pavement.

Maintain and repair the construction fence throughout the duration of the project, at no cost to the County, to insure that the barrier continuously performs its intended function.

559.5 Submittal Required. The Contractor shall submit manufacturer's certification that materials meet the requirements of this Item.

559.6 Removal and Disposal. Remove and dispose of the construction safety fence upon completion of the project. Dispose of the material in compliance with current local, State and Federal Regulations.

After the fence is removed, the Contractor shall maintain field conditions equal to or better than the original condition.

559.7 Measurement. Construction safety fence of the height specified, will be measured by the linear foot of fence, complete in place.

559.8 Payment. The work performed and the material furnished and installed by this Item, measured as provided under measurement, will be paid for at
the unit price bid for "Construction Safety Fence", of the height specified, which price shall be full compensation for furnishing, installing, maintaining, and removing all fencing materials, including all miscellaneous fittings, plastic fence ties, T-posts, driving/setting T-posts; all hauling; and for all manipulations, labor, tools, equipment and incidentals necessary to complete the work, including excavation, grading and disposal of surplus material.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 559
560.1 Description. This Item shall govern for the maintenance and cleanup of the jobsite both during the term of the construction and at the end of construction.

560.2 General Requirements. The Contractor is required to remove from the job site and dispose of all trash, excess materials, etc., accumulated as a result of and during this work in compliance with current local, State and Federal Regulations.

At such time (daily or weekly) as directed by the Engineer, the Contractor shall remove any debris, trash or excess material off the site. He shall make every effort to keep the site in a neat, presentable condition, at all times.

In addition, at the end of each month, the entire construction site shall be generally cleaned and all trash and material over the length of the site shall be removed off site to the complete satisfaction of the Engineer.

The Contractor will mow, trim and edge the right-of-way and medians on the project for the entire project duration. The mowing schedule shall be as follows:

<table>
<thead>
<tr>
<th>April – October:</th>
<th>Once per month</th>
</tr>
</thead>
<tbody>
<tr>
<td>November – March:</td>
<td>Once every six weeks</td>
</tr>
</tbody>
</table>

After the construction work has been completed, the Contractor shall remove all debris, trash, excess materials, forms, stakes, empty sacks etc. from the site and leave the site with a neat appearance. All excavation shall be backfilled and all excess excavated material shall be disposed of off the site of the work.

560.3 Measurement and Payment. There shall be no separate payment for this Item.

There are no line code(s), description(s), or unit(s) for this Item.

END OF ITEM 560
ITEM 561

VIDEO RECORDING CONSTRUCTION

561.1 Description. This Item shall govern for the video recording of the construction project by the Contractor. Two copies of each of the video recordings of the project shall be prepared at the following intervals and submitted to the Engineer:

A. after the pre-construction meeting and before construction begins;
B. after clearing and grubbing (if this item is applicable);
C. after construction of all detours;
D. after construction is completed.

561.2 Equipment. The equipment used for video recording shall be an audio/visual recording device, such as a camcorder, capable of recording on DVD media. The finished product shall be capable of being viewed on a DVD player.

561.3 Methods. Prior to beginning the video recording of the construction project, a sign board shall be filmed showing the name of the project, the date, and time the video recording begins.

The physical limits for video recording the project shall be as set out in these Standard Specifications. Unless otherwise stated, the entire project shall be video recorded along both right-of-way lines.

Video recording shall progress along the stationing. The cameraman shall verbally note the stationing where the video recording is taking place. During video recording, the cameraman shall pay particular attention to privately maintained features located in or adjacent to the County's right-of-way, or easement. These privately maintained features would be such items as trees, shrubs, mailboxes, fences, gates, etc. If a tree or other feature has been damaged or is dead, prior to beginning construction, it shall be verbally noted and the damage shall be video recorded. The cameraman shall video record all driveways. The cameraman shall pay particular attention to any other features on the project where, in his/her opinion, some future conflict may arise. He/she may elect to do interim video recording of such items as barricades, at no additional cost to the County.
Measurement and Payment. This Item shall be paid for as a lump sum item which shall include the full cost of video recording for all the intervals noted, and providing two copies (DVD disks) of all video recordings to the County.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 561
ITEM 562

PREPARING THE RIGHT-OF-WAY

562.1 Description. This Item shall govern for the removal of all obstructions and objectionable material from the right-of-way and designated easements, so as to prepare the right-of-way for construction.

Included under this Item is the removal of trees, shrubs, other landscaping features not designated for preservation, stumps, fences, brush, logs, curb and gutter, driveways, pavement and paved parking areas, miscellaneous stone, brick, concrete, sidewalks, drainage structures, manholes, inlets, abandoned utilities, scrap iron, rubbish and debris, if within the right-of-way or designated easements.

It is the duty and responsibility of the Contractor to locate all "live" utility facilities, within the right-of-way or designated easements and to protect these facilities, except when instructed on the plans to do otherwise.

562.2 Construction Methods. The removal of all trees, shrubs, stumps, and brush shall be in accordance with Item 102 "Clearing and Grubbing". The removal of concrete curb and gutter, concrete driveways, concrete pavement and parking areas shall be in accordance with Item 104 "Removing Old Concrete". The removal of fences shall be in accordance with Item 550 "Existing Fencing and Gates". The removal of roadway signs, mail boxes, traffic signs and light and traffic poles shall be in accordance with Item 500 "Remove and Relocate or Dispose of Traffic Signs, Mail Boxes and Roadway Signs". The removal of existing underground utilities shall be in accordance with Item 465 "Remove and Dispose of Existing Concrete or Metal Pipe". The removal of concrete inlets, boxes and other concrete structures shall be in accordance with Item 104 "Removing Old Concrete". Debris, scrap iron, cans, etc. shall be removed in accordance with Item 200 "Stripping".

562.3 Measurement. Measurement shall be the full width and length of the right-of-way or designated easement.

562.4 Payment. Payment will be on a lump sum basis for "Preparing the Right-Of-Way".

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 102 “Clearing and Grubbing”
Item 104 “Removing Old Concrete”
Item 200 “Stripping”
Item 465 “Remove and Dispose of Existing Concrete or Metal Pipe”
Item 500 “Remove and Relocate or Dispose of Traffic Signs, Mail Boxes and Roadway Signs”
Item 562
Page -2-

FOR PROJECTS INITIATED
AFTER NOVEMBER 1, 2008
REVISION 1

Item 550 “Existing Fencing and Gates”

END OF ITEM 562
ITEM 563

CLOSED CIRCUIT TELEVISION INSPECTION
OF AS-BUILT STORM SEWER SYSTEMS

563.1 Description. This Item shall govern for furnishing all materials, labor and equipment necessary for the inspection, of the new constructed storm sewer lines or systems indicated on the drawings.

Inspection shall be by means of a closed circuit television inspection; and be documented in a written report, including DVD copies of the televised inspection.

563.2 Definitions.

Stationing - The term denoting longitudinal measurement in linear feet. For example: Manhole No.1 is at Sta. 0+50, and Manhole No.2 is at Sta. 5+01.

Manhole Section - The term "manhole section" as used in these Standard Specifications shall mean the length of pipe and/or box culverts connecting manholes and/or junction boxes.

Lateral Pipe and/or Lead Pipe – the pipe connecting an inlet to a manhole and/or a junction box.

Outfall Pipe – a section of pipe run from a manhole or junction box to an outfall ditch.

563.3 Contractor Obligations.

A. The Contractor shall furnish at no cost to the television crew, the following items during the entire project:

1. Site Access. Access to the site of work with sufficient area for the placement of the equipment and personnel. All work will be within easements and roadway rights-of-way.

2. Drawings. A set of drawings indicating the location of the storm sewer system to be inspected, along with identification of the manholes, junction boxes, inlets, outfalls and all pipe and/or box culvert runs.

3. Prior to beginning the televising of the storm sewer system, a sign board shall be filmed showing the name of the project, the date, and time filming begins.
563.4 Closed Circuit Television (CCTV) Inspection.

A. Equipment and Procedures

1. A self contained and air conditioned mobile trailer or van shall be provided which is large enough to accommodate representatives of the Engineer and the Contractor for purpose of viewing/monitoring the work while inspection is in progress. Trailer or van shall be equipped with a closed circuit television camera, color monitor, video tape recorder and/or DVDR, winches (power and mechanical), cable, and cable reel, suitable metering device so that exact location of camera within the line being televised can be noted at all times, and all necessary equipment for successful completion of television inspection, recorded on technicolor DVD media.

2. Perform cleaning prior to performing closed circuit television inspection. Cleaning shall include utilizing variable water pressure nozzles, up to 3,000 psi. The CCTV Contractor shall remove, collect, transport, and dispose of sand, debris, and liquid wastes to legal disposal sites.

3. Television equipment shall consist of a tilt and pan color camera and a monitoring unit connected by a coaxial cable. Camera shall be small enough to ensure passage through the lines, be waterproof and provide a continuous, clear picture showing the entire inside periphery of the pipe or box culvert. The Contractor shall provide suitable lighting system to allow all features and condition of the pipe or box culvert to be clearly visible on the colored DVD media.

4. The television inspection shall be performed on one manhole section at a time. Each manhole section being inspected shall be isolated from the remainder of the line by the use of a line plug to insure total viewing of the inside periphery of the pipe or box culvert. The inspection shall be performed by pulling the television camera through the line along the axis of the pipe or box culvert. A crawler type tractor for the camera is also acceptable. The inspection shall be performed in a forward and/or backward direction, according to line conditions at the time the inspection is made.

5. During the television inspection operation an inspection record shall be kept which will show clearly the exact
location, in relation to the centerline of the adjacent manhole, of each defect, crack, gap, or separation discovered by the television. To ensure accurate measurement, the measurement shall be made from an object at a fixed distance in front of the television camera, being positioned at the exact location of the defect, crack, separation of pipe or box culvert failure. The measurement reading shall be made at ground level by means of a meter device.

6. Should a water level be encountered that would prevent the viewing of the storm sewer interior, the Contractor shall dewater the segment to allow for inspection. In the case where there is constant water infiltration due to an adjacent pipe or box culvert break, the Contractor shall notify the utility operator.

563.5 Records.

A. A record shall be kept of the locations of defects located in the storm sewer using the distance from the nearest manhole or junction box so that the defects can be easily re-located.

B. Contractor shall furnish a minimum 2 complete recorded/televised, narrated, record of all lines televised (2 DVD’s). All recorded media shall have a continuous audio recording that reflects footage during the televising operations. At the completion of each recording, the televised media become the property of the Owner. All costs incurred in connection with the television operation are to be included as a lump sum bid price for this televising and recording. The DVD’s shall be labeled with the following:

- Contractor’s name …
- Inspection Type- “Post Installation”
- Date of Inspection
- Project name
- DVD Number of Total number of DVD’s
- Date Submitted

C. Following the CCTV inspection, the Contractor shall provide 2 copies of the bound written report indicating the physical location of the storm sewer elements, with a map that illustrates the relationship between the televised footage and above ground location between manholes and/or junction boxes, size of lines, pipe or box culvert materials used, location of deficiencies observed, and depth of flow line relative to the natural grade.
563.6 Measurement and Payment. This Item shall be paid for as a lump sum bid item which shall include the full cost of cleaning and televising/recording the complete as-built storm sewer system.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 563
600 ITEMS

- 624 – Aluminum Signs
- 646 – Roadside Traffic Sign Support
- 649 – Wide Angle Prismatic Retroreflective Sheeting for Traffic Control Signs (Diamond Grade)
- 658 – Delineators and Object Markers
- 660 – Reflectorized Pavement Markings
- 661 – Traffic Paint (Solvent Based)
- 662 – Glass Reflective Spheres for Traffic Paint
- 663 – Traffic Buttons and Pavement Markers
- 665 – Work Zone Pavement Markers
- 666 – Prefabricated Pavement Markings
- 669 – Pavement Surface Preparation for Markings
- 670 – Barricades
- 671 – Traffic Control
- 672 – Flagmen
- 673 – Constructing Detours for Maintaining Two-Way Traffic
- 674 – Removing Pavement Striping and Markings
- 675 – Traffic Paint Striping (Water Based)
- 676 – Traffic Paint (Water Based)
- 677 – Electrical Conduits for Traffic Signal Installation
- 678 – Zinc Coated Steel Wire Strand
- 679 – Insulated Jacketed Traffic Signal Cable
- 680 – Steel Mast Arm and Steel Strain Pole Assemblies
- 681 – Treated Timber Poles
- 683 – Traffic Signal Supports – Pedestal Poles
- 686 – Road Illumination Assemblies (On Traffic Signal Poles)
- 687 – Flasher Assembly Installation
- 688 – Flasher Assemblies
- 689 – Twelve Inch LED Traffic Signal Lamp Unit
- 690 – Traffic Signal Heads
- 691 – Twelve Inch Signal Head with Programmable Visibility of Signal Faces
- 692 – Pedestrian Signal Head
• 694 – LED Sign Lights for Traffic Signals
• 696 – Low Profile Concrete Barrier
• 698 – Temporary Polyethylene Water-Filled Barrier
• 699 – LED Pedestrian Traffic Signal Lamp Unit
ITEM 624

ALUMINUM SIGNS

624.1 Description. This Item shall govern for furnishing and/or installing aluminum signs which are of one piece construction, and which may or may not have the face side reflectorized.

624.2 Materials. All traffic signs shall be in accordance with the Latest Edition of the “Texas Manual on Uniform Traffic Control Devices for Streets and Highways”, Texas Department of Transportation. Detailed drawings of the standard signs illustrated in the manual are available from the Texas Department of Transportation, Austin, Texas 78701-2483.

Sign blanks shall be aluminum 5052-H 38 alloy, 0.080 inches in thickness and in accordance with Texas Department of Transportation Material Specification DMS-7110, “Aluminum Sign Blanks”. All sign face sheeting shall be in accordance with Item 649 “Wide Angle Prismatic Retroreflective Sheeting for Traffic Control Signs (Diamond Grade)” unless otherwise specified.

624.3 Fabrication. Sign blanks shall be cut to the proper size and shape as specified in the plans or specifications and shall be free of buckles, warps, burrs, dents, cockles, and other defects resulting from fabrication and shall be essentially a plane surface.

The sign blanks shall not be handled except by device or clean canvas gloves between all cleaning operations and the application of the reflective material. There shall be no opportunity for the blanks to come in contact with grease, oils or contaminants prior to the application of reflective material. Sign blanks shall be pre-drilled, unless otherwise noted and "radiussed" prior to delivery.

Sheeting shall be applied to sign faces in conformance with the recommended procedures of the manufacturer of the sheeting. When splicing of sheeting is necessary, the number of splices shall be held to a minimum consistent with the sheeting widths furnished by the manufacturers, and the minimum dimensions for any one piece of sheeting shall be 1'- 0".

624.4 Measurement. The majority of aluminum signs will be measured by each unit, of the type specified on the plans. Some projects will require aluminum signs to be measured by the square foot.
624.5 Payment. Payment for aluminum signs shall be made of the unit price bid per each unit, which price shall be full compensation for furnishing sheet aluminum sign blanks, fabrication of the sign blanks, treatment of the sign blanks required by the specifications, furnishing and installing reflective sheeting to the sign faces, screening of messages as required, furnishing and installing sign connections, and supports, washing and cleaning the sign after installation and all incidentals necessary to provide signs completed, erected, and attached to the sign support as specified. Aluminum signs installed temporarily as part of the traffic control plan during construction shall be paid in accordance with Item 671 “Traffic Control”. Some projects may require aluminum signs paid for by the square foot.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications.

Item 649 “Wide Angle Prismatic Retroreflective Sheeting for Traffic Control Signs (Diamond Grade)”
Item 671 “Traffic Control”

END OF ITEM 624
ITEM 646

ROADSIDE TRAFFIC SIGN SUPPORTS

646.1 Description. This Item shall govern for furnishing and installing supports of steel tubing which are used for traffic signs normally erected to a minimum height of 7 feet from top of pavement edge to the bottom of the lowest sign on the support, in accordance with the Latest Edition of the “Texas Manual on Uniform Traffic Control Device” (TMUTCD). Placement of roadside traffic sign supports shall also provide appropriate lateral clearance to signs in accordance with the TMUTCD.

646.2 Materials. High visibility yellow coated galvanized sign posts shall be as shown in Table 1:

| TABLE 1 |
|---------|---------|---------|---------|
|         | PIPE    | SQUARE TUBING |
| Nominal Size | 2"     | 1-3/4" x 1-3/4" |
| Outside Diameter | 2.375" (2-3/8") | 1-3/4" x 1-3/4" |
| Wall Thickness | 0.065" | 0.083" |
| Weight per Foot | 1.604 lbs. | 1.75 lbs. |
| Length | 10 or 11 Feet, as specified | 10 or 11 Feet, as specified |
| Holes | 3/8" holes punched as required | 3/8" holes punched as required |
| Hardware | 5/16" hex bolt with nut, lock washer, 2 flat washers per ASTM A307 galvanized per ASTM A153 | 5/16" hex bolt with nut, lock washer, 2 flat washers per ASTM A307 galvanized per ASTM A153 |

Tubing shall be manufactured from steel sheeting conforming to ASTM A513 “Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing.” The tubing shall be hot dipped galvanized per ASTM A653 “Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process” to obtain a zinc weight of 1.8 ounces per square foot inside and outside of the tube. Galvanizing shall be done after fabrication and punching or drilling of any holes.
Coating color shall be high visibility traffic yellow. Yellow coating shall be applied over the galvanized post to an average minimum dry mil thickness of 2.0. The tubing shall be properly cleaned and pre-treated to achieve the coating properties below as shown in Table 2.

TABLE 2

<table>
<thead>
<tr>
<th>COATING PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage Resistance</td>
</tr>
<tr>
<td>Coating flexibility shall conform to ASTM D522, 1/8 inch mandrel, with no cracking</td>
</tr>
<tr>
<td>Corrosion Resistance</td>
</tr>
<tr>
<td>Salt spray tested, scribed to meet ASTM B117, 500 hours, salt spray 1/8 inch creepage</td>
</tr>
<tr>
<td>Humidity Cabinet</td>
</tr>
<tr>
<td>Coating shall meet the requirements of ASTM D1735, 500 hours - no blisters</td>
</tr>
<tr>
<td>Weathering Resistance</td>
</tr>
<tr>
<td>QUV weathering, 50% gloss at 60% after 500 hours</td>
</tr>
</tbody>
</table>

There shall be no loss of integrity of adhesion. Color retainage shall be with a minimum of chalking. There shall be no effect on the coating for the following substances:

A. Gasoline
B. Motor Oil
C. Alcohol
D. Thirty-percent Sodium Hydroxide
E. Thirty-percent Hydrochloric Acid
F. Thirty-percent Nitric Acid
G. Thirty-percent Sulfuric Acid

646.3 Measurement and Payment. Roadside traffic sign supports shall not be paid for directly, but shall be incidental to Item 624 "Aluminum Signs". There are no line code(s), description(s), or unit(s) for this Item.
NOTE: This Item requires a Standard Civil Drawing that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications.

Item 624 "Aluminum Signs"

END OF ITEM 646
ITEM 649

WIDE ANGLE PRISMATIC RETROREFLECTIVE SHEETING
FOR TRAFFIC CONTROL SIGNS (DIAMOND GRADE)

649.1 Description. This Item shall govern for furnishing and installing sign face material fabricated from flexible, colored, wide angle prismatic retroreflective sheeting and related processing materials to be used for traffic control signs.

649.2 Applicable Documents.

ASTM Standards:

B117 “Standard Practice for Operating Salt Spray (Fog) Apparatus”

B209 “Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate”

D523 “Standard Test Method for Specular Gloss”

E284 “Standard Terminology of Appearance”

E308 “Standard Practice for Computing the Colors of Objects by Using the CIE System”

E810 “Standard Test Method for Coefficient of Retroreflection of Retroreflective Sheeting Utilizing the Coplanar Geometry”

E1164 “Standard Practice for Obtaining Spectrometric Data for Object-Color Evaluation”

CIE Publication Number 39.2 “Recommendations for Surface Colours for Visual Signaling”

649.3 Requirements. The retroreflective sheeting for sign faces/finished signs shall have a smooth surface with a distinctive interlocking diamond seal pattern and orientation marks visible from the face. The sheeting shall be precoated with a pressure sensitive adhesive backing protected by a removable liner.

The adhesive shall require no heat for proper bonding when applied in accordance with the manufacturer's recommendations to substrates 65°F or above.
649.4 Test Methods.

A. Test Conditions. Unless otherwise specified herein, all applied and unapplied test samples and specimens shall be conditioned at the standard conditions of 73 ± 3 degrees F. (23 ± 3 degrees C.) and 50 ± 5% relative humidity for 24 hours prior to testing.

B. Test Panels. Unless otherwise specified herein, when tests are to be performed using test panels, the specimens of retroreflective material shall be applied to smooth aluminum cut from ASTM B209 alloy 5052-H36, 5052-H38, 5154-H38 or 6061-T6 sheets in 0.020 inch (0.051 cm), 0.040 inch (0.102 cm) or 0.063 inch (0.160 cm) thickness. The aluminum shall be degreased and lightly acid etched before the specimens are applied. The specimens shall be applied to the panels in accordance with the recommendations of the retroreflective sheeting manufacturer.

649.5 Physical Requirements.

A. Color Requirements:

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>COLOR SPECIFICATION LIMITS* (DAYTIME)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COLOR</td>
</tr>
<tr>
<td></td>
<td>x</td>
</tr>
<tr>
<td>White</td>
<td>0.303</td>
</tr>
<tr>
<td>Yellow</td>
<td>0.498</td>
</tr>
<tr>
<td>Red</td>
<td>0.648</td>
</tr>
<tr>
<td>Blue</td>
<td>0.078</td>
</tr>
<tr>
<td>Green</td>
<td>0.026</td>
</tr>
<tr>
<td>Orange</td>
<td>0.558</td>
</tr>
<tr>
<td>Brown</td>
<td>0.430</td>
</tr>
<tr>
<td>Purple</td>
<td>0.302</td>
</tr>
</tbody>
</table>

* The four pairs of chromaticity coordinates determine the acceptable color in terms of the CIE 1931 standard colorimetric system measured with standard illuminant D65.
TABLE 2
COLOR SPECIFICATION LIMITS* (NIGHTTIME)

<table>
<thead>
<tr>
<th>COLOR</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>Y</td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>White</td>
<td>0.475</td>
<td>0.452</td>
<td>0.360</td>
<td>0.415</td>
</tr>
<tr>
<td>Yellow</td>
<td>0.513</td>
<td>0.487</td>
<td>0.500</td>
<td>0.470</td>
</tr>
<tr>
<td>Red</td>
<td>0.650</td>
<td>0.348</td>
<td>0.620</td>
<td>0.348</td>
</tr>
<tr>
<td>Blue</td>
<td>0.033</td>
<td>0.370</td>
<td>0.180</td>
<td>0.370</td>
</tr>
<tr>
<td>Green</td>
<td>0.007</td>
<td>0.570</td>
<td>0.200</td>
<td>0.500</td>
</tr>
<tr>
<td>Orange</td>
<td>0.595</td>
<td>0.405</td>
<td>0.565</td>
<td>0.405</td>
</tr>
<tr>
<td>Brown</td>
<td>0.595</td>
<td>0.405</td>
<td>0.540</td>
<td>0.405</td>
</tr>
<tr>
<td>Purple</td>
<td>0.355</td>
<td>0.088</td>
<td>0.385</td>
<td>0.288</td>
</tr>
</tbody>
</table>

* The four pairs of chromaticity coordinates determine the acceptable color in terms of the CIE 1931 standard colorimetric system measured with standard illuminant A.

B. Color Test. Conformance to color requirements shall be determined by instrumental method in accordance with ASTM E1164 on sheeting applied to test panels and conditioned as in Section 649.4 A. The values shall be determined on a HunterLab Labscan II 0/45 spectrocolorimeter with option CMR 559. Computations shall be done in accordance with ASTM E308.

C. Coefficient of Retroreflection ($R'$). The coefficients of retroreflection shall not be less than the minimum values specified in Table 3 and Table 3A. Testing shall be in accordance with ASTM E810 except that the Table 3 values shall be met at 0 degrees and at 90 degrees orientation without averaging and the Table 3A values shall be met using only the 45 degree orientation.

1. Units. Coefficients of retroreflection ($R'$) shall be specified in units of candelas per lux per square meter.

2. The observation angles shall be 0.1, 0.2, 0.5 and 1 degree.

3. The entrance angles shall be -4, 30 and 45 degrees.

4. For screen printed transparent colored areas or transparent colored overlay films on white sheeting, the ratio of coefficients of retroreflection ($R'$) of the white to the other color, when measured at 0.2° observation, -4° entrance, and
0° rotation, shall be 5:1 to 15:1 for red, and not less than 5:1 for all other colors.

### TABLE 3

**MINIMUM COEFFICIENT OF RETROREFLECTION R' (CANDELAS PER LUX PER METER SQUARED)**

<table>
<thead>
<tr>
<th>OBSERVATION ANGLE (DEG.)</th>
<th>ENTRANCE ANGLE (DEG.)</th>
<th>WHITE</th>
<th>YELLOW</th>
<th>RED</th>
<th>GREEN</th>
<th>BLUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>-4</td>
<td>625</td>
<td>565</td>
<td>165</td>
<td>80</td>
<td>42</td>
</tr>
<tr>
<td>0.1</td>
<td>+30</td>
<td>430</td>
<td>315</td>
<td>110</td>
<td>45</td>
<td>22</td>
</tr>
<tr>
<td>0.1</td>
<td>+45</td>
<td>120</td>
<td>90</td>
<td>24</td>
<td>12.5</td>
<td>6</td>
</tr>
<tr>
<td>0.2</td>
<td>-4</td>
<td>370</td>
<td>300</td>
<td>98</td>
<td>45</td>
<td>22</td>
</tr>
<tr>
<td>0.2</td>
<td>+30</td>
<td>225</td>
<td>180</td>
<td>65</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td>0.2</td>
<td>+45</td>
<td>90</td>
<td>70</td>
<td>26</td>
<td>9.8</td>
<td>4.5</td>
</tr>
<tr>
<td>0.5</td>
<td>-4</td>
<td>275</td>
<td>220</td>
<td>70</td>
<td>32</td>
<td>17</td>
</tr>
<tr>
<td>0.5</td>
<td>+30</td>
<td>125</td>
<td>100</td>
<td>32</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>0.5</td>
<td>+45</td>
<td>35</td>
<td>27</td>
<td>10</td>
<td>3.5</td>
<td>1.5</td>
</tr>
<tr>
<td>1.0</td>
<td>-4</td>
<td>75</td>
<td>58</td>
<td>20</td>
<td>9</td>
<td>4.5</td>
</tr>
<tr>
<td>1.0</td>
<td>+30</td>
<td>42</td>
<td>35</td>
<td>11</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>1.0</td>
<td>+45</td>
<td>10</td>
<td>8.8</td>
<td>3</td>
<td>1.6</td>
<td>.8</td>
</tr>
</tbody>
</table>

80 percent of values listed in Table 3 after 7 years and 70 percent of values listed in Table 3 after ten years must be maintained.

Failure of processing inks or overlay films provided and/or sold for use on recommended sheeting shall constitute a failure of entire sign and shall be replaced under manufacturer's replacement obligation.

### TABLE 3A

**MINIMUM COEFFICIENT OF RETROREFLECTION R' (CANDELAS PER LUX PER METER SQUARED)**

<table>
<thead>
<tr>
<th>OBSERVATION ANGLE (DEG.)</th>
<th>ENTRANCE ANGLE (DEG.)</th>
<th>YELLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>-4</td>
<td>550</td>
</tr>
</tbody>
</table>
D. Specular Gloss. The retroreflective sheeting shall have an 85 degree specular gloss of not less than 50 when tested in accordance with ASTM D523.

E. Color Processing. The retroreflective sheeting shall permit cutting and color processing with compatible transparent and opaque process colors in accordance with the sheeting manufacturer's recommendations at temperatures of 60 to 100 degrees F. (16 to 38 degrees C.) and relative humidities of 20 to 80 percent. The sheeting shall be heat resistant and permit force curing without staining of applied or unapplied sheeting at temperatures recommended by the sheeting manufacturer.

F. Flexibility. The retroreflective sheeting with the liner removed and conditioned as in Section 649.4 A, shall be sufficiently flexible to show no cracking when slowly bent, in one seconds' time, around a 1/8 inch mandrel, with the adhesive contacting the mandrel, at test conditions. Talcum powder shall be spread on the adhesive to prevent sticking to the mandrel.

G. Adhesive. The protective liner attached to the adhesive shall be removed by peeling without soaking in water or other solutions, without breaking, tearing, or removing any adhesive from the backing. The protective liner shall be easily removed following accelerated storage for 4 hours at 160 degrees F. (71 degrees C.) under a weight of 2.5 pounds per square inch (0.176 kg/cm²). The adhesive backing of the retroreflective sheeting shall produce a bond to support a 1.75 pound (0.79 kg) weight for 5 minutes without the bond peeling for a distance of more than 2 inches (5.08 cm) when applied to a test panel prepared as in Section 649.4 B. Apply 4 inches (10.16 cm) of a 1 inch x 6 inch (2.54 cm x 15.2 cm) specimen to a test panel. Condition and then position the panel face down horizontally; suspend the weight from the free end of the sample and allow it to hang free at an angle of 90 degrees to the panel surface for 5 minutes.

H. Impact Resistance. The retroreflective sheeting applied according to the sheeting manufacturer's recommendations to a test panel of alloy 6061-T6, 0.040 inch (0.10 cm) by 3 inch (7.6 cm) by 5 inch
(12.7 cm) and conditioned as in Section 649.4 A, shall show no cracking outside the impact area when the face of the panel is subjected to an impact of a 4 lb. (1.82 kg) weight, with a 5/8 inch (15.8 mm) diameter rounded tip, dropped from a height necessary to generate an impact of 10 in. lb. (1.13 N-m) at test temperatures of 32 degrees F. (0 degrees C.) and 72 degrees F. (22 degrees C.).

I. Resistance to Accelerated Outdoor Weathering. The retroreflective surface of the sheeting shall be weather resistant and show no appreciable cracking, blistering, crazing or dimensional change after 3 years unprotected outdoor exposure, facing the equator and inclined 45 degrees from the vertical. Following weather exposure, panels shall be washed in a 5 percent HCL solution for 45 seconds, rinsed thoroughly with clean water, blotted with a soft clean cloth and brought to equilibrium at standard conditions. After cleaning, the coefficient of retroreflection shall not be less than 70 percent of the values in Table 3.

The sample shall:

1. Show no appreciable evidence of cracking, scaling, pitting, blistering, edge lifting, or curling, or more than 1/32 inch (0.08 cm) shrinkage or expansion;

2. Be measured only at angles of 0.2 degrees observation, -4 degrees entrance and 90 degrees orientation. Where more than one panel of a color is measured, the coefficient of retroreflection shall be the average of all determinations.

J. Resistance to Heat. The retroreflective sheeting, applied to a test panel and conditioned as in Section 649.4 A, shall be measured in accordance with Section 649.5 C at 0.2 degrees observation and -4 degrees entrance angles at both 0 degree and 90 degree orientations and exposed to 170 ± 5 degrees F. (77 ± 3 degrees C.) for 24 hours in an air circulating oven. After heat exposure the sheeting shall retain a minimum of 70 percent of the original coefficient of retroreflection at both orientations when measured at room temperature.

K. Resistance to Corrosion. The retroreflective sheeting applied to a test panel and conditioned as in Section 649.4 A, shall show no loss of adhesion, appreciable discoloration, or corrosion, and after cleaning shall retain a minimum of 80 percent of the original coefficient of retroreflection when measured at 0.2 degrees observation, -4 degrees entrance and 0 degrees and 90 degrees orientation angles only, after 1000 hours exposure to a 5 percent
concentration salt spray at 95 degrees F. (35 degrees C.) when tested in accordance with ASTM B117.

L. General Characteristics and Packaging. The faces/finished signs supplied shall be of good appearance, free from ragged edges, cracks, and extraneous materials, and show careful workmanship with the message and border sharply defined.

When furnished as faces the sheeting shall be packaged flat in accordance with commercially accepted standards. Faces shall be interleaved with slipsheets as called for in this Item. The slipsheet glossy side shall be placed against the face with a maximum of 25 faces per carton.

When furnished as finished signs the signs must be protected with slipsheet and foam padding. The slipsheet glossy side shall be placed against the face and sign face padded with closed cell packaging foam. Finished signs shall be packaged in quantities of 10 or less to facilitate handling.

The packaged faces or signs shall include the appropriate number of washers as called for in this Item.

649.6 Performance Requirements and Obligations.

A. Certification. The sheeting manufacturer shall, upon request, submit with each lot or shipment, a certification which states that the material supplied will meet all of the requirements listed herein.

B. Field Performance Requirements: Retroreflective sheeting processed and applied to sign blank materials in accordance with the sheeting manufacturer's recommendations, shall perform effectively for a minimum of 10 years. The retroreflective sheeting will be considered unsatisfactory if it has deteriorated due to natural causes to the extent that:

1. The sign is ineffective for its intended purpose when viewed from a moving vehicle under normal day and night driving conditions; or
2. The coefficient of retroreflection is less than the minimums specified in Table 3.

C. All measurements shall be made after sign cleaning according to the sheeting manufacturer's recommendations.
D. For screen printed transparent colored areas on white sheeting, the coefficients of retroreflection shall maintain the ratios required by this Item as indicated in Section 649.5 C.

E. Sheeting Manufacturer’s Replacement Obligation. Where it can be shown that retroreflective signs with Types A and B sheeting supplied and used according to the sheeting manufacturer’s recommendations have not met the performance requirements of Section 649.6 B, the sheeting manufacturer shall cover the restoration costs as follows for sheetings shown to be unsatisfactory during:

1. The entire 10 years: the sheeting manufacturer will replace the sheeting required to restore the sign surface to its original effectiveness.

2. In addition, during the first 7 years the sheeting manufacturer will cover the cost of restoring the sign surface to its original effectiveness at no cost to Harris County for materials and labor.

Harris County shall require the dating of all signs at the time of application. The date constitutes the start of the field performance obligation period.

649.7 Measurement and Payment. Measurement and payment for wide angle prismatic retroreflective sheeting for traffic control signs shall be incidental to Item 624 “Aluminum Signs”.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 649
ITEM 658

DELINEATORS AND OBJECT MARKERS

658.1 Description. This Item shall govern for furnishing and/or installing delineators and object markers of the types shown on the plans.

658.2 Materials

A. General. Delineators shall consist of one, two, three or nine reflectors of the color specified for the various types as shown on the plans. Delineators shall be either the acrylic plastic prismatic type reflector or the encapsulated reflective sheeting type reflector which conforms to the requirements specified herein; however, all delineators furnished and/or installed shall be of the same type and manufacture. Object markers shall consist of three or nine reflector units or reflectorized panels of the color specified for the various types.

B. Independently Housed Acrylic Plastic Prismatic Reflector Unit Delineators.

1. General Description. Delineators and object markers shall consist of one, two, three or nine acrylic plastic prismatic reflectors of the color specified for the various types of delineators as shown on the plans, complete with aluminum housing, backplate and assembly hardware. The reflector unit shall be a circular shape conforming with the dimensions shown on the plans.

2. Design and Fabrication. Delineator and object markers housings and backplates shall be 0.063 inch, 3003-H-14 or similar aluminum, conforming with the dimensions shown on the plans, including all assembly hardware and post mounting hardware. The post mounting hardware shall consist of all bolts, nuts, plain washers, lock washers, fastening plates and brackets as required by the plans.

3. Reflector Unit Requirements. The reflector unit shall consist of a clear and transparent plastic face herein referred to as the lens, and a back material attached to the lens to form a unit hermetically sealed against water, dust and air. The lens shall consist of a smooth front surface free from projections or indentations other than for identification. The
manufacturer’s name or trade mark shall be molded legibly on the reflector unit.

Specific Intensity. 96 percent or more of the reflector units shall equal or exceed the following minimum values of specific intensity:

<table>
<thead>
<tr>
<th>ENTRANCE ANGLE DEGREES</th>
<th>DIVERGENCE ANGLE DEGREES</th>
<th>SPECIFIC INTENSITY CP./FOOT-CANDEL/REFLECTOR-UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>White</td>
</tr>
<tr>
<td>0</td>
<td>1/10</td>
<td>60</td>
</tr>
<tr>
<td>20</td>
<td>1/10</td>
<td>30</td>
</tr>
<tr>
<td>0</td>
<td>1/3</td>
<td>30</td>
</tr>
<tr>
<td>20</td>
<td>1/3</td>
<td>15</td>
</tr>
</tbody>
</table>

Seal Test. 96 percent or more of the reflector units shall pass the seal test, when tested in accordance with TxDOT Test Procedure Tex-845-B.

Heat Test. The reflector units shall pass the heat test when run in accordance with TxDOT’s Test Procedure Tex-846-B.

C. Encapsulated Reflective Sheeting Delineators.

1. General Description. Delineators and object markers shall consist of one, two, three or nine units of reflective sheeting of the color specified for the various types as shown on the plans, encapsulated within a clear weatherproof rigid plastic, comprising a sealed optical system, complete with aluminum housing and assembly hardware. The reflector unit shall be a circular shape of approximately three inches diameter or it may be another geometric shape so long as the surface area of the unit will contain an inscribed circle having a diameter of approximately three inches.

2. Design and Fabrication. Delineator housing shall be 0.063 inch 5052-H-14 or similar aluminum, conforming with the dimensions shown on the plans, including all assembly hardware and post mounting hardware. The post mounting hardware shall consist of all bolts, nuts, plain washers, lock washers, fastening plates and brackets as required by the plans.
3. Reflector Requirements. The reflector sheeting shall consist of glass spheres, adhered to a synthetic sheet resin or other suitable non-cellulosic material. The completed encapsulated reflectors shall have the following minimum brightness values:

<table>
<thead>
<tr>
<th>ENTRANCE ANGLE DEGREES</th>
<th>DIVERGENCE ANGLE DEGREES</th>
<th>SPECIFIC INTENSITY CP./FOOT-CANDLE/SQ.FOOT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>White</td>
</tr>
<tr>
<td>0</td>
<td>1/3</td>
<td>130</td>
</tr>
<tr>
<td>10</td>
<td>1/3</td>
<td>120</td>
</tr>
<tr>
<td>20</td>
<td>1/3</td>
<td>35</td>
</tr>
</tbody>
</table>

D. Center Mount Acrylic Plastic Prismatic Reflector Unit Delineators.

1. General Description. Delineators and object markers shall consist of one, two, three or nine acrylic plastic prismatic reflectors of the color specified for the various types of delineators as shown on the plans, complete with aluminum housing and mounting hardware. The reflector unit base shall be a circular shape conforming with the dimensions shown on the plans.

2. Design and Fabrication. Reflector units shall be securely fastened in a 0.020 inch aluminum housing that completely covers the back, sides and sealing edge of the reflector unit. The delineator shall have a mounting hole in its center with an aluminum grommet with a 3/16 inch inside diameter expanded within its mounting hole. A suitable mounting fastener conforming with the plans or other fastening means approved by the Engineer shall be furnished with each reflector.

3. Reflector Unit Requirements. The reflector unit shall comply with Section 658.2 of this Item with an exception to permit mounting hole.

658.3 Construction Methods. Delineators shall be mounted on the delineator posts as shown on the plans, or as directed by Engineer.

658.4 Measurement. Delineators shall be measured as "each" of the several types of delineators completely assembled and mounted in place.
658.5 Payment. The work performed and materials furnished as prescribed by this Item, measured as provided under measurement will be paid for at the unit price bid for "Delineators and object markers (Independently Housed)" of the type specified or "Delineators and object markers (Center Mount)" of the type specified, which price shall be full compensation for furnishing, fabricating and erecting the delineators as shown on the plans and as specified herein, including housings, backplates, frames, reflector units, fastening plates or brackets where required and all bolts, nuts and washers.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 661 “Traffic Paint (Solvent Based)”
Item 662 “Glass Reflective Spheres for Traffic Paint”
Item 669 “Pavement Surface Preparation for Markings”
Item 674 “Removing Pavement Striping and Markings”

END OF ITEM 658
ITEM 660

REFLECTORIZED PAVEMENT MARKINGS

660.1 Description. This Item shall govern for furnishing and installing reflectorized pavement markings of the types, colors, shapes, sizes, widths and thickness shown on the plans.

660.2 Materials.

A. Type I Marking Materials. Type I markings are thermoplastic type materials that require heating to elevated temperatures for application. Type I marking materials shall conform to Texas Department of Transportation Materials Specification DMS-8220. Each container of Type I marking material shall be clearly marked to indicate the color, weight, type of material, manufacturer’s name and the lot/batch number.

1. Submittal. Submit supplier’s certification verifying shelf life of Type I thermoplastic material.

B. Type II Marking Materials. Type II markings are paint-type materials that are applied at ambient or slightly elevated temperatures. Type II marking materials shall be in conformance with Item 661 “Traffic Paint (Solvent Based) and Item 662 “Glass Reflective Spheres for Traffic Paint”.

660.3 Equipment Requirements. Equipment used to place pavement markings shall:

A. Be maintained in satisfactory operating condition.

B. Be considered in satisfactory operating condition if it has an average placement rate of 5,000 linear feet per hour of acceptable 4 inch solid or broken lines over any 5 consecutive working days.

C. Meet or exceed the material handling at elevated temperatures requirements of the National Fire Underwriters and the Texas Railroad Commission.

D. Be capable of placing a minimum of 40,000 linear feet of 4 inch solid or broken markings per working day.

E. Have production capabilities similar to 4 inch marking equipment and shall be capable of placing linear markings up to 8 inches in
width in a single pass when used for placing markings in widths other than 4 inches.

F. Have production capabilities considered satisfactory by the Engineer when used to place markings other than solid or broken lines.

G. Be capable of placing a center-line and no-passing barrier-line configuration consisting of 1 broken line with 2 solid lines at the same time to the alignment and spacing shown on the plans.

H. Be capable of placing broken and/or continuous white line from both sides.

I. Be capable of placing lines with clean edges and of uniform cross-section. All lines shall have a tolerance of ± 1/8 inch per 4 inch width.

J. Have an automatic cut-off device with manual operating capabilities to provide clean, reasonably square marking ends to the satisfaction of the Engineer, and to provide a method of applying broken line in an approximate stripe-to-gap ratio of 15 to 25. The length of the stripe shall not be less than 15 feet or more than 15.5 feet. The total length of any stripe-gap cycle shall not be less than 39.5 feet or more than 40.5 feet.

K. Provide continuous mixing and agitation of the pavement marking material. The use of pans, aprons or similar appliances which the die overruns will not be permitted for longitudinal striping applications.

L. Apply beads by an automatic bead dispenser attached to the pavement marking equipment in such a manner that the beads are dispensed uniformly and almost instantly upon the marking as the marking is being applied to the road surface. The bead dispenser shall have an automatic cut-off control, synchronized with the cut-off of the pavement marking equipment.

When Type I markings are to be placed, the Contractor shall have a hand-held thermometer on the project. The thermometer shall be capable of measuring the temperature of the pavement marking material to be placed.

660.4 Construction Methods.
A. General. When required by the Engineer, the Contractor and the Engineer shall review the sequence of work to be followed and estimated progress schedule.

Markings may be placed on roadways either free of traffic or open to traffic. On roadways already open to traffic, the markings shall be placed under traffic conditions that exist with a minimum of interference to the operation of the facility. Traffic control shall be as shown on the plans or as approved by the Engineer in writing. All markings placed under open-traffic conditions shall be protected from traffic damage and disfigurement. On roadways open to traffic, with 3 lanes of travel in one direction, all markings shall be placed from the outside lanes only, unless otherwise approved in writing by the Engineer.

Guides, to mark the lateral location of pavement markings shall be established as shown on the plans or as directed by the Engineer. The Contractor shall establish the pavement marking guides and the Engineer will verify the location of the guides.

Markings shall be placed in proper alignment with the guides. The deviation rate in alignment shall not exceed 1 inch per 200 feet of roadway. The maximum deviation shall not exceed 2 inches nor shall any deviation be abrupt.

Markings shall have a uniform cross-section. The density and quality of markings shall be uniform throughout the marking. The applied markings shall have no more than 5 percent, by area, of holes or voids, and shall be free of blisters.

Markings, in place on the roadway, shall be reflectorized both internally and externally. Glass beads shall be applied to the materials at a uniform rate sufficient to achieve uniform and distinctive retroreflective characteristics when observed in accordance with TxDOT’s Test Procedure Tex-828-B.

The Contractor’s personnel shall be sufficiently skilled in the work of installing pavement markings.

If the Contractor’s placement of the markings is not in alignment or sequence, as shown on the plans or as stated in this Item, shall be removed by the Contractor at the Contractor’s expense. Removal shall be in accordance with Item 674 “Removing Pavement Striping and Markings” except for measurement and payment. Guides placed on the roadway for alignment purposes shall not establish a permanent marking on the roadway.
Unless otherwise shown on the plans, pavement markings may be applied by any method that will yield markings meeting the requirements of this Item.

B. Surface Preparation. New portland cement concrete surfaces shall be cleaned in accordance with Item 669 “Pavement Surface Preparation for Markings” to remove curing membrane, dirt, grease, loose and/or flaking existing construction markings and other forms of contamination.

Older portland cement concrete surfaces and asphaltic surfaces that exhibit loose and/or flaking existing markings shall be cleaned in accordance with Item 669 “Pavement Surface Preparation for Markings”, to remove all loose and flaking markings.

Pavement to which material is to be applied shall be completely dry. Pavement shall be considered dry if, on a sunny day after observation for 15 minutes, no condensation occurs on the underside of a one (1) foot square piece of clear plastic that has been placed on the pavement and weighted on the edges.

C. Application of Type II Markings.

The application of Type II marking materials shall be done only on surfaces with a minimum surface temperature of 50 F.

The application rate for Type II marking material shall be:

1. between 15 and 20 gallons per mile of solid 4 inch line and
2. between 30 and 40 gallons per mile for solid 8 inch line

For new surface treatment projects (e.g. one course surface treatment, etc.) the application rate shall be:

1. between 25 and 30 gallons per mile of solid 4 inch line and
2. between 40 and 50 gallons per mile for solid 8 inch line.

Pavement marking for new surface treatment projects shall be applied in 2 applications each approximately one-half the application rates specified in the paragraph above. The first application shall not contain glass beads. The interval between the first and second applications shall be a minimum of 1 hour.
In the case of inclement weather, if the Engineer has directed the Contractor to apply water-based traffic paint, and the markings are damaged by subsequent rain, sleet, hail, etc., the Contractor will be paid for the initial placement and the replacement markings. However, if the Contractor placed the markings at his option, the Contractor is responsible for all costs associated with the replacement markings.

D. Application of Type I Markings. New portland cement concrete surfaces shall be further prepared for Type I markings, after cleaning, by placing a Type II marking as a sealer in accordance with this Item.

Type II markings shall be placed a minimum of 2 and a maximum of 30 calendar days in advance of placing Type I markings when placing Type I markings on:

1. asphaltic surfaces 3 years old or older, or
2. any portland cement concrete.

Type II markings which become dirty due to inclement weather or road conditions shall be cleaned by washing, brushing, compressed air or other means approved by the Engineer, prior to application of Type I markings. If washing is used, the surface of Type II markings shall become thoroughly dry before placing Type I markings. Color, location and configuration of Type II markings shall be the same as that of Type I markings.

Type I pavement marking material shall be applied within temperature limits recommended by the material manufacturer. Type I pavement markings shall be applied only on clean, dry pavement having a surface temperature above 50° F. Pavement temperature shall be measured in accordance with TxDOT’s Test Procedure Tex-829-B.

When Type I pavement marking is applied by spraying, and operations cease for 5 minutes or more, the spray head shall be flushed by spraying pavement marking material into a pan or similar container until the pavement marking material being sprayed is at the proper temperature for application.

Unless otherwise shown on the plans, Type I marking minimum thickness shall be 0.060 inches (60 mil) for edgeline markings and 0.090 inches (90 mil) for stop-bars, legends, symbols, gore and center-line/no-passing barrier-line markings, when measured in
accordance with TxDOT’s Test Procedure Tex-854-B. The maximum thickness of all Type I markings shall be 0.180 inches (180 mil).

The thickness of Type I markings at the time of placement will be measured above the plane formed by the pavement surface. The Engineer will supply a device to measure the thickness of the applied markings. The markings shall be of uniform thickness throughout their lengths and widths.

660.5 Performance Period for Type I Markings.

Type I pavement markings shall meet all requirements of this Item for a minimum of 15 calendar days after installation. Pavement markings that fail to meet all requirements of this Item shall be removed and replaced by the Contractor at the Contractor’s expense. The Contractor shall replace all pavement markings failing the requirements of this Item within 30 calendar days following notification by the Engineer of the failure. All replacement markings shall also meet all requirements of this Item for a minimum of 15 calendar days after installation.

660.6 Measurement.

Reflectorized Pavement Markings will be measured by the linear foot, or by each for the various words, symbols or shapes, or by any other unit as shown on the bid documents.

Where double stripes are placed, each stripe will be measured separately.

Type II pavement markings requiring two applications on new surface treatments will be measured as one marking.

Type II pavement marking materials, when used as a sealer for Type I markings will be considered incidental to the Type I markings.

660.7 Payment.

The work performed and the materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Reflectorized Pavement Markings” of the various types, colors, shapes, sizes, widths, and thickness (Type I markings only) specified. Type II pavement markings used as a sealer for Type I markings will be considered incidental to the Type I markings. This price shall be full compensation for furnishing all materials; surface preparation for application of pavement markings; and for all other labor, tools,
equipment and incidentals necessary to complete the work, except as shown below.

Final Work Zone Pavement Markings (paint and beads) which will be used as a sealer for Type I pavement markings will be paid for under Item 665.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 661 “Traffic Paint (Solvent Based)”
Item 662 “Glass Reflective Spheres for Traffic Paint”
Item 665 “Work Zone Pavement Markings”
Item 669 “Pavement Surface Preparation for Markings”
Item 674 “Removing Pavement Striping and Markings”

END OF ITEM 660
ITEM 661

TRAFFIC PAINT (SOLVENT BASED)

661.1 Description. This Item shall govern for the materials, composition, manufacture and testing of all traffic paint and related materials as covered herein.

661.2 Bidder's and/or Vendor's Requirements. All prospective bidders are hereby notified that, before any bid is considered, Harris County may require the bidder to submit a statement in detail of the facts as to the previous experience of the bidder in performing similar or comparable work, as to the business and technical organization, financial resources and the manufacturing facilities of the bidder which are to be used in performing the contemplated work. Any bid submitted by a firm with unsatisfactory facilities, resources, equipment or experience may be rejected by Harris County.

661.3 Intent. The coating design specified has been stipulated by means of carefully controlled formulations durability testing methods. The intent of Harris County Engineering Department is to procure coatings which are identical in all essential respects to the standards of the Texas Department of Transportation (TxDOT); hereafter referred to as "Standards". Paints provided under this Item shall meet all applicable requirements of the Environmental Protection Agency.

Specifications, codes and accepted practices not specifically listed in these Standard Specifications are not applicable.

When required, the paint manufacturer shall supply Labor Form LSB-OOOS-4, "Material Safety Data Sheet."

661.4 Conformance of Finished Products. Coatings shall conform, on a weight basis, to the composition requirements of the standard formulae. No section variation from the standard formulae will be permitted except for replace of volatiles lost in processing, or those approved by the Engineer. The finished coatings shall conform with all requirements stipulated for each standard formulae, and shall equal a Wet Standard in characteristics such as color, drying, flow, settling, brush ability, can stability, hiding, etc.

Film characteristics such as gloss, hardness, light permanency, adhesion, etc., shall also conform. When testing for such conformity, the coating shall be applied and tested under parallel conditions with the Wet Standard.
The finished product shall be free of skins and foreign materials.

661.5 Mill Tests and Testing. All paint Contractor's shall be required to furnish to the Engineer a copy of certified Mill test report for all paint to be furnished and delivered to Harris County. Harris County shall have the option of performing necessary tests on material purchased directly by Harris County, the cost of testing shall be borne by the Contractor and/or supplier. The manufacturer shall be required to reimburse Harris County for the cost of storage and/or handling of paint failing to meet specification requirements.

Testing shall be in accordance with TxDOT requirements. Any questions should be addressed to the Engineer.

Raw materials and finished products which fail to meet any requirements of these Standard Specifications shall be subject to rejection. Final acceptance or rejection shall be based on results of tests on samples of raw materials and paint taken during production, and upon tests made on finished paints prior to delivery. Approval of materials, as a result of preliminary testing prior to manufacture into finished coatings, shall not be binding upon final approval or rejection. Because of the possibility of contamination and volatile losses, it shall be agreed that only the Wet Standard, currently in possession of Harris County or the licensed testing agencies, shall constitute standards for final comparison involving acceptance or rejection. The judgment of the Engineer shall be final in all questions relative to conformance with the provisions of these Standard Specifications.

661.6 Manufacturing procedures, except when specified, shall be left to the discretion of the Contractor. It is the responsibility of the manufacturer to ascertain that the raw materials and manufacturing procedures he proposes to use will produce a product meeting the specification requirements.

661.7 Shipment shall be made in suitable, strong, well sealed containers which not only meet specifications and Federal requirements, but are also sufficiently sturdy to withstand normal handling to which shipments are subjected in transit. FINISHED COATING CONTAINERS AND CASES SHALL BE PLAINLY AND SECURELY LABELED WITH THE NAME AND THE DESIGNATION OF THE COATING, ORDER NUMBER, REQUISITION NUMBER, BATCH NUMBER, DATE OF MANUFACTURE, GROSS WEIGHT, AND MANUFACTURER'S NAME. LABELING SHALL BE ON THE SIDES OF CONTAINERS AND CASES. LABELS MUST BE SUFFICIENTLY MOISTURE-RESISTANT TO WITHSTAND OUTDOOR STORAGE FOR A MINIMUM OF ONE YEAR. When the finished product is palletized for shipment, the labels shall be to the outside for easy
identification. Once the finished product has been labeled properly, the label shall not be modified or changed in any manner without specific approval of the Engineer.

Containers shall be filled by weight based on the actual gallon weight of the paint at 77 degrees F.

661.8 Raw Materials. The exact brands and types of raw materials used in the Wet Standard are listed for the purpose of facilitating the selection of parallel material equal not only in quality and composition but also in physical and chemical behavior after being used in the finished product. Since evaluation of paint containing questionable materials may require sixty days and since meeting delivery schedules is a responsibility of the paint manufacturer, he is reminded that he should schedule material procurement and paint production to permit him to meet delivery commitments. The final decision as to the equality of materials shall be made by Harris County. After Harris County has agreed to the brand names of raw materials proposed by the Contractor, no substitutions will be allowed during the manufacture without prior agreement with the Engineer.

"The Contractor should be aware that it is his responsibility to select raw materials that not only meet the individual raw material specifications but will also produce coating conforming to the specific formulae requirements."

A. Materials of Foreign Origin: Because of the limited information available on materials manufactured outside the continental limits of the United States, the manufacturer is advised to review Sections 661.5 and 661.8 of this Item when considering the use of materials of foreign origin.

B. Materials Required to Meet Federal and ASTM Specifications: All materials required to meet Federal or ASTM specifications must conform to the specifications as shown. Specifications or Amendments of other dates will not supersede.

C. PIGMENTS:

1. White:
   a. Titanium Dioxide, shall meet ASTM D476 “Standard Classification for Dry Pigmentary Titanium Dioxide Products”, Type I or II.
b. Lead free Zinc Oxide shall meet ASTM D79 “Standard Specification for Zinc Oxide Pigments” either American process or French process.

2. Colored: Titanium Dioxide, Special, Tutile, non-chalking:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>4.1 + 0.05</td>
</tr>
<tr>
<td>Oil Absorption</td>
<td>18 + 10%</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.5% max.</td>
</tr>
<tr>
<td>Retained on #325 Screen</td>
<td>0.1% max.</td>
</tr>
<tr>
<td>TiO₂</td>
<td>95% min.</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>2.0 - 3.0%</td>
</tr>
<tr>
<td>PH</td>
<td>6.5 - 7.0</td>
</tr>
<tr>
<td>Ignition Loss</td>
<td>0.34% max.</td>
</tr>
<tr>
<td>Y (luminosity)</td>
<td>42.5-45.5</td>
</tr>
</tbody>
</table>

3. Medium Chrome Yellow:

Color and Color Characteristics. The luminance factor of the pigment shall be within the limits listed below when tested before and after exposure.

<table>
<thead>
<tr>
<th></th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>53</td>
<td>59</td>
</tr>
<tr>
<td>Final</td>
<td>45</td>
<td>-</td>
</tr>
</tbody>
</table>

In addition, the allowable change between the initial and final luminance factors shall be not more than 9 units.

The initial X, Y chromaticity color coordinates of the pigment shall be within the rectangle defined by the sets of coordinates shown below:

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.490</td>
<td>0.455</td>
</tr>
<tr>
<td>0.511</td>
<td>0.433</td>
</tr>
<tr>
<td>0.514</td>
<td>0.480</td>
</tr>
<tr>
<td>0.535</td>
<td>0.458</td>
</tr>
</tbody>
</table>

Method of Test: The pigment shall be tested according to TxDOT’s Test Procedure Tex-810-B.
Color Standard: National Bureau of Standards, Chromatic Standard No. SCH-30. The formula of the test enamel using the pigment to be tested is as follows:

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>PARTS BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color Pigment</td>
<td>54.0</td>
</tr>
<tr>
<td>Long Oil Alkyd (1)</td>
<td></td>
</tr>
<tr>
<td>Resin (1)</td>
<td>31.5</td>
</tr>
<tr>
<td>4% Calcium Drier</td>
<td>0.6</td>
</tr>
<tr>
<td>6% Cobalt Drier</td>
<td>0.3</td>
</tr>
<tr>
<td>Anti-Livering Agent</td>
<td>0.1</td>
</tr>
<tr>
<td>Anti-Skinning Agent</td>
<td>0.2</td>
</tr>
<tr>
<td>Mineral Spirits (2)</td>
<td>13.3 (3)</td>
</tr>
</tbody>
</table>


c. The amount of Mineral Spirits may be varied slightly to produce the desired grinding consistency.

Number of coats: Two

4. Inert:

a. Talc, Paint-Grade Magnesium Silicate shall meet ASTM D605 “Standard Specification for Magnesium Silicate Pigment (Talc).”

b. Calcium Carbonate:

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaCO₃</td>
<td>97.0% min.</td>
</tr>
<tr>
<td>H₂O</td>
<td>0.4% max.</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.63 - 2.73</td>
</tr>
<tr>
<td>Wt. retained on #325 Screen</td>
<td>0.75% max.</td>
</tr>
</tbody>
</table>

Color: Equal to material listed in Standard Formula. Substitution in a Standard Formula shall not result in a viscosity variation greater than 4 KU.
c. Calcined Kaolin (Aluminum Silicate Anhydrous)

<table>
<thead>
<tr>
<th></th>
<th>MINIMUM %</th>
<th>MAXIMUM %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A$_2$O$_3$</td>
<td>39.6</td>
<td>44.0</td>
</tr>
<tr>
<td>SiO$_2$</td>
<td>51.0</td>
<td>56.5</td>
</tr>
<tr>
<td>Fe$_2$O$_3$</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>TiO</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>CAO$^2$ + MgO</td>
<td></td>
<td>0.8</td>
</tr>
<tr>
<td>Na$_2$O + K$_2$O</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Ignition Loss</td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

In addition, the X-ray diffraction pattern shall match the X-ray diffraction pattern specified by the TxDOT.

Materials having color requirements shall be tested according to TxDOT’s Test Procedure Tex-810-B.

D. RESINS:


2. Acrylic Copolymer Resin
   This material shall be an acrylic copolymer composed of i-butylmethacrylate-diethyl aminoethyl methacrylate copolymer binder resin. The characteristics of the acrylic copolymer resin shall be as follows:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity, 25°C(77°)</td>
<td>1.0</td>
</tr>
<tr>
<td>Color, Gardner, 20% by Weight in Toluene, Maximum</td>
<td>1.0</td>
</tr>
<tr>
<td>Acid Number, Maximum</td>
<td>1.0</td>
</tr>
<tr>
<td>Glass Transition Temperature</td>
<td>50°C (122°F)</td>
</tr>
<tr>
<td>Viscosity, 20% by Weight in Toluene, Pascal Seconds (Centipoises)</td>
<td>0.020-0.030 (20-30)</td>
</tr>
</tbody>
</table>

3. Traffic Paint Alkyd Resin Solution:
   a. General:
<table>
<thead>
<tr>
<th>Type</th>
<th>Pure, drying alkyd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Length/Type*</td>
<td>Medium/Soya, linseed or tall</td>
</tr>
<tr>
<td>Solvent</td>
<td>Toluene</td>
</tr>
</tbody>
</table>

No mixture of two or more oils is permitted.

Compatibility – A 1:5 solution 75% Traffic Alkyd Resin Solution and Toluene shall be clear and transparent and shall show no separation after 24 hours of storage in a 3/4 full test tube at 75° to 85° F. This rubber alkyd-solvent solution shall produce a clear film upon drying.

b. Solid Resin Basis (based on non-volatile material):

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Phthalic Anhydride</td>
<td>33 to 37%</td>
</tr>
<tr>
<td>Oil Acids</td>
<td>48 to 55%</td>
</tr>
<tr>
<td>Acid Number</td>
<td>8.0 max.</td>
</tr>
<tr>
<td>Ash Residue</td>
<td>0.10% max.</td>
</tr>
<tr>
<td>Unsaponifiable Material</td>
<td>2.0% max.</td>
</tr>
<tr>
<td>Iodine Number of Fatty Acids</td>
<td>115 min.</td>
</tr>
<tr>
<td>Refractive Index of Fatty Acids</td>
<td>1.4660 min.</td>
</tr>
<tr>
<td>Tall Oil Alkyd Resin</td>
<td>1.0% max.</td>
</tr>
</tbody>
</table>

c. 45% Resin Solids Basis:


Drying Time: Reduce the resin to 45% solids with Toluene, add (based on the resin solids present) the equivalent of 0.06% Cobalt (metal) and 1% Lead (metal). Let the mixture set for 3 hours before testing. A 3 mil wet film of this solution shall set-to-touch in less than 90 minutes.

d. In addition to the above requirements, the Traffic Alkyd Resin Solution shall meet the following Percent Transmittance requirements when tested according to TxDOT’s Test Procedure Tex-814-B, utilizing methyl isobutyl ketone as the primary solvent and methyl alcohol as the precipitating agent.


<table>
<thead>
<tr>
<th>% TRANSMITTANCE</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>10</td>
<td>70%</td>
</tr>
<tr>
<td>T</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculate volume in milliliters of precipitating agent as follows:

\[ V = 91 \times X \text{ and } V = 1.398 \times V \]

Where: \( V \) = volume of precipitating agent required for \( T \);

\( X \) = grams of alkyd resin solids and

\( V \) = additional volume of precipitating agent for \( T \).

E. THINNERS:

1. Acetone
2. Toluene
3. Methyl Alcohol meet ASTM D1152 “Standard Specification for Methanol (Methyl Alcohol)”

F. ADDITIVES AND CHEMICALS:

2. Additives listed below must be similar and equal to the standard sample submitted to an independent licensed testing laboratory by the manufacturer and approved by the Engineer prior to the award of contract for coatings in which the additive is proposed for use:
   a. Soya Lecithin
      
      This material shall be of suitable quality for use in the manufacture of paint.
   b. Anti-Skinning Agent
      
      This material shall be an anti-skinning agent suitable for use in paints.
c. Treated Bentonite Clay:
   1. Bentone 34, NL Industries;
   2. Claytone 40, Southern Clay Products:
   3. Tixogel VP, United Catalyst, Inc.

G. STANDARD FORMULAE:
   1. WPT - 8f, WHITE PAINT, TRAFFIC

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>POUNDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Alkyd, 75% solids Toluene RCI, Beckosol 97-150</td>
<td>140</td>
</tr>
<tr>
<td>Acrylic Copolymer BR-210</td>
<td>125</td>
</tr>
<tr>
<td>Chlorinated Paraffin, Type 1, Dover, Paroil 40E</td>
<td>30</td>
</tr>
<tr>
<td>Soya Lecithin</td>
<td>6</td>
</tr>
<tr>
<td>Titanium Dioxide, Rutile, DuPont, Ti-Pure R-900</td>
<td>150</td>
</tr>
<tr>
<td>Lead Free Zinc Oxide, ASARCO, AZO-66</td>
<td>50</td>
</tr>
<tr>
<td>Talc, WC&amp;D 2664</td>
<td>175</td>
</tr>
<tr>
<td>Calcium Carbonate, J.M. Huber, Hubercarp M-4</td>
<td>275</td>
</tr>
<tr>
<td>Treated Bentonite Clay</td>
<td>5</td>
</tr>
<tr>
<td>Methanol</td>
<td>3</td>
</tr>
<tr>
<td>36% Lead Drier</td>
<td>2</td>
</tr>
<tr>
<td>12% Cobalt Drier</td>
<td>1</td>
</tr>
<tr>
<td>Toluene</td>
<td>35</td>
</tr>
<tr>
<td>Anti-Skinning Agent</td>
<td>3</td>
</tr>
<tr>
<td>Acetone</td>
<td>270</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>1,270</td>
</tr>
</tbody>
</table>

Gallon Weight: ±0.05 of theoretical gallon weight

Grid: 4 minimum, Particles: 8 maximum (TxDOT’s Test Procedure Tex-806-B)
Viscosity: 83 to 97 KU

Skinning: No skinning within 48 hours (TxDOT's Test Procedure Tex-811-B)

2.

<table>
<thead>
<tr>
<th>YPT-8f, YELLOW PAINT, TRAFFIC</th>
<th>POUNDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Alkyd, 75% Solids Toluene RCI, Becksol 97-150</td>
<td>140</td>
</tr>
<tr>
<td>Acrylic Copolymer BR-210</td>
<td>125</td>
</tr>
<tr>
<td>Chlorinated Paraffin, Type 1, 1C1 Occidental, Chloroway 41sw</td>
<td>30</td>
</tr>
<tr>
<td>Soya Lecithin</td>
<td>6</td>
</tr>
<tr>
<td>Lead Free Zinc Oxide, ASARCO, AZO-66</td>
<td>50</td>
</tr>
<tr>
<td>Titanium Dioxide Special, Rutile, Hitox Corp. Hitox</td>
<td>35</td>
</tr>
<tr>
<td>Medium Chrome Yellow, Cookson, Y-969-L</td>
<td>125</td>
</tr>
<tr>
<td>Talc, WC&amp;D 2664</td>
<td>290</td>
</tr>
<tr>
<td>Calcium Carbonate, J.M. Huber, Hubercarb M-4</td>
<td>175</td>
</tr>
<tr>
<td>Treated Bentonite Clay</td>
<td>5</td>
</tr>
<tr>
<td>Methanol</td>
<td>3</td>
</tr>
<tr>
<td>36% Lead Drier</td>
<td>2</td>
</tr>
<tr>
<td>12% Cobalt Drier</td>
<td>1</td>
</tr>
<tr>
<td>Toluene</td>
<td>35</td>
</tr>
<tr>
<td>Anti-Skinning Agent</td>
<td>3</td>
</tr>
<tr>
<td>Acetone</td>
<td>270</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1,295</td>
</tr>
</tbody>
</table>

Gallon Weight: ±0.05 lbs. of theoretical gallon weight

Grind: 4 minimum, Particles: 8 maximum (TxDOT's Test Procedure Tex-806-B)
Viscosity: 83 to 97 KU

Skinning: No skinning within 48 hours (TxDOT’s Test Procedure Tex-811-B)

661.9 Installation Methods. All traffic paint applications shall meet the following requirements:

A. Traffic paint shall be applied at the rate of one gallon of unthinned paint per 105 square feet of surface area.

B. Traffic paint shall be applied with a minimum thickness of 15 mils, measured in a wet condition.

C. Paint striping shall be applied and measured to ± 1/4" of the specified widths.

All traffic paint striping not meeting these requirements shall be "touched up", removed and/or completely restriped to these standards and in accordance with the drawings at no additional cost to Harris County, as directed by the Engineer.

Where traffic buttons exist, the paint shall be applied to the pavement adjacent to, but not on the buttons or markers, unless another method is specified.


661.10 Testing. When required, the Contractor shall pay for and provide to Harris County, a testing report performed by a local testing laboratory designated by the Engineer. The report shall verify that the raw and finished materials to be supplied under this contract meet the requirements of this Item.

661.11 Rejection, materials and finished products which fail to meet any or all requirements of these Standard Specifications shall be subject to rejection. All materials and finished products rejected by the Engineer, whether in containers or applied to roadway surface shall be removed from the jobsite and replaced with materials meeting specifications and requirements and all costs of such removal and replacement shall be borne by the Contractor.
Measurement and Payment. Payment for this material and its installation shall be in accordance with the conditions prescribed in the contract awarded by Harris County and as shown on the bid items, or payment shall not be made directly but will be considered subsidiary to the furnishing and installation of white or colored traffic paint, as specified.

There are no line code(s), description(s), or unit(s) for this Item.

END OF ITEM 661
ITEM 662

GLASS REFLECTIVE SPHERES FOR TRAFFIC PAINT

662.1 Description. This Item shall govern for the quality of materials and the delivery of glass reflective spheres to be used with traffic paint.

662.2 Delivery of Materials. All materials shall be delivered to the job site in suitable, strong, well sealed containers which not only meet specifications and Federal requirements, but are also sufficiently sturdy to withstand normal handling to which shipments are subjected to transit. CONTAINERS AND CASES SHALL BE PLAINLY AND SECURELY LABELED WITH THE NAME AND THE DESIGNATION, ORDER NUMBER, REQUISITION NUMBER, BATCH NUMBER, DATE OF MANUFACTURE, GROSS WEIGHT, AND MANUFACTURER'S NAME. LABELING SHALL BE ON THE SIDE OF CONTAINERS AND CASES. LABELS MUST BE SUFFICIENTLY MOISTURE-RESISTANT TO WITHSTAND STORAGE FOR A MINIMUM OF ONE YEAR. When the finished product is palletized for shipment, the labels shall be on the outside for easy identification. Once the finished product has been labeled properly the label shall not be modified or changed in any manner without specific approval of the Engineer.

A. Drop-In Marking Material: Not more than 30 percent of the Glass Spheres shall be irregular or fused spheroids, and at least 70 percent of the spheres shall be true spheres.

The method of test shall be in accordance with ASTM D1155 "Standard Test Method for Roundness of Glass Spheres."

B. Refractive Index: The spheres when tested by liquid immersion method at 25°C., shall show an index of refraction within the range of 1.50 to 1.60.

C. Silica Content: The Silica Content (SiO₂) of the Glass Spheres shall not be less than 60 percent.

D. Gradation: The Glass Spheres shall conform to the following Gradation U.S. Standard Sieve Size

<table>
<thead>
<tr>
<th>Gradation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passing #20, Retained #30</td>
<td>5%</td>
<td>20%</td>
</tr>
<tr>
<td>Passing #30, Retained #50</td>
<td>30%</td>
<td>75%</td>
</tr>
<tr>
<td>Passing #50, Retained #80</td>
<td>9%</td>
<td>32%</td>
</tr>
</tbody>
</table>
The method of test shall be in accordance with ASTM D1214, "Standard Test Method for Sieve Analysis of Glass Spheres."

E. Moisture Resistance: A minimum of 2 lbs. of Spheres are placed in the cotton bag furnished with the sample and shall be subjected to the following moisture resistance test. Immerse the bag containing the sample in a container of water for 30 seconds or until water covers the spheres, whichever is longer. Remove the bag and force excess water from the sample by squeezing the bag. Suspend the bag and allow to drain for 2 hours at room temperature (70°F - 72°F). At the end of this time, mix the sample in the bag by shaking the bag thoroughly. Transfer sample slowly to a clean, dry funnel having a stem 4" in length, with a 3/8" inside dia. stem entrance opening and minimum exit (which is made of glass). If the spheres clog, it is permissible to lightly tap the glass funnel to initiate the flow.

662.3 Testing. The Contractor shall permit inspection and sampling of all raw materials and finished materials furnished and applied under this contract for the purpose of testing the said materials by an independent licensed testing laboratory to insure the specified quantity and quality requirements as set out herein.

The Contractor shall submit one quart of beads proposed for use to an independent licensed testing laboratory for testing. All testing shall be done by an independent licensed testing laboratory and 2 copies of the test results shall be furnished to the Engineer and the County Purchasing Agent prior to delivery of product. Contractor shall not be considered complete until such copies are received by Harris County.

662.4 Rejection. Materials and finished product which fail to meet any or all requirements of these Standard Specifications shall be subject to rejection.

All materials and finished products rejected by the Engineer, whether in containers or applied to roadway surface, shall be removed from the job site and replaced with materials meeting specifications and requirements and all costs of such removal and replacement shall be borne by the Contractor.

662.5 Measurement. Glass reflective beads shall not be measured, but shall be considered subsidiary to the cost of paint striping.
662.6 Payment. Glass reflective beads shall not be paid for separately but shall be subsidiary to the cost of paint striping.

There are no line code(s), description(s), or unit(s) for this Item.

END OF ITEM 662
ITEM 663

TRAFFIC BUTTONS AND PAVEMENT MARKERS

663.1 Description. This Item shall govern for furnishing and installing traffic buttons and reflectorized pavement markers and jiggle bars at the locations and of the type and color designated on the plans.

663.2 Design & Shape

A. Non-reflectorized Traffic Buttons: The traffic buttons shall be round and dome-shaped with a uniform curvature. Each button shall be 4 inches ±1/8 inch in diameter at the roadway surface and the height of the button shall be 11/16 inch ±1/16 inch. The base of the button shall not deviate from a flat plane by more than 1/16 inch. The top and sides of the buttons shall be smooth and free from surface irregularities, pits, cracks, checks, chipping, discoloration and any other defects which adversely affect appearance and application. The bottom of the buttons shall be rough-textured, free from gloss, glaze or any other substance that may reduce its bond to the adhesive.

B. Reflectorized Pavement Markers: The reflectorized markers shall be either round traffic buttons or square pavement markers, as shown on plans or designated in special specifications.

1. The round traffic buttons shall be dome-shaped with a flat area on the top and an acrylic rod lens reflector(s) inserted in a protective ramp and adhered to a recess in the base providing mono-directional and/or bi-directional reflection. Each mono-directional traffic button shall be 4 inches ±1/8 inch in diameter at the base. Each bi-directional button shall be an oval shape 4 inches ±1/8 inch wide by 4-3/4 inches ±1/8 inch long. Height of the button shall be 3/4 inch ±1/16 inch. The base of the button shall not deviate from a flat plane by more than 1/16 inch. The reflector lens shall be a single acrylic rod reflector, approximately 1-3/4 inches in length for each reflector.

The bottom of the buttons shall be rough-textured, free from gloss, glaze or any other substance that may reduce its bond to the adhesive.

2. The square pavement markers shall have a base width of 4 inches ±1/2 inch and a minimum area exposed to traffic 12.5
square inches. The maximum height shall be 3/4 inch. The maximum slope of the reflective face or faces shall be not more than 30 degrees from the horizontal.

The outer surface of the marker shall be smooth and all corners and edges exposed to traffic must be rounded.

The button surface of the marker shall not be grooved such that air will be trapped in the grooves when it is pressed into the epoxy adhesive.

3. The reflectorized pavement markers shall be of the following types:

a. Type I-A shall contain one face that reflects amber light and the body other than the reflective face shall be yellow.

b. Type I-C shall contain one face that reflects white light and the body other than the reflective face shall be white, silver white or light gray.

c. Type I-R shall contain one face that reflects red light and the body other than the reflective face shall be white, silver white or light gray.

d. Type II-A-A shall contain two reflective faces each of which shall reflect amber light and the body other than the reflective faces shall be yellow.

e. Type II-C-C shall contain two reflective faces, each of which shall reflect white light and the body other than the reflective faces shall be white, silver white or light gray.

f. Type II-A-C shall contain two reflective faces one of which shall reflect amber light and one of which shall reflect white light; the body other than the reflective faces shall be white, silver white or light gray or may be one-half yellow on the side that reflects amber light and one-half white, silver white or light gray on the side that reflects white light.

g. Type II-A-R shall contain two reflective faces, one of which reflects amber light and one of which reflects red light; the body other than the reflective faces shall
be one-half yellow on the side which reflects amber light and one-half red on the side which reflects red light or may be all white, silver white or light gray.

h. Type II-C-R shall contain two reflective faces, one of which reflects white light and one of which reflects red light; the body other than the reflective faces shall be white, silver white or light gray or may be one-half white, silver white or light gray on the side that reflects white light and one-half red on the side that reflects red light.

The reflective faces of the Type II markers shall be located so that the direction of reflection from one face shall be directly opposite to the direction of reflection of the other face.

663.3 Materials. The traffic buttons, and pavement markers shall be made from ceramic, glass or plastic material conforming to this Item and as called for by the plans and/or specifications. All buttons and/or pavement markers used on any project shall be of the same material and manufacturer.

Traffic buttons, and pavement markers shall have the following physical requirements:

A. Water Absorption: The water absorption of the button shall not exceed 1.0 percent of the original dry weight when tested in accordance with ASTM C373 “Standard Test Methods for Determination of Water Absorption and Associated Properties by Vacuum Method for Pressed Ceramic Tiles and Glass Tiles and Boil Method for Extruded Ceramic Tiles and Non-tile Fired Ceramic Whiteware Products.”

B. Autoclave Test (does not apply to Plastic Traffic Buttons). The glazed surface of the button shall not craze, spall or peel when subjected to one cycle of the Autoclave test at 250 psi (ASTM C424 “Standard Test Method for Crazing Resistance of Fired Glazed Whitewares by Autoclave Treatment”).

C. Strength Requirements: A random sample of 5 buttons shall be subjected to the compressive load test. The average compressive strength of the 5 buttons shall not be less than 1500 pounds and no individual button shall have a compressive strength less than 1200 pounds when tested in accordance with TxDOT’s Test Procedure Tex-434-A. The square pavement markers shall withstand a 200 lb. falling-ball impact of 5 feet without breaking, cracking, or being
significantly deformed when tested according to TxDOT’s Test Procedure Tex-430-A.

D. Impact Test (applies to Plastic Traffic Buttons only). The button shall not break or crack when subjected to the impact test in accordance with TxDOT’s Test Procedure Tex-435-A.

E. Color. The color of the buttons and pavement markers (base and reflector) shall be as designated on the plans, shall be uniform and shall be determined by visual comparison with calibrated standards having C.I.E. Chromaticity Coordinate limits determined in accordance with Federal Methods of Tests TT-T-141, Method 4252 falling within an area having the following corner points:

<table>
<thead>
<tr>
<th>COLOR</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>BRIGHT (%MgO) Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x y</td>
<td>x y</td>
<td>x y</td>
<td>x y</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>.290</td>
<td>.316</td>
<td>.310</td>
<td>.296</td>
<td>.330 .321 .310 .342</td>
</tr>
<tr>
<td>Yellow</td>
<td>.470</td>
<td>.460</td>
<td>.515</td>
<td>.485</td>
<td>.545 .455 .490 .425</td>
</tr>
</tbody>
</table>

COLOR COMBINATIONS

<table>
<thead>
<tr>
<th>Base</th>
<th>White</th>
<th>YellowWhite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflector</td>
<td>White</td>
<td>AmberRed and/or White</td>
</tr>
</tbody>
</table>

F. Glaze Thickness (applies to Ceramic Traffic Buttons only). The glazed surface shall have a mean thickness not less than 0.005 inch when measured not closer than 1/4 inch from the edge of the button. The glaze thickness shall be measured on a fractured edge of the button to the nearest 0.001 inch by a calibrated scale microscope.

G. Hardness (applies to Plastic Traffic Buttons only). The Shore Durometer Hardness (Type D) when determined in accordance with ASTM D2240 “Standard Test Method for Rubber Property—Durometer Hardness”, shall be a minimum of 86 when measured at room temperature and a minimum of 83 when measured at 150°F.

H. Heat Test. The buttons and markers shall show no change in shape or color when subjected to the requirements of TxDOT’s Test Procedure Tex-846-B. The temperature shall be 140° F with the marker in a vertical position.
I. Adhesion Requirements. The buttons and markers shall comply with the adhesion requirements of TxDOT’s Test Procedure Tex-611-J.

663.4 Optical Requirements

A. Definitions. Horizontal entrance angle shall mean the angle, in a plane parallel to the base of the marker, between a line in the direction of the incident light and a line perpendicular to the leading edge of the reflective surface.

Divergence angle at the reflector shall be between observer's line of sight and the direction of the light incident on the marker.

Specific intensity shall mean candlepower of the returned light at the chosen divergence and entrance angles for each foot candle of incident light per reflective face.

TxDOT’s Test Procedure Tex-842-B will be used to determine specific intensity.

B. Optical Performance. The reflective lens of the traffic buttons and markers shall be capable of providing Mono-directional and/or Bi-Directional Reflection of amber, red or white light as required by the plans and/or specifications. The specific intensity of the reflecting surface at 1/5 degree divergence angle shall be not less than the following when the incident light is parallel to the base of the button or marker:

<table>
<thead>
<tr>
<th>HORIZONTAL ENTRANCE ANGLE, DEGREE</th>
<th>SPECIFIC INTENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CRYSTAL</td>
</tr>
<tr>
<td>0</td>
<td>3.0</td>
</tr>
<tr>
<td>20</td>
<td>1.5</td>
</tr>
</tbody>
</table>

The specific intensity of the button or marker shall be not less than 80 percent of the above minimum values after being subjected to the heat test required above.

663.5 Epoxy Adhesives. The adhesive used to bond the traffic buttons and markers to the roadway surface shall conform to the requirements of the Section 663.7.

663.6 Construction Methods. The traffic buttons, and pavement markers shall be placed at locations and spacing indicated on the plans. The reflectorized buttons and markers shall be oriented in such a way that the
color of the reflected light is in accordance with the plans or as directed by the Engineer.

The portion of the roadway surface to which the marker is attached by the adhesive shall be prepared in accordance with Item 669 “Pavement Surface Preparation for Markings.”

The wet epoxy adhesive shall be spread on the bonding surface so that 100 percent of the bonding area of the marker will be covered. The wet adhesive applications shall be of sufficient thickness so that when the markers are pressed into adhesive, excess adhesive shall be forced out around the entire perimeter of the pavement markers. All excess adhesive shall be removed from the front of the reflective faces, or the marker shall be replaced.

When the project is complete the markers shall be firmly bonded to the pavement, lines formed by the marker shall be true and the entire installation shall present a neat appearance.

663.7 Epoxy Adhesive. The following is set forth as the requirements for the epoxy adhesive to be used to bond traffic buttons, lane markers and other devices to concrete paved roadway and bridge surface.

A. General Requirements. The epoxy adhesive shall be furnished in two components, herein referred to as the epoxy resin component and the hardener component, the two components to be mixed just prior to use.

The epoxy adhesive must be suitable for use when the structure or pavement temperature is between 60°F and 120°F and the atmospheric temperature is between 60°F and 105°F.

B. Component Properties: Any pigments, fillers and/or thixotropic agents present in either the resin component or the hardener component must be sufficiently dispersed that no appreciable separation or settling will occur during storage.

The ratio of the resin and hardener components to be mixed together to form the finished adhesive shall be specified by the manufacturer and the components packaged in the proper proportions.

C. Properties of the Mixed Adhesive: The adhesive mixture shall be of such a consistency that it may be applied to the surfaces which are to be bonded without difficulty. The adhesive must be capable of wetting the surfaces which are to be bonded so that a good bond
will be obtained. The adhesive must have a minimum resistance to flow, or thixotrophy, as specified below.

1. Thixotropy: The degree of thixotrophy shall be determined as described herein. (the ambient temperature and the temperature of the materials used in this test shall be 75°F) The two components of the epoxy adhesive shall be stirred together for approximately 5 minutes and then applied to a smooth clean steel plate to form a panel of epoxy material 2 inches wide, 4 inches in length, and 0.10 inch (100 mils) in thickness. A removable form of the proper dimensions may be used in placing the epoxy on the steel plate. The epoxy may be poured into the form and the excess struck off level with the top edge and then the form removed. Immediately after forming the epoxy adhesive, the steel panel shall be placed in a vertical position, the 4 inch dimension of the epoxy panel perpendicular to the horizontal. Not more than 7 minutes shall elapse between the initiation of mixing and the placing of the steel panel in the vertical position.

2. Requirements. The adhesive must be sufficiently resistant to flow that an average thickness of 0.03 inch (30 mils) of cured material will remain on the test panel.

D. Physical requirements of the cured adhesive: The following tests shall be performed on the specimens cured for 7 days between 70°F and 80°F.


The surface of the test specimens used in the adhesive shear strength test shall be prepared by blasting to white metal. The blasted surfaces shall be washed with methyl ethyl ketone and allowed to dry before applying the adhesive. The test specimens shall have a prepared surface of equivalent "anchor pattern" to that which would be obtained by abrasive blasting the surfaces to be bonded with a gun of 50 to 75 psi using a 1/4 inch diameter nozzle and employing Garnet Blasting Abrasive "Gem Blast", 60 mesh (No. 45 to No. 74 U.S. Standard Screens), as marketed by Clemtex, Incorporated, P.O. Box 15214, Houston, Texas 77020.

The given ASTM procedure shall be modified in that the specimens shall be prepared by casting disks of the epoxy adhesive 2-3/4 inches in diameter and approximately 3/8 inch thick. Prior to testing, the plane surfaces of the disks shall be ground to machine flat and parallel. The machining or grinding must be done in such a way as to not heat the disks above 100°F. The thickness of the disks after preparing the surfaces shall be 0.30 ± 0.02 inch.

3. Impact Strength: (70°F - 80°F) - Falling Ball Method - 6-1/2 foot-pounds minimum.

For this test the specimens shall be prepared as outlined in Water Gain. The finished specimens shall be placed on a concrete slab and a one pound steel ball dropped onto the center of the disks from an initial height of 5 feet. The height shall be increased by 1/2 foot for each successive drop until the specimen fails by cracking or shattering. The height of drop at which failure occurs shall be recorded as the impact strength in foot pounds. A minimum of three specimens shall be tested and the average reported to the nearest 1/2 foot pound.

663.8 Adhesive For Asphalt Pavement. The adhesive used to bond buttons and pavement markers to asphalt pavements shall conform to the requirements of the Latest Edition of TxDOT's Material Specification, DMS-6130, “Bituminous Adhesive For Pavement Markers”; stipulating that only the use of flexible bituminous marker adhesive will be allowed.

663.9 Testing. When required, by the Engineer, certified test results from an approved testing laboratory shall be submitted to Harris County, indicating that the traffic buttons and pavement markers have been tested and found to meet the requirements as outlined herein.

663.10 Measurement. Traffic buttons, jiggle bars and pavement markers will be measured as each button, jiggle bar or marker complete in place. Workzone Pavement Markings installed for temporary use shall be measured in accordance with Item 665 “Work Zone Pavement Markings”.
663.11 Payment. Unless otherwise specified, the work performed and material furnished as prescribed by this Item measured as provided under "Measurement", will be paid for at the unit price bid, which price shall include all labor, epoxy adhesive and all other materials and services necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 665 “Work Zone Pavement Markings”
Item 669 “Pavement Surface Preparation for Markings”

END OF ITEM 663
ITEM 665

WORK ZONE PAVEMENT MARKINGS

665.1 Description. This Item shall govern for the placement and maintenance of work zone pavement markings of the colors, types and sizes as shown on the plans.

665.2 General. Work zone pavement markings shall consist of short term markings and/or standard pavement markings. All sections of roadways to be opened to traffic shall be marked with short term markings or standard markings, as shown on the plans, at the end of each day's operation.

Short term markings are required for asphaltic surface treatment projects (e.g. one or two course surface treatments, hot or cold-in-place recycling, etc.), and may also be used prior to an asphalt recycling project for projects located within a floodplain where it is not permissible to raise the roadway elevation, so the existing pavement must be milled down before a recycling process can be implemented.

Work zone pavement markings are also broken down into two types:

A. removable work zone pavement markings

B. non-removable work zone pavement markings

Removable work zone pavement markings may be any combination of the following:

A. raised pavement markers and/or buttons,

B. removable prefabricated pavement marking material,

C. temporary flexible-reflective roadway marker tabs or

D. other materials as approved by the Engineer.

Paint and beads shall not be used for removable markings. Longitudinal lines wider than 4 inches may be simulated by the side-by-side placement of markers to increase the apparent line width in multiples of 4 inches as shown on the Standard Traffic Drawings.

Non-removable work zone pavement markings consist of the following:
A. paint and beads.

B. non-removable prefabricated pavement marking material.

Non-removable work zone pavement markings are used when the existing section of pavement is to be demolished in the next phase of construction, or if they are being placed as a sealer for a subsequent Permanent Pavement Marking. Otherwise, removable work zone pavement markings are required.

665.3 Materials. Materials used for work zone pavement markings shall be:
A. paint and beads,
B. raised pavement markers,
C. prefabricated pavement marking material,
D. temporary flexible-reflective roadway marker tabs or
E. other materials as approved by the Engineer.

Unless otherwise shown on the plans, paint shall be water-based. Paint shall conform to Item 676 “Traffic Paint (Water Based)”. Beads shall conform to Item 662 “Glass Reflective Spheres for Traffic Paint”.

Temporary flexible-reflective roadway marker tabs shall be used as short term work zone pavement markings for surface treatments as shown on the Standard Civil Drawings. The tabs shall conform to TxDOT’s DMS-8242, “Temporary Flexible, Reflective Roadway Marker Tabs.”

The Contractor shall be required to use temporary raised pavement markers where application of temporary marking is to be on permanent pavement surfaces. Raised pavement markers and traffic buttons shall conform to the requirements of Item 663 “Traffic Buttons and Pavement Markers”. Unless otherwise shown on the plans, raised pavement markers will not be allowed for words, symbols, and shapes, diagonal or transverse lines.

Unless otherwise shown on the plans, removable work zone pavement markings on final pavement surfaces shall be removable tape conforming to Item 666 “Prefabricated Pavement Markings”.

665.4 Performance Requirements. Markings in construction areas shall remain in proper alignment and, when dry, shall be distinctly visible from a minimum distance of 300 feet in daylight conditions and from a minimum
of 160 feet when illuminated by automobile low-beam headlights at night. Visibility distances will be determined when viewed from an automobile traveling on the roadway.

The daytime color as well as the nighttime reflected color of the markings shall be distinctly white or yellow as shown on the plans. The markings shall exhibit uniform retroreflective characteristics.

665.5 Construction Methods.

A. Placement and Maintenance. The Contractor shall exercise diligence in the selection of materials and placement of work zone pavement markings. Work zone pavement markings shall be maintained, in accordance with this Item, by the Contractor and at the expense of the Contractor to the satisfaction of the Engineer.

Unless otherwise approved in writing by the Engineer, all concrete surfaces shall have standard markings in place prior to opening to traffic.

All asphaltic surface treatment projects which are to be opened to traffic shall be marked with short term pavement markings immediately following placement and final rolling of any course. Short term pavement markings shall consist of temporary flexible-reflective roadway marker tabs spaced as shown on the Standard Traffic drawings.

Short term pavement markings shall be placed in proper alignment with the final location of future standard markings. Any short term pavement markings not in alignment with standard markings shall be removed by the Contractor at the Contractor's expense.

Standard pavement markings shall be installed in accordance with the TMUTCD and as shown on the plans. Unless otherwise shown on the plans, short term markings shall be removed immediately prior to placement of standard pavement markings.

Asphalt surface treatments shall be marked in accordance with the plans. Unless otherwise shown on the plans, standard permanent pavement markings in accordance with the TMUTCD shall be placed not sooner than 3 days nor later than 2 weeks after the placement of the surface treatment.

B. Marking Removal. Work zone pavement markings placed by the Contractor that conflict with any succeeding work zone markings shall be removed by the Contractor at the Contractor's expense in
accordance with Item 674 “Removing Pavement Striping and Markings”, except for measurement and payment.

**Remove all temporary markings with minimal damage to the roadway to the satisfaction of the Engineer.**

665.6 **Measurement.** This Item will be measured by the linear foot of standard marking or short term marking, by each word, shape or symbol, by each temporary flexible-reflective roadway marker tab on surface treatments or by any other unit as shown on the plans. Raised pavement markers used to simulate a stripe shall be measured by the linear foot of simulated stripe (as shown on the Standard Traffic Drawing) or by each raised pavement marker as shown on the plans. Where double stripes are placed, each stripe will be measured separately.

665.7 **Payment.** The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Work Zone Pavement Markings (Removable)”, “Work Zone Pavement Markings (Non-removable)” and “Work Zone Pavement Markings (Short Term)” of the width, color and type shown on the plans. This price shall be full compensation for furnishing all materials, labor, tools, equipment and incidentals necessary to place, maintain and remove, when required, the markings, except as shown below.

Removal of permanent markings will be paid for under Item 674 “Removing Pavement Striping and Markings”.

There are line code(s), description(s), and unit(s) for this Item.

**NOTE:** This Item requires other Standard Specifications

Item 662 “Glass Reflective Spheres for Traffic Paint”
Item 663 “Traffic Buttons and Pavement Markers”
Item 666 “Prefabricated Pavement Markings”
Item 674 “Removing Pavement Striping and Markings”
Item 676 “Traffic Paint (Water Based)”

END OF ITEM 665
ITEM 666

PREFABRICATED PAVEMENT MARKINGS

666.1 Description. This Item shall govern for furnishing and installing prefabricated pavement markings of the types, colors, shapes and sizes as shown on the plans.

666.2 Materials. Prefabricated pavement marking materials shall conform to Texas Department of Transportation Material Specification DMS-8240 “Permanent Prefabricated Pavement Markings.”

Materials shall be stored in a weather-proof enclosure in such a manner to prevent damage.

666.3 Sampling. Sampling will be in accordance with TxDOT’s Test Procedure Tex-732-I “Sampling Prefabricated Pavement Marking Materials.”

666.4 Construction Methods.

A. General. When required by the Engineer, the Contractor and the Engineer shall review the sequence of work to be followed and the estimated progress schedule. Waste generated by this work shall be removed from the job site before the end of each working day.

Guides to mark the lateral location of pavement markings shall be established as shown on the plans or as directed by the Engineer. The Contractor shall establish the pavement marking guides and the Engineer will verify the location of the guides prior to installation.

The pavement markings shall be placed in proper alignment with the guides. The deviation rate in alignment shall not exceed 1 inch per 200 feet of roadway. The maximum deviation shall not exceed 2 inches nor shall any deviation be abrupt.

B. Seasonal Limitation. Unless otherwise directed in writing by the Engineer, pavement marking materials shall not be placed between September 30 and March 1, subject to temperature and moisture limitations specified.

C. Dimensions. Markings shall be in accordance with the color, length, width, shape and configuration shown on the plans. The alignment and location shall be as shown on the plans or as directed by the Engineer in writing.
D. Methods. All material placement shall be in accordance with the material manufacturer’s instructions, unless otherwise directed in writing by the Engineer. In addition to the manufacturer’s instructions, material placement shall be in accordance with surface condition, moisture and temperature requirements specified by this Item.

E. Surface Preparation. Surface preparation shall be accomplished by any cleaning method approved by the Engineer that effectively removes contaminants, loose materials and conditions deleterious to proper adhesion. Surface preparation by blast cleaning will not be required unless shown on the plans. When required, blast cleaning shall be done in accordance with Item 669 “Pavement Surface Preparation for Markings”. Surfaces shall be further prepared after cleaning by sealing or priming, as recommended by the manufacturer of the pavement marking materials or as directed in writing by the Engineer.

Adhesive, when required, shall be of the type and quality recommended by the manufacturer of the pavement marking material. Portland cement concrete pavement surfaces shall not be cleaned by grinding.

F. Moisture. Pavement to which material is to be applied shall be completely dry. Pavements shall be considered dry if, on a sunny day after observation for 15 minutes, no condensation occurs on the underside of a 1 foot square piece of clear plastic that has been placed on the pavement and weighted on the edges.

G. Temperature. Pavement and ambient air temperature requirements recommended by the material manufacturer shall be followed. If no temperature requirements are established by the material manufacturer, material shall not be placed if the pavement temperature is below 60°F or above 120°F.

666.5 Performance Requirements.

A. Adhesion. Installed pavement markings shall not lift, shift, smear, spread, flow or tear by traffic action.

B. Appearance. Pavement markings shall present a neat, uniform appearance, free of excessive adhesive, ragged edges and irregular lines or contours.
C. Visibility. Installed pavement markings shall have uniform and distinctive retroreflectance when observed in accordance with TxDOT’s Test Procedure Tex-828-B “Determining Functional Characteristics of Pavement Markings”.

D. Observation Period. Unless otherwise shown on the plans, pavement markings shall meet all requirements of this Item for a minimum of 15 calendar days after installation. Pavement markings that fail to meet all requirements of this Item shall be removed and replaced at the expense of the Contractor. The Contractor shall replace all pavement markings failing the requirements of this Item within 30 working days following notification in writing by the Engineer. All replacement pavement markings shall also meet all performance requirements of this Item for a minimum of 15 calendar days after installation.

666.6 Measurement. This Item will be measured by each word(s), shape or symbol as shown on the plans.

666.7 Payment. The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Prefabricated Pavement Markings” of the various types, colors, shapes and sizes specified. This price shall be full compensation for cleaning the pavement by any suitable means, for furnishing and placing all materials; and for all labor, tools, equipment and incidentals necessary to complete the work.

There are line code(s), description(s) and unit(s) for this Item:

NOTE: This Item requires other Standard Specifications

Item 669 “Pavement Surface Preparation for Markings”

END OF ITEM 666
ITEM 669

PAVEMENT SURFACE PREPARATION FOR MARKINGS

669.1 Description. This Item shall govern for surface preparation of pavement surface areas any time that permanent painted or thermoplastic pavement marking, or raised pavement markers are to be applied.

669.2 Materials. Abrasive blasting medium, when used, shall be a quality commercial product capable of producing the specified surface cleanliness without the deposition of deleterious materials on the cleaned surface. Water used in blasting operations shall be potable.

669.3 Equipment. Equipment shall be in good condition. Air compression equipment shall utilize moisture and oil traps, in working order, of sufficient capacity to remove contaminants from blasting air and prevent the deposition of moisture, oil or other contaminants on the roadway surface.

669.4 Construction Methods. Pavement surface preparation is required to some degree for all forms of permanent pavement markings and raised pavement markers depending on the condition of the surface, the type of surface, and the manufacturer’s recommendations.

It is the Contractor’s responsibility to determine the method and degree of preparation required to sufficiently remove all dirt, dust, chemicals, oil, loose material, moisture, and other contaminants.

Both, concrete and asphalt surfaces can be prepared by sweeping, brushing, washing, air blasting, high pressure water blasting or any combination thereof. Concrete surfaces can also be prepared by sand blasting.

Whichever technique is used, it shall be carefully controlled to prevent visible damage to the pavement surface.

When new permanent pavement markings are to be placed in the same location as existing markings, small spots of the existing marking may remain if in the opinion of the Engineer, further removal would damage the pavement surface.

669.5 Payment. The work performed and the materials used in accordance with this Item for “Pavement Surface Preparation for Marking” will not be paid for directly, but will be considered subsidiary to the bid item for the pavement marking or raised pavement marker for which the surface preparation work is being performed.
There are no line code(s), description(s), or unit(s) for this Item.

END OF ITEM 669
ITEM 670

BARRICADES

670.1 Description. This Item shall govern for furnishing, installing, moving, replacing, maintaining, cleaning, and removing upon completion of work all barricades.

670.2 Materials. All barricades shall be in accordance with the requirements of the "Texas Manual on Uniform Traffic Control Devices" (TMUTCD).

Markings for permanent Type III barricade rails shall be alternating red and white chevron striping sloping downward at an angle of 45 degrees in the direction traffic is to pass. All parts of the barricade not striped shall be painted white.

Markings for temporary Type III barricade rails shall be alternating orange and white chevron striping sloping downward at an angle of 45 degrees in the direction traffic is to pass. All parts of the barricade not striped shall be painted white.

Where a Type III barricade extends entirely across a roadway, the stripes shall slope downward in the direction toward which traffic must turn when detouring. Where both right and left turns are provided for, the chevron striping shall slope downward in both directions from the center of the barricade.

Reflectorized sheeting used for the chevron striping on both permanent and temporary barricades shall be, as a minimum, in accordance with Item 649 “Wide Angle Prismatic Retroreflective Sheeting for Traffic Control Signs (Diamond Grade)”. The above does not preclude the requirements of the “Harris County General Conditions”.

670.3 Construction Methods. All barricades shall be installed in accordance with the drawings, the TMUTCD and Item 671 “Traffic Control”.

670.4 Responsibility for Damage or Claims. The Contractor shall hold harmless the County and all its representatives from all suits, actions or claims, of any character brought on account of any injuries or damages sustained by any person or property in consequence of any neglect in safeguarding the work or through the use of unacceptable materials in the construction of the improvement, or on account of any act of omission by the Contractor. He shall not be released from said responsibility until the roadway has
been completed and accepted, and so much of the money due the said Contractor under and by virtue of his contract may be retained by the County, or his Surety may be held until such claims have been settled and suitable evidence to that effect furnished to the County.

All barricades, whether temporary or permanent, shall be checked daily to see if they are in their proper location.

670.5 Measurement. Except for Permanent Type III barricades, this Item shall not be measured for payment. Permanent Type III barricades shall be measured by each unit of barricade constructed, complete in place.

670.6 Payment. Except for Permanent Type III barricades, payment shall not be made for this Item. Temporary Barricades shall be paid for in accordance with Item 671 “Traffic Control”.

The basis of payment for Type III barricades shall be the contract unit price bid per each unit, which price shall be full compensation for furnishing and placing all materials and for all labor, tools, equipment and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires drawings that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications

Item 649 “Wide Angle Prismatic Retroreflective Sheeting for Traffic Control Signs (Diamond Grade)”
Item 671 “Traffic Control”

END OF ITEM 670
ITEM 671

TRAFFIC CONTROL

671.1 Description. This shall govern for furnishing, installing, moving, replacing, maintaining, cleaning and removing upon completion of work, all barricades, signs, barriers, barrels, cones, lights, delineators, pavement markings, and other such devices and detours in conformance with the drawings or as directed by the Engineer.

A Traffic Control Plan (TCP) has been established for this project in accordance with the Texas Manual on Uniform Traffic Control Devices (TMUTCD). The Contractor may propose an alternate TCP, and if the alternate plan is approved by the Engineer, it may be used. The alternate TCP must be prepared in accordance with Harris County Traffic Control Guidelines (Latest Edition) and sealed by a Professional Engineer registered in the State of Texas proficient in the field of Traffic Engineering.

671.2 Construction Methods. All barricades, signs and other types of traffic control devices shall conform to details shown on the drawings, and those indicated in Part VI of the TMUTCD.

Prior to beginning work, the Contractor shall designate in writing a competent person who will be responsible and available on the project site or in the immediate area to insure compliance with the TCP.

The Contractor is solely responsible for furnishing, erecting and maintaining all barricades, signs, barriers, barrels, cones, lights, delineators, pavement markings, and other such devices as necessary to adequately protect the project and workers and warn, advise and safeguard the traveling public over the entire length of the project. The Contractor’s responsibility in this regard extends for the entire duration of the project, from the start of construction until acceptance by the County.

All reflective traffic control devices such as barricades, vertical panels, signs, etc. shall be maintained at all times by cleaning, replacing or a combination thereof such that during darkness and rain the reflective characteristics shall equal or exceed the retroreflective characteristics of the standard reflective panels in the Engineer’s possession. Unless otherwise set forth in these Standard Specifications, the Contractor shall receive compensation for furnishing, erecting and maintaining the necessary barricades, signs, barriers, barrels, cones, lights, delineators, pavement markings, other such devices and any incidentals necessary for
the good and proper safety, convenience and direction of traffic prior to final inspection and acceptance by the County.

Detours and temporary structures necessary for public travel during the prosecution of the work will be indicated on the TCP and the cost included in the bid and contract price. Any necessary detours or temporary structures not indicated on the drawings or provided for in the specifications shall be at the expense of the Contractor. Increased maintenance costs incurred incidental to resulting traffic over an established road, street, or highway as a result of any detour shall not be considered as a cost of maintaining detours and will be paid for by the Contractor.

The Contractor shall provide at his expense, means of ingress and egress for all residents and businesses along any closed section of the work and shall provide property owners a means of access to a public road.

Temporary access driveways shall provide an all-weather surface and shall be maintained by the Contractor in a condition acceptable to the Engineer. Where indicated in the bid documents, asphalt millings may be used for temporary driveways.

No section of the work shall be closed to traffic until so directed by the Engineer. No bridge, culvert or drainage structure shall be closed until an adequate detour has been arranged and constructed.

If, in the opinion of the Engineer, the Contractor does not comply with the above requirements such work as the Engineer may deem necessary for the safety, comfort and convenience of the traveling public may be performed and the charges therefore withheld from any money due or to become due to the Contractor. The Contractor shall not be paid to provide traffic control during delays caused by the Contractor.

The above does not preclude the requirements of the “Harris County General Conditions”.

Providing, installing, moving, replacing, maintaining, cleaning and removing upon completion of work all barricades, signs, barriers, barrels, cones, lights, delineators, pavement markings, and other such devices shall be in accordance with Item 665 “Work Zone Pavement Markings”, Item 670 “Barricades”, Item 696 “Low Profile Concrete Barrier” and Item 698 “Temporary Polyethylene Water-Filled Barrier”. Flagmen shall be furnished, maintained and possess the minimum qualification and requirements stipulated in the TMUTCD. Operation of flagmen shall be as outlined in Item 672 “Flagmen.”
Temporary pavement markings shall be in accordance with Item 665 “Work Zone Pavement Markings”.

Temporary signs and supports shall be made from wood, metal, or other approved materials. Wood for signs shall be minimum 1/2 inch, medium density, outdoor grade plywood. Metal signs shall be in conformance with Item 624 “Aluminum Signs”. Reflectoized sign sheeting shall be in conformance with Item 649 “Wide Angle Prismatic Retroreflective Sheeting for Traffic Control Signs (Diamond Grade).” Signs may be erected on portable, temporary, or fixed supports for use in the work zone. Signs erected on portable supports shall be for daytime use only. All wood supports shall be painted white. Sandbags shall be used where portable or temporary sign supports require the use of weights to prevent a sign assembly from falling over. All signs shall be placed in accordance with the drawings and the TMUTCD.

671.3 Measurement & Payment. Barricades, signs, barriers, barrels, cones, lights, delineators, and other such devices shall be paid for by the month or per each Jobsite, provided the traffic control plan is properly installed and maintained. This includes preparation of an alternative Traffic Control Plan by the Contractor, if any, and approved by the Engineer.

Detours shall be paid for in accordance with Item 673 “Constructing Detours for Maintaining Two-Way Traffic”.

Work Zone Pavement Markings shall be paid for in accordance with Item 665 “Work Zone Pavement Markings”.

Barriers designated as “Low Profile Concrete Barrier” and “Temporary Polyethylene Water-Filled Barrier” shall be paid for in accordance with Items 696 and 698 respectively.

Temporary driveways and the removal of temporary driveways shall be measured and paid for as follows: “Temporary Commercial Driveways per Each” and “Temporary Residential Driveways per Each”. Payment shall include all labor and materials, including shaping, furnishing and hauling necessary to complete the work.

There are line code(s), description(s) and unit(s) for this Item:

NOTE: This Item requires other Standard Specifications.

Item 624 “Aluminum Signs”
Item 649 "Wide Angle Prismatic Retroreflective Sheeting for Traffic Control Signs (Diamond Grade)"
Item 665 “Work Zone Pavement Markings”
Item 670 “Barricades”
Item 672 “Flagmen”
Item 673 “Constructing Detours for Maintaining Two-Way Traffic”
Item 696 “Low Profile Concrete Barrier”
Item 698 “Temporary Polyethylene Water-Filled Barrier”

END OF ITEM 671
ITEM 672

FLAGMEN

672.1 Description. This Item shall govern for the furnishing of flagmen to insure the even flow of traffic through the construction site. The primary function is to move vehicles and pedestrians safely and expeditiously through or around the construction area.

672.2 General Requirements. All flagmen shall possess the minimum qualifications and meet the requirements stipulated in the Texas Manual on Uniform Traffic Control Devices (TMUTCD). The Contractor shall use flagmen for the work associated with the control and safety of all traffic and pedestrian flow throughout the project as shown in the project traffic control plan (TCP), Harris County standard guidelines, the TMUTCD, and as directed by the Engineer.

It is the responsibility of the Contractor to ensure that all flagmen are properly trained in flagging procedures. Flagmen will use paddles, lights, flags, and other equipment which meet the required guidelines and dimensions of the TMUTCD. The STOP/SLOW paddle, which gives drivers more positive guidance than a flag, shall be the primary hand-signaling device. Reusable, removable (temporary) white stop bars should be used to the maximum extent possible and removed when flaggers are not present. Flags should be limited to emergency situations and at low-speed and/or low volume locations that can be best served by a single flagger. The use of an orange vest and cap shall be required for all flagmen. For nighttime conditions, these similar garments shall be reflectorized.

The flagmen are provided at work sites to stop traffic intermittently, as required to protect the Contractor's workmen and equipment, pedestrians and motorists. The flagmen must, at all times, be clearly visible to approaching traffic for a distance sufficient to permit proper response by the motorists to flagging instructions and to permit traffic to reduce speed before entering the work site.

The use of flagmen does not relieve the Contractor of his responsibility to insure proper protection of the public, or of the construction. The Contractor is liable for all damages that occur at the construction site, as a result of accidents with citizens and motorists, even though he has provided flagmen.

All costs for flagmen shall be incidental to the other work.
672.3 Off-Duty Uniformed Local Law Officers. When directed by the Engineer, the Contractor shall use a combination of off-duty uniformed local law officers and flagmen for intersection work and for the implementation of initial traffic control phases or traffic switches (traffic directed to change lanes or stop). When off-duty uniformed local law officers are used, they shall be used in addition to flagmen, not as a substitute for flagmen. The Contractor may at his own expense elect to use off-duty uniformed local law officers when not directed by the Engineer. The Engineer may direct the use of off-duty uniformed local law officers for circumstances which could not have been reasonably anticipated in the planning of the project. The direction may be based upon, but certainly not limited to, one, or all of the following reasons:

A. traffic volume;

B. the nature and location of the work to be accomplished;

C. weather conditions;

D. the safety of the motorists, pedestrians or construction workers.

672.4 Submittal Required. If flagmen are to be used during the project the Contractor shall demonstrate ownership of 2 radios, 2 stop/slow paddles, 2 temporary white stop bars, 2 flags, 2 orange vests and 2 safety caps at the start of the project.

672.5 Measurement and Payment.

Flagmen. Flagmen shall not be paid for directly, but shall be incidental to the other work.

Off-duty Uniformed Peace Officers. Off-duty, uniformed, peace officers shall be paid for by the hour when the use is approved as directed by the Engineer.

The Contractor may at his own expense elect to use off-duty uniformed local peace officers when not directed by the Engineer.

There are line code(s), description(s) and unit(s) for this Item:

END OF ITEM 672
ITEM 673

CONSTRUCTING DETOURS FOR MAINTAINING TWO-WAY TRAFFIC

673.1 Description. This Item shall govern for furnishing and installing materials for the construction, maintenance and removal, if required, of a detour road for maintaining two-way traffic. The location of the detour road shall be as indicated on the drawings.

673.2 Construction Methods. If temporary detours become necessary to maintain two-way traffic, the proposed plan view shall be constructed as shown on the drawings. The proposed detour section shall be constructed in accordance with this Item.

Where the Contractor is required to maintain two-way, two lane traffic at all times during the term of the contract, he/she shall construct a minimum 20 foot wide detour road with minimum 8 inches of black base over a suitably compacted subgrade. All materials shall be in accordance with Item 250 “Hot Mix Asphaltic Concrete Base Course (Black Base).”

The Contractor is required to furnish and install all necessary fill material, temporary drainage structures, pavement markings and signage.

The Contractor shall provide, means of ingress and egress for all residents and businesses along all detours and shall provide the public with a means of access at all times. Temporary access driveways along the detour(s) shall provide an all weather surface and shall be maintained by the Contractor in a condition acceptable to the Engineer.

On the completion of any portion of the permanent paving, which can provide two-way traffic movement, that portion of the detour road and all related materials shall then be milled and delivered to the designated location noted in the bid documents or construction notes. If no designated location is provided in the bid documents or construction notes, it shall be the responsibility of the Contractor to remove and dispose of the materials in compliance with current local, State and Federal Regulations at no additional costs. Drainage structures and fill material used on the detour road may be incorporated in the permanent construction provided no damage has been done to the structures and the fill material meets the requirements of Item 130 "Borrow" and Item 132 "Embankment", or is otherwise approved by the Engineer.

The detour road, while in service, shall be maintained to the satisfaction of the Engineer.
Maintenance shall include, but not be limited to, the repair of all base and surface failures and the furnishing and installing of all additional materials required by the Engineer.

673.3 Measurement. This Item will be measured by square yard units set out in Section 673.4 (below) of this Item.

673.4 Payment. The basis of payment for this Item shall be as follows:

A. The following earthwork items of construction for temporary detours are incidental to the pay item 673:
   1. Roadway Excavation
   2. Borrow
   3. Embankment
   4. Stripping
   5. Subgrade

B. The black base shall be paid for by square yard at the specified depth, complete in place as outlined in this Item. Square yard measurement shall be made at the top of surface area.

C. Unit prices shall include all maintenance costs during the life of the project, and the ultimate removal by:
   1. milling and delivery to a designated location, if salvaging of the detour asphalt is required by the plans, or
   2. removal and disposal of the material if salvaging of the detour asphalt is not required.

D. Temporary drainage structures shall be paid for per each, complete in place, as indicated in the drawings.

E. Temporary concrete or metal pipe shall be paid for by the linear foot regardless of size, including bedding, backfill and removal.

F. Temporary pavement markings shall be paid for by the linear foot, which includes removal.

The unit prices include the maintenance during the life of the project and the ultimate removal.
There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications.

Item 130 "Borrow"
Item 132 "Embankment"
Item 250 "Hot Mix Asphaltic Concrete Base Course (Black Base)"

END OF ITEM 673
ITEM 674

REMOVING PAVEMENT STRIPING AND MARKINGS

674.1 Description. This Item shall govern for the blast cleaning of surface areas for the removal of existing permanent pavement markings and striping (all types including Type I and Type II), and removal of symbols and traffic buttons.

674.2 Material. Blasting medium shall be a quality commercial product capable of producing the specified surface cleanliness without the deposition of deleterious materials on the cleaned surface.

674.3 Equipment. All equipment shall be approved by the Engineer, prior to use and shall be of sufficient capacity to efficiently and economically clean the roadway surface to the specified cleanliness. Equipment shall be power driven and in good operating condition. Equipment shall utilize moisture and oil traps, in working order, of sufficient capacity to remove contaminants from the air and prevent deposition of moisture, oil, or other contaminants on the roadway surface.

674.4 Construction Methods. The blast cleaning shall be performed only on that portion of the roadway surface specified. Widths, lengths and shapes of the blast cleaned surface shall be of sufficient size to include the full area of the specified pavement marking/striping to be removed.

Pavement marking/striping on asphalt pavement shall be removed by water blasting. Cleaning shall be sufficient to remove loose and flaking conditions or markings on the roadway surface.

Blast cleaning of Portland cement concrete surface shall be by light sand blasting and shall be sufficient to remove all old pavement markings/striping and other contaminants.

Overblasting to the extent that it damages the roadway surface shall be held to a minimum. Very small particles of tightly adhering existing markings can remain in place if, in the opinion of the Engineer, complete removal of the small particles will result in pavement surface damage.

Existing pavement markings to be removed by blast cleaning, as specified, shall be removed by blasting to the extent that the pavement marking is either completely removed or obliterated to the satisfaction of the Engineer.
674.5 Measurement. “Removing Pavement Striping and Markings” shall be measured by:

A. Linear Foot - for longitudinal markings.
B. Each - for words, arrows and symbols
C. Square Foot - for non-longitudinal markings (gores, stop bars, crosswalks, etc.)

Removal of incidental raised pavement markers in conjunction with removing paint striping shall be considered incidental to striping removal, otherwise, raised pavement markers and buttons will be measured by each.

Where double stripes are removed, each stripe will be measured separately.

674.6 Payment. The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Removing Pavement Striping and Markings” of the type and width as applicable. This price is full compensation for the elimination method used and materials, equipment, tools, labor, and incidentals.

When existing permanent pavement markings are removed from permanent pavement surfaces and not replaced (i.e., where proposed improvements necessitate realignment of travel lanes, medians, etc., and/or the installation of work zone pavement markings, etc.), measurement and payment for the removal of existing pavement markings shall be paid for in accordance with this Item.

For re-striping projects, measurement and payment for the removal of the existing pavement markings shall be considered subsidiary to the placement of the permanent pavement markings.

There are line code(s), description(s) and unit(s) for this Item:

NOTE: This Item requires other Standard Specifications:

END OF ITEM 674
ITEM 675

TRAFFIC PAINT STRIPING (WATER BASED)

675.1 Description. This Item shall govern for the installation of water based reflectorized traffic paint striping on pavement, where the color and width of line shall be as specified on the drawings.

675.2 Material. Materials shall consist of paint and glass beads. Paint for striping shall conform to the requirements of Item 676 "Traffic Paint (Water Based)".

675.3 Equipment. Equipment used for applying traffic paint shall:

A. Be maintained in satisfactory operating condition

B. Paint striping equipment used to place 4 inch solid or broken lines shall have a capability of an average hourly placement rate of 7,000 linear feet of 4 inch line in any five consecutive working days of seven hours or more. The equipment shall be capable of applying one 4 inch broken line and either one or two solid lines simultaneously.

C. Have production capabilities similar to 4 inch marking equipment and shall be capable of placing linear markings up to 8 inches in width in a single pass when used for placing markings in widths other than 4 inches.

D. Have production capabilities considered satisfactory by the Engineer when used to place markings other than solid or broken lines.

E. Be capable of placing centerline and no-passing barrier line configuration consisting of one broken line and two solid lines at the same time, to the alignment and spacing shown on the drawings.

F. Be capable of placing edge lines and broken lines simultaneously.

G. Be capable of placing lines with clean edges and of uniform cross-section. All lines shall have a tolerance of ±1/8 inch per 4 inch width.

H. The equipment shall be equipped with an automatic cut-off device (with manual operating capabilities) to provide clean square marking ends and to provide a method of applying a broken line with a stripe gap ratio of 15 to 25. The equipment shall be capable
of placing lines of all widths with clean edges and of uniform cross-section. Four inch lines shall be 4 inch ±1/8 inch in width. Eight inch lines shall be 8 inches minimum and 8-1/4 inches maximum in width.

I. The equipment shall provide mixing and agitation of the pavement marking material. The use of pans, aprons, or similar appliances which cause overruns will not be permitted for longitudinal striping applications.

J. The beads shall be applied by means of automatic bead dispenser attached to the pavement marking equipment in such a manner that the beads are dispensed uniformly and almost instantly upon the marking as the marking is being applied to the road surface. The bead dispenser shall have an automatic cut-off control, synchronized with the cut-off of the pavement marking equipment.

675.4 Construction Methods. The Contractor shall use a crew experienced in the work of installing paint striping and in the necessary traffic control for such operations on the roadway surface and shall supply all of the equipment, personnel, traffic control and materials necessary for the placement of paint striping as shown on the drawings, or as directed by the Engineer. All work shall be in accordance with the Latest Edition of the Texas Department of Transportation's "Manual on Uniform Traffic Control Devices".

Paint shall be applied with a minimum thickness of 10 mils, measured in the dry condition, prior to adding any glass reflective spheres, as per Item 676 "Traffic Paint (Water Based)".

Markings may be placed on roadways either free of traffic or open to traffic. On roadways already open to traffic, the markings shall be placed under traffic conditions that exist with a minimum of interference to the operation of the facility. All markings placed under open traffic conditions shall be protected from traffic damage and disfigurement.

The pavement surface to receive the striping shall be thoroughly cleaned of all dirt, organic growth, oil, grease, or other materials that will prevent adhesion of the paint to the roadway surface.

Guides to mark the lateral location of pavement markings shall be established by the Contractor. The Engineer shall verify the location.

Materials used for pilot markings and equipment used to place such markings shall be approved by the Engineer.
The striping shall be placed in the proper alignment with the guides established on the roadway. The deviation rate in alignment shall not exceed 1 inch per 200 feet of roadway. The maximum deviation shall not exceed 2 inches, nor shall any deviation be abrupt.

Markings shall essentially have a uniform cross-section. The density and quality of markings shall be uniform throughout their thickness.

The applied markings shall have no more than five percent, by area, of holes or voids and shall be free of blisters.

Glass beads shall be applied by an automatic bead dispenser attached to the pavement marking equipment in such a manner that the beads are dispensed uniformly and almost instantly upon the marking as the marking is being applied to the road surface. Where two coats of traffic paint is used to achieve the required dry mil thickness, beads shall only be applied to the second coat.

Glass reflective spheres for traffic paint shall be applied in accordance with Item 662 "Glass Reflective Spheres for Traffic Paint". Under no circumstances shall the bead application rate be less than 7 1/2 pounds of beads per gallon of paint applied to the last coat.

675.5 Removal. When construction operations require the alteration of any pavement marking, the Contractor shall provide for the complete removal of any markings to the satisfaction of the Engineer. Removal of the markings shall leave no discernible evidence of the marking having ever been in place. Removal of existing pavement striping and markings shall be in accordance with Item 674 "Removing Pavement Striping and Markings".

675.6 Measurement and Payment. The installation of water-based paint striping shall be paid for under Item 665 “Work Zone Pavement Markings”.

There are no line codes for this Item.

NOTE: This Item requires other Standard Specifications:

Item 662 “Glass Reflective Spheres for Traffic Paint”
Item 665 “Work Zone Pavement Markings”
Item 674 “Removing Pavement Striping and Markings”
Item 676 “Traffic Paint (Water Based)"

END OF ITEM 675
ITEM 676

TRAFFIC PAINT (WATER BASED)

676.1 Description. This Item shall govern for the materials, composition, manufacture and testing of all water based traffic paint and related materials as covered herein.

676.2 Bidders’ Requirements. All prospective bidders are hereby notified that, before any bid is considered, Harris County may require the bidder to submit a statement in detail of the facts as to the previous experience of the bidder in performing similar or comparable work, as to the business and technical organization, financial resources and the manufacturing facilities of the bidder which are to be used in performing the contemplated work. Any bid submitted by a firm with unsatisfactory facilities, resources, equipment or experience may be rejected by Harris County.

676.3 Intent. The coating design specified has been stipulated by means of carefully controlled formulation durability testing methods. The intent of the Harris County Engineering Department is to procure coatings which are identical in all essential respects to the standards of the State Department of Transportation; hereafter referred to as "Standards".

Specifications, codes, accepted practices, etc., not specifically listed in these Standard Specifications are not acceptable.

When required, the paint manufacturer shall supply Labor Form LSB-000S-4, "Material Safety Data Sheet".

676.4 Conformance of Finished Products. Coatings shall conform on a weight basis, to the composition requirements of the standard formula. No variation from the standard formula will be permitted except for replacement of materials lost in processing, or those approved by the Engineer. The finished coatings shall conform with all requirements stipulated for each standard formula and in addition shall equal a Wet Standard in characteristics such as color, drying, flow, settling, brush ability, can stability, hiding, etc.

Film characteristics such as gloss, hardness, light permanency, adhesion, etc., shall also conform. When testing for such conformity, the coating shall be applied and tested under parallel conditions with the Wet Standard.

The finished product shall be free of skins and foreign materials.
676.5 Inspection, Sampling & Testing. All products required to meet these Standard Specifications shall be inspected and tested.

All tests on finished products and raw materials, as well as inspection during manufacture, will be made by an independent licensed testing laboratory and 2 copies of the results shall be furnished to the Engineer, prior to delivery of product.

Contract shall not be considered complete until such copies are received by Harris County.

On material purchased directly by Harris County, the cost of inspection and testing shall be borne by the Contractor and/or supplier. The manufacturer shall be required to reimburse Harris County for the cost of storage and/or handling of paint failing to meet specification requirements.

Samples of raw materials used in production and samples of paint will be taken during production.

Manufacture shall be witnessed in whole or in part, depending upon the discretion of the testing agency. Production shall not begin prior to the arrival of the designated testing agency, unless prior specific approval for such starting has been obtained from the Harris County Engineering Department. The manufacturer shall accord the representatives of the testing agency free access to those parts of the plant wherein the paints are being manufactured or raw materials are being stored and in all other ways shall facilitate the representative of the testing agency in performing his duties. Raw materials and finished coatings, when stored, shall be in an orderly fashion that will permit proper and correct inventory of these materials at all times. Testing shall be done in accordance with the Texas Department of Transportation, "Manual on Testing Procedures". Any questions should be addressed to the Engineer.

676.6 Manufacturing procedures, except when specified, shall be left to the discretion of the Contractor. It is the responsibility of the manufacturer to ascertain that the raw materials and manufacturing procedures he proposes to use will produce a product meeting the specification requirements.

676.7 Shipment shall be made in suitable, strong, well sealed containers which not only meet specifications and federal requirements, but are also sufficiently sturdy to withstand normal handling to which shipments are subjected in transit. Finished coating containers and cases shall be plainly marked and securely labeled with the name and designation of the coating, order number, requisition number, batch number, date of manufacture, gross weight and manufacturer's name. Labeling shall be
on the sides of containers and cases. Labels must be sufficiently moisture resistant to withstand outdoor storage for a minimum of one year. When the finished product is palletized for shipment, the labels shall be on the outside for easy identification. Once the finished product has been labeled properly, the label shall not be modified or changed in any manner without specific approval of the Engineer.

Containers shall be filled by weight based on the actual gallon weight of the paint at 77°F.

676.8 Raw Materials. The exact brands and types of raw materials used in the Wet Standard are listed for the purpose of facilitating the selection. The selection of parallel material equal not only in quality and composition but also in physical and chemical behavior after being used in the finished product. Since evaluation of paint containing questionable materials may require 60 days and since meeting delivery schedules is a responsibility of the paint manufacturer, he is reminded that he should schedule material procurement and paint production to permit him to meet delivery commitments. The final decision as to the equality of materials shall be made by Harris County. After Harris County has agreed to the brand names of raw materials proposed by the Contractor, no substitution will be made during the manufacture, without prior agreement with the Engineer.

The Contractor should be aware that it is his responsibility to select raw materials that not only meet the individual raw material specifications, but will also produce coating conforming to the specific formula requirements.

A. Materials of Foreign Origin. Because of the limited information available on materials manufactured outside the continental limits of the United States, the manufacturer is advised to review Sections 661.5 and 661.8 of Item 661 “Traffic Paint (Solvent Based)”, when considering the use of materials of foreign origin.

B. Materials Required to Meet Federal & ASTM Specifications:

All materials required to meet Federal or ASTM specifications must conform to the Latest Edition of the specifications.

C. PIGMENTS:

1. White

   a. Titanium Dioxide shall meet ASTM D476 “Standard Classification for Dry Pigmentary Titanium Dioxide Products”, Type I or II.
b. Lead Free Zinc Oxide shall meet ASTM D79 "Standard Specification for Zinc Oxide Pigments", either American process or French process.

2. Colored: Titanium Dioxide, Rutile, non-chalking:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>4.05 to 4.15</td>
<td></td>
</tr>
<tr>
<td>Oil Absorption</td>
<td>16 to 20%</td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>0.5% Max.</td>
<td></td>
</tr>
<tr>
<td>Pigment Retained</td>
<td>0.1% Max.</td>
<td></td>
</tr>
<tr>
<td>On No. 325 Sieve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TiO₂ Content</td>
<td>95% Min.</td>
<td></td>
</tr>
<tr>
<td>Fe₂O₃ Content</td>
<td>2.0 to 3.0%</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>6.5 to 7.0</td>
<td></td>
</tr>
<tr>
<td>Ignition Loss</td>
<td>0.35% Max.</td>
<td></td>
</tr>
<tr>
<td>Y (luminosity)</td>
<td>42.5 to 45.5</td>
<td></td>
</tr>
</tbody>
</table>

D. Medium Chrome Yellow

Color and Color Characteristics. The luminance factor of the pigment shall be within the limits listed below when tested before and after exposure.

<table>
<thead>
<tr>
<th></th>
<th>MIN.</th>
<th>MAX.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>53</td>
<td>59</td>
</tr>
<tr>
<td>Final</td>
<td>45</td>
<td></td>
</tr>
</tbody>
</table>

In addition, the allowable change between the initial and final luminance factors shall be no more than 9 units. The initial and final CIE Chromaticity Color coordinates of the pigment shall be within the rectangle defined by the sets of coordinates (0.490, 0.455), (0.511, 0.433), (0.514, 0.480), and (0.535, 0.488).

Method of Test: The pigment shall be tested in accordance with TxDOT’s Test Procedure Tex-810-B, two coats.

The formulation for the test enamel using the pigment to be tested is as follows:

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>PARTS BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium Chrome Yellow</td>
<td>600</td>
</tr>
</tbody>
</table>
1. Traffic Alkyd Resin Solution shall meet the requirements of the part of this specification titled "Traffic Alkyd Resin Solution" of this specification.

2. The amount of Mineral Spirits may be varied slightly to produce the desired grinding consistency.

3. Extenders
   a. Calcium Carbonate

<table>
<thead>
<tr>
<th>Material</th>
<th>Parts by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaCO₃</td>
<td>97.0% Min.</td>
</tr>
<tr>
<td>H₂O</td>
<td>0.4% Max.</td>
</tr>
<tr>
<td>Density</td>
<td>2.6302 to 2.7299</td>
</tr>
<tr>
<td>Weight Retained on No. 325 Sieve</td>
<td>0.75% Max.</td>
</tr>
</tbody>
</table>

   Color: Equal to material listed in Standard Formula. Substitution in a Standard Formula shall not result in a viscosity variation greater than 5 KV.


   c. Silica

<table>
<thead>
<tr>
<th>Material</th>
<th>Parts by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>99.5% Min.</td>
</tr>
<tr>
<td>H₂O</td>
<td>0.05% Max.</td>
</tr>
<tr>
<td>Density</td>
<td>2.5810 to 2.7011</td>
</tr>
<tr>
<td>Oil Absorption</td>
<td>25 lbs./100 lbs. Max.</td>
</tr>
<tr>
<td>ASTM D281 Weight Retained on No. 325 Sieve</td>
<td>1.0% Max.</td>
</tr>
</tbody>
</table>
E. Resins

Acrylic Traffic Resin shall be similar and equal to the standard sample approved by the Texas Department of Transportation.

<table>
<thead>
<tr>
<th>Solid Contents, Percent</th>
<th>60.0 - 62.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity, #3 Spindle 60 RPM, cps</td>
<td>840 - 860</td>
</tr>
<tr>
<td>pH</td>
<td>8.8 - 9.0</td>
</tr>
<tr>
<td>Density, 25°C</td>
<td>1.066 to 1.078</td>
</tr>
</tbody>
</table>

In addition to the above requirements, the infrared spectrum and gel permeation chromatogram shall match the standard spectrum and chromatogram on file with the Texas Department of Transportation.

F. Miscellaneous Materials

1. Water, Potable

2. Methyl Alcohol, ASTM D1152 “Standard Specification for Methanol (Methyl Alcohol)” with Refractive Index 1, 3320 Max.

3. Diethylene Glycol Monobutyl Ether, Glycol Ether DB

<table>
<thead>
<tr>
<th>Boiling Range, °C</th>
<th>228 to 234</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash Point, °C, COC</td>
<td>115 Min.</td>
</tr>
<tr>
<td>Density, 25°C</td>
<td>0.948 to 0.953</td>
</tr>
<tr>
<td>Refractive Index, 20°C</td>
<td>1.4314 to 1.418</td>
</tr>
<tr>
<td>Color</td>
<td>Water, White</td>
</tr>
<tr>
<td>Appearance</td>
<td>Clear, Sediment Free</td>
</tr>
<tr>
<td>Refractive Index</td>
<td>1.4290 Min.</td>
</tr>
</tbody>
</table>

4. Anti-Skinning Agent

5. Dispersant-Byk 156, Byk Chemie

6. Surfacant-Triton CF-10, Union Carbide

7. Defoamer
8. Hydroxy Ethyl Cellulose - Natrasol 250 LR, Aqualon
9. Attapulgate Clay - Attagel 50, Eulehard
10. Preservative

<table>
<thead>
<tr>
<th>WPT-10, WHITE WATER BASED TRAFFIC PAINT</th>
<th>POUNDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic Emulsion, 60% Solids, Rhom &amp; Haas, TP-257</td>
<td>460</td>
</tr>
<tr>
<td>Coalescent, Glycol Ether DB</td>
<td>20</td>
</tr>
<tr>
<td>Coalescent, Exxon, Exxate 800</td>
<td>10</td>
</tr>
<tr>
<td>Titanium Dioxide, Rutile Type II</td>
<td>150</td>
</tr>
<tr>
<td>Silica</td>
<td>125</td>
</tr>
<tr>
<td>Calcium Carbonate, JM Huber, Hubercarb M-4</td>
<td>400</td>
</tr>
<tr>
<td>Attapulgate Clay, Engelhard, Attagel 50</td>
<td>4</td>
</tr>
<tr>
<td>Hydroxy Ethyl Cellulose, Aqualon, Natrosol, 250 LR</td>
<td>2</td>
</tr>
<tr>
<td>Defoamer</td>
<td>4</td>
</tr>
<tr>
<td>Dispersant, Byk Chemie, Byk 156</td>
<td>6</td>
</tr>
<tr>
<td>Surfactant, Union Carbide, Triton CF-10</td>
<td>2</td>
</tr>
<tr>
<td>Methyl Alcohol</td>
<td>20</td>
</tr>
<tr>
<td>Preservative</td>
<td>3-7</td>
</tr>
<tr>
<td>Water, Potable</td>
<td>90</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,300</strong></td>
</tr>
</tbody>
</table>

Density: ±0.05 Kg of theoretical density
Grind: 4 Min Particles: 8 Max (TxDOT’s Test Procedure Tex-806-B)
Viscosity: 80-100 KV
Skinning: No skinning within 48 hours (TxDOT’s Test Procedure Tex-811-B)

<table>
<thead>
<tr>
<th>YPT-10, YELLOW WATER BASED TRAFFIC PAINT</th>
<th>POUNDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic Emulsion, 60% Solids, Rhom &amp; Haas, TP-257</td>
<td>460</td>
</tr>
<tr>
<td>Coalescent, Glycol Ether DB</td>
<td>20</td>
</tr>
<tr>
<td>Coalescent, Exxon, Exxate 800</td>
<td>10</td>
</tr>
</tbody>
</table>
### YPT-10, YELLOW WATER BASED TRAFFIC PAINT

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium Chrome Yellow, Cookson Y-969-L</td>
<td>125</td>
</tr>
<tr>
<td>Titanium Dioxide, Rutile Special</td>
<td>25</td>
</tr>
<tr>
<td>Silica</td>
<td>125</td>
</tr>
<tr>
<td>Calcium Carbonate, JM Huber, Hubercarb M-4</td>
<td>430</td>
</tr>
<tr>
<td>Attapulgate Clay, Eugelhard, Attagel 50</td>
<td>4</td>
</tr>
<tr>
<td>Hydroxy Ethyl Cellulose, Aqualon, Natrosol, 250 LR</td>
<td>2</td>
</tr>
<tr>
<td>Defoamer</td>
<td>4</td>
</tr>
<tr>
<td>Dispersant, Byk Chemie, Byk 156</td>
<td>6</td>
</tr>
<tr>
<td>Surfactant, Union Carbide, Triton CF-10</td>
<td>2</td>
</tr>
<tr>
<td>Methyl Alcohol</td>
<td>20</td>
</tr>
<tr>
<td>Preservative</td>
<td>5</td>
</tr>
<tr>
<td>Water, Potable</td>
<td>90</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,328</strong></td>
</tr>
</tbody>
</table>

**Gallon Weight:** ±0.10 lb. of theoretical gallon weight  
**Grind:** 4 Min Particles: 8 Max (TxDOT’s Test Procedure Tex-806-B)  
**Viscosity:** 80-100 KV  
**Skinning:** No skinning within 48 hours (TxDOT’s Test Procedure Tex-811-B)

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676.9  
Construction Methods. All traffic paint applications shall meet the following requirements, and shall be applied in accordance with the Item 675 "Traffic Paint Striping (Water Based)."

- **A.** Traffic paint shall be applied with a minimum thickness of 10 mils, measured in dry condition, prior to adding any glass reflective spheres.

- **B.** The paint shall be transported to the job site in five gallon unopened containers. No thinning of the paint is allowed after the paint is received from the manufacturer. Paint striping shall be applied when the air temperature is 45°F., and rising.

- **C.** Paint striping shall be applied and measured to ±1/4 inch of the specified widths.

Paint thinner can only be used to flush the pumps. The flushing liquid is not to go through the spray nozzles and onto the roadway.
All traffic paint striping not meeting these requirements shall be "touched up" and/or completely restriped to these standards and in accordance with the drawings at no additional cost to Harris County.

Where traffic buttons exist, the paint shall be applied to the pavement adjacent to, but not on the buttons or markers, unless another method is specified.

Word and symbol markings on pavement shall be in accordance with “Pavement Word and Symbol Markings” section of the Latest Edition of the Texas Manual on Uniform Traffic Control Devices of the Texas Department of Transportation.

Prior to beginning work, the Contractor shall furnish mill certificates, from the paint manufacturer, indicating in detail that the paint meets the requirements of this Item. As stated, Harris County retains the option to test this material to determine if it meets the requirements of this Item. The tests shall be paid for by the Contractor.

676.10 Testing. When required, the Contractor shall pay for and provide to Harris County, a testing report performed by a local testing laboratory designated by the Engineer. The report shall verify that the raw and finished materials, to be supplied under this contract, meet the requirements of this Item. These tests shall be paid for by the Contractor. One set of tests shall be made on each batch of paint.

676.11 Rejection. Materials and finished products which fail to meet any or all requirements of these Standard Specifications shall be subject to rejection. All materials and finished products rejected by the Engineer, whether in containers or applied to the roadway surface, shall be removed from the job site and replaced with materials meeting specifications and requirements and all costs of such removal and replacement shall be borne by the Contractor.

676.12 Measurement & Payment. Payment for this material shall be in accordance with the conditions prescribed in the contract awarded by Harris County and as shown on the bid items, or payment shall not be made directly but will be considered subsidiary to the furnishing and application of white or colored water based traffic paint, as specified.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications
Item 676

FOR PROJECTS INITIATED
AFTER MARCH 1, 2012
REVISION 2

Item 661 “Traffic Paint (Solvent Base)”
Item 675 “Traffic Paint Striping (Water Base)"

END OF ITEM 676
ITEM 677

ELECTRICAL CONDUITS FOR TRAFFIC SIGNAL INSTALLATION

677.1 Description. This Item shall govern for furnishing and installing of electrical conduits and fittings for traffic signal post or pedestal bases. Unless otherwise shown on the drawings, all conductors shall be in conduit except when in metal poles. All conduits and fittings shall be of the sizes and types shown on the drawings. Each section of conduit shall bear evidence of approval of Underwriter's Laboratories.

The Contractor may, at his own expense, use conduit of larger size than specified on the drawings providing that the larger size is used for the entire length of the conduit run.

Conduit terminating in posts or pedestal bases shall extend vertically approximately 2 inches above the concrete foundation. Field bends in rigid metal conduit shall have a minimum radius of 12 diameters of the nominal size of the conduit.

677.2 Installation. Each length of galvanized rigid metal conduit, where used, shall be reamed and threaded on each end and couplings shall be made up tight. White-lead paint or equal shall be used on threads of all joints.

PVC conduit shall be joined by solvent-weld method in accordance with the conduit manufacturer's recommendation. No reducer couplings shall be used unless specifically indicated on the drawings.

All conduits and fittings shall have the burrs and rough places smoothed and shall be clean and free of obstructions before the cable is installed. Ends of the conduits shall be capped or plugged until installation of cable.

Upon request of the Engineer, the Contractor shall draw a full-time metal brush, attached by swivel joint to a pull tape through "metal conduit" and a special template having a diameter not less than 75 percent of the inside diameter through PVC conduits to insure that the conduit is clean and free from obstructions. A nylon or non-metal pull tape shall be used in pulling cable and conductors through PVC conduit. Metal tapes will not be permitted in PVC conduit. The conduits shall be placed as shown on the drawings or as directed by the Engineer.

Unless otherwise shown on the drawings or directed by the Engineer, conduit placed in an open trench shall be placed at least 24 inches deep.
Conduit placed for concrete encasement shall be secured and supported in such a manner that the alignment will not be disturbed during placement of the concrete. No concrete shall be placed until all of the conduit ends have been capped and all box openings closed.

PVC conduit which is placed under existing pavement, sidewalks, and driveways shall be placed by first providing a void through which the PVC conduit shall be inserted. The void may be accomplished by either boring or jacking a mandrel. Metal conduit which is to be placed under existing pavement, sidewalks, and driveways shall be placed by jacking or boring (no boring or pushing will be allowed for conduits less than 1-1/2” in diameter).

Existing conduit which has been placed in position on the job site by others for this installation shall be checked to see that there are no obstructions in the conduit prior to threading the wire through. Any such obstructions shall be cleared without damage to the conduit, prior to installing cable.

Conduit runs shall be installed in such a manner as to minimize the accumulation of moisture at low points and pockets.

The component parts of conduit systems shall, in general, be of like material. Where dissimilar metals are used together, suitable provisions shall be made to prevent galvanic action.

The ends of all conduit runs shall be closed immediately after installation to prevent the accumulation of water, dirt and other foreign material. Conduit shall be swabbed out where necessary before conductors are pulled in. Bends may be either factory or field made.

677.3 Materials.

A. Rigid Steel Conduit. When rigid metal galvanized conduits are specified or shown on the drawings, all conduits, including elbows, couplings and nipples, shall be standard weight schedule 40 zinc-coated steel rigid threaded conduit (Hot-Dip Galvanized), with the following requirements:

<table>
<thead>
<tr>
<th>NOM. SIZE (Inches)</th>
<th>EXTERNAL DIAMETER (Inches)</th>
<th>INTERNAL DIAMETER (Inches)</th>
<th>WALL THICKNESS (Inches)</th>
<th>THREADS PER INCH</th>
<th>FEET/BUNDLE</th>
<th>WEIGHT (lbs./100’)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>0.840</td>
<td>0.622</td>
<td>0.109</td>
<td>14</td>
<td>50</td>
<td>79</td>
</tr>
<tr>
<td>3/4</td>
<td>1.050</td>
<td>0.824</td>
<td>0.113</td>
<td>14</td>
<td>50</td>
<td>105</td>
</tr>
</tbody>
</table>
### PVC Conduit

When polyvinyl chloride conduits are specified or shown on the drawings, all conduits, including elbows, couplings, and nipples shall be a minimum of schedule 40 PVC conduit, with the following requirements:

<table>
<thead>
<tr>
<th>NOM. SIZE (Inches)</th>
<th>EXTERNAL DIAMETER (Inches)</th>
<th>INTERNAL DIAMETER (Inches)</th>
<th>WALL THICKNESS (Inches)</th>
<th>WEIGHT (lbs./100')</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>0.840</td>
<td>0.622</td>
<td>0.109</td>
<td>16</td>
</tr>
<tr>
<td>3/4</td>
<td>1.050</td>
<td>0.824</td>
<td>0.113</td>
<td>21</td>
</tr>
<tr>
<td>1</td>
<td>1.315</td>
<td>1.049</td>
<td>0.133</td>
<td>31</td>
</tr>
<tr>
<td>1-1/4</td>
<td>1.660</td>
<td>1.380</td>
<td>0.140</td>
<td>42</td>
</tr>
<tr>
<td>1-1/2</td>
<td>1.900</td>
<td>1.610</td>
<td>0.145</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>2.375</td>
<td>2.067</td>
<td>0.154</td>
<td>67</td>
</tr>
<tr>
<td>2-1/2</td>
<td>2.875</td>
<td>2.469</td>
<td>0.203</td>
<td>107</td>
</tr>
<tr>
<td>3</td>
<td>3.500</td>
<td>3.068</td>
<td>0.216</td>
<td>140</td>
</tr>
<tr>
<td>3-1/2</td>
<td>4.000</td>
<td>3.548</td>
<td>0.226</td>
<td>169</td>
</tr>
<tr>
<td>4</td>
<td>4.500</td>
<td>4.026</td>
<td>0.237</td>
<td>199</td>
</tr>
</tbody>
</table>
677.4 Measurement and Payment. Electrical Conduit for the Traffic Signal Installation shall not be paid for directly, but shall be incidental to other work.

There are no line codes for this Item.

END OF ITEM 677
ITEM 678

ZINC COATED STEEL WIRE STRAND

678.1 Description. This Item shall govern for zinc coated steel wire strand for use as messengers for supporting aerial cable, signaling equipment and for guying of overhead poles.

678.2 Material. The material covered by this Item shall be strand composed of round zinc coated steel wires of characteristics necessary to produce a finished product which will meet all of the requirements of this Item. All wires of the strand shall be of the same quality.

678.3 Zinc. The zinc used for the coating shall be of any grade of zinc conforming to ASTM B6 “Standard Specification for Zinc”.

678.4 Weight and Uniformity of Coating. The wires from the finished strand shall have a weight of zinc coating and a uniformity of zinc coating not less than the values in Table 1.

The weight of coating shall be tested by the Stripping Method in accordance with ASTM A90 “Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.”

678.5 Uniformity of Coating. The uniformity of the zinc coating shall be determined by the Preece Test as described in the Standard Method of Test for Uniformity of Coating by the Preece Test (Copper Sulphate Dip) on Zinc Coated (galvanized) Iron or Steel Articles (ASTM A239, “Standard Practice for Locating the Thinnest Spot in a Zinc (Galvanized) Coating on Iron or Steel Articles”). This test shall not be used to determine the weight of the coating and shall be applied only after the coating has been found to conform to the minimum weight of coating requirement.

678.6 Diameter. Sizes of wire shall be expressed by the diameter in decimal fractions of an inch.

678.7 Pitch and Lay. The pitch of the strand shall not be less than 10 or more than 16 times the outside diameter of the strand for 3 wire strand. On 7 wire strand the pitch of the strand shall be not less than 12 or more than 16 times the outside diameter of the strand. Left lay strand shall be furnished unless otherwise specified on the Purchase Order. Stranding shall be sufficiently close to insure no appreciable reduction in diameter when stressed 10% of specified strength.
678.8  Preformed Strand. Preformed strand shall be supplied when so specified by the purchaser. Strand is preformed when the component wires are set to the helical form that they assume in the product by any means or process other than by merely laying them about the strand core.

678.9  Joints. There shall be no strand joints or strand splices in any length of complete strand. Joints in individual wires in their finished size shall be either the brazed type or electric butt welded type. When the brazed type of joint is used, the length of the lap shall be not less than three times the diameter of the wire and the overlapping faces shall be smooth, clean and properly fluxed, and completely covered with brazing metal. When the electric welded type of joint is used, care shall be taken to prevent injury to the wire by reason of overheating. All joints shall be made well, and shall be coated with zinc after completion.

In three wire strand there shall be no joints in individual wires. In seven wire strand, joints in individual wires shall be acceptable provided there is no more than one joint in any 150 foot section of the completed strand.

678.10 Properties. The finished zinc coated strand shall have characteristics and properties in accordance with the requirements of Table 2.

678.11 Breaking Strength and Elongation. The breaking strength and elongation tests shall be made on 24 inch samples which do not contain wire joints. The elongation shall be determined by the increase in separation between the jaws of the testing machine at the initial failure in the test specimen. The separation of the jaws of the testing machine shall be approximately 2 feet when under a load equal to 10 percent of the required minimum breaking strength of the strand. The elongation values shall be recorded only for specimens which break over one inch from the jaws of the testing machine.

678.12 Ductility of Steel. The individual wires of the completed strand shall not fracture when wrapped in a close helix at least twice around the cylindrical mandrel at the rate of not more than fifteen turns per minute. The mandrel in terms of the diameter of the individual wire shall be as given in Table 2.

678.13 Adherence of Coating. The zinc coating shall adhere to the wire without flaking and without being removable by rubbing with the bare fingers after the individual wires have been wrapped in a close helix at least twice at the rate of not more than fifteen turns per minute around a cylindrical mandrel with a diameter equal to three times the nominal diameter of the wires of the strand.

678.14 Workmanship and Finish. The zinc coated wire shall be uniform in diameter and shall be free from splints, scales, inequalities, flaws and
other imperfections not consistent with good commercial practice. The zinc coating shall be smooth and continuous.

678.15 Sampling, Inspection and Acceptance. Where the lot consists of 25,000 feet or less of strand, two samples for mechanical tests shall be taken from separate reels or coils in the lab except where the total amount of strand is 5,000 feet or less, when only one sample shall be required.

If the lot consists of more than 25,000 feet, one sample shall be taken from every 15,000 feet or fraction thereof, but in no case less than three samples for any size of strand.

The Contractor shall furnish a certified report of the test made on the cable to show compliance with this Item.

Each coil or reel which fails to meet this Item may be rejected.

In case there is a reasonable doubt in the first trial as to the failure of the wire or strand to meet any requirements of these Standard Specifications, two additional tests shall be made on samples of wire or strand from the same coil or reel, and if failure occurs in either of these tests, the strand shall be rejected.

Inspection and tests shall be in accordance with Section 14 of I.M.S.A. Specification No. 1-1950, Latest Edition.

**TABLE 1**

DIMENSIONS, WEIGHT OF COATING, UNIFORMITY OF COATING OF ZINC COATED STEEL WIRES

<table>
<thead>
<tr>
<th>NOMINAL DIAMETER OF WIRE (Inches)</th>
<th>MINIMUM WEIGHT OF COATING PER SQUARE FOOT OF UNCOATED WIRE (Ounces)</th>
<th>UNIFORMITY OF COATING (MIN. # OF DIPS PREECE TEST)</th>
<th>PERMISSIBLE VARIATION IN DIAMETER OF COATED WIRE (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.062</td>
<td>0.50</td>
<td>2-1/2</td>
<td>0.003</td>
</tr>
<tr>
<td>0.072</td>
<td>0.50</td>
<td>2-1/2</td>
<td>0.003</td>
</tr>
<tr>
<td>0.080</td>
<td>0.60</td>
<td>3</td>
<td>0.003</td>
</tr>
<tr>
<td>0.093</td>
<td>0.70</td>
<td>3</td>
<td>0.004</td>
</tr>
<tr>
<td>0.100</td>
<td>0.70</td>
<td>3</td>
<td>0.004</td>
</tr>
<tr>
<td>0.104</td>
<td>0.80</td>
<td>4</td>
<td>0.004</td>
</tr>
</tbody>
</table>
### TABLE 2

**PHYSICAL PROPERTIES OF ZINC COATED STEEL WIRE STRAND**

<table>
<thead>
<tr>
<th>NOMINAL DIAMETER OF STRAND (Inches)</th>
<th>NOMINAL DIAMETER COATED WIRES IN STRAND (lbs./1000 ft.)</th>
<th>APPROX. WEIGHT OF STRAND (lbs.)</th>
<th>MINIMUM BREAK STRENGTH OF STRAND (Percent)</th>
<th>MINIMUM ELONGATION 24&quot; DIAMETER</th>
<th>DUCTILITY OF STEEL MANDREL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7 Wire Strand (Siemens Martin)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/16</td>
<td>0.062</td>
<td>72.9</td>
<td>1,900</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>1/4</td>
<td>0.080</td>
<td>121</td>
<td>3,150</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9/32</td>
<td>0.093</td>
<td>164</td>
<td>4,250</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>5/16</td>
<td>0.104</td>
<td>205</td>
<td>5,350</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td><strong>7 Wire Strand (High Strength)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/16</td>
<td>0.109</td>
<td>225</td>
<td>8,000</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>3/8</td>
<td>0.120</td>
<td>273</td>
<td>10,800</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>7/16</td>
<td>0.143</td>
<td>399</td>
<td>14,500</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>1/2</td>
<td>0.165</td>
<td>517</td>
<td>18,800</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td><strong>7 Wire Strand (Extra High Strength)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/16</td>
<td>0.104</td>
<td>205</td>
<td>11,200</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>3/8</td>
<td>0.120</td>
<td>273</td>
<td>15,400</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>
### 678.16 Measurement and Payment

Zinc Coated Steel Wire shall not be paid for directly, but shall be incidental to other work.

There are no line codes for this Item.

---

<table>
<thead>
<tr>
<th>NOMINAL DIAMETER OF STRAND (Inches)</th>
<th>NOMINAL DIAMETER COATED WIRES IN STRAND (lbs./1000 ft.)</th>
<th>APPROX. WEIGHT OF STRAND (lbs.)</th>
<th>MINIMUM BREAK STRENGTH OF STRAND (Percent)</th>
<th>MINIMUM ELONGATION 24” DIAMETER</th>
<th>DUCTILITY OF STEEL MANDREL</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/16</td>
<td>0.145</td>
<td>399</td>
<td>20,800</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>1/2</td>
<td>0.165</td>
<td>517</td>
<td>26,900</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>3 Wire Strand (High Strength)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/4*</td>
<td>0.120</td>
<td>116.7</td>
<td>2,979</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1/4</td>
<td>0.120</td>
<td>116.7</td>
<td>4,629</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>5/16</td>
<td>0.145</td>
<td>170.6</td>
<td>6,214</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>3/8</td>
<td>0.165</td>
<td>220.3</td>
<td>8,057</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

* Siemens Martin

**NOTE:** Minimum requirements of any strand sizes and grades not shown above will conform to A.I.S.I. Standards, Latest Edition.
ITEM 679

INSULATED JACKETED TRAFFIC SIGNAL CABLE

679.1 Description. This Item shall govern for polyvinyl chloride compound jacketed polyethylene insulated cables, rated 600 volts, for use in signal systems in underground conduit, as aerial cable supported by a messenger, or for installation in buildings.

679.2 General Construction. Cable under this Item shall be composed of uncoated copper conductors individually insulated with heat stabilized polyethylene. The insulated conductors shall be laid up in a compact cable form and bound with suitable tape. The cable core shall be enclosed in a polyvinyl chloride compound jacket.

679.3 Conductors. The copper conductors shall, before insulating, conform to the requirements of ASTM B3 “Standard Specification for Soft or Annealed Copper Wire.”

The conductors shall be stranded unless otherwise specified by the purchaser.

The number and size of the conductors shall be as specified by the purchaser, or sized according to the load per the National Electrical Code.

679.4 Insulation. The insulating compound before application to the conductors shall be heat stabilized polyethylene conforming to the requirements of ASTM D1248 “Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable”, 63T, Type 1, Class B, Grade 4. The insulation shall be applied concentrically about the conductor. Insulation after the application to the conductors shall meet the following requirements when tested in accordance with the procedures given in ASTM D1351 “Standard Specification for Thermoplastic Polyethylene Insulation for Electrical Wire and Cable” and ASTM D470 “Standard Test Methods for Crosslinked Insulations and Jackets for Wire and Cable.”

<table>
<thead>
<tr>
<th>PHYSICAL PROPERTIES OF POLYETHYLENE INSULATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>INITIAL PROPERTIES</td>
</tr>
<tr>
<td>Tensile Strength</td>
</tr>
<tr>
<td>Elongation at Rupture</td>
</tr>
<tr>
<td>AFTER 48 HOURS IN AIR OVEN AT 100° C</td>
</tr>
<tr>
<td>Tensile Strength</td>
</tr>
</tbody>
</table>
The nominal thickness of the insulation shall not be less than that specified in Table 1. The minimum thickness of the insulation shall be not less than 90 percent of the nominal value.

Moisture Absorption.

A. After a twenty-four hour immersion in tap water at 50º C. plus or minus 1º C., the specific inductive capacity of the insulation shall be not more than 2.5. After a continued fourteen day immersion, the specific inductive capacity shall be not more than 1.5 percent higher than the value determined at the end of the first day, nor more than 1.0 percent higher than at the end of the seventh day.

B. The moisture absorption tests shall be conducted in accordance with methods specified in IPCEA-S-61-402, NEMA WC5, Latest Edition.

Electrical Properties.

A. Dielectric Strength. Each processed length of insulated conductor before cabling shall withstand the test voltage specified in Table 1 for a period of 5 minutes after immersion in water for not less than 6 hours and while still immersed.

B. Insulation Resistance. Each processed length of insulated conductor, after withstanding the Dielectric Strength Test, and while still immersed, shall comply with the insulation resistance requirements of Table 1.

C. The Dielectric Strength and Insulation Resistance Tests shall be conducted in accordance with the requirements of ASTM D470.

**TABLE 1**

**INSULATION RESISTANCE**

<table>
<thead>
<tr>
<th>CONDUCTOR SIZE AWG</th>
<th>INSULATION THICKNESS (Inch)</th>
<th>TEST VOLTAGE</th>
<th>INSULATION RESISTANCE AT 60°F. (Megohms-1,000 ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.025</td>
<td>2,500</td>
<td>15,000</td>
</tr>
<tr>
<td>CONDUCTOR SIZE AWG</td>
<td>INSULATION THICKNESS (Inch)</td>
<td>TEST VOLTAGE</td>
<td>INSULATION RESISTANCE AT 60°F. (Megohms-1,000 ft.)</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------------------</td>
<td>--------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>19</td>
<td>0.025</td>
<td>2,500</td>
<td>15,000</td>
</tr>
<tr>
<td>18</td>
<td>0.025</td>
<td>2,500</td>
<td>15,000</td>
</tr>
<tr>
<td>17</td>
<td>0.025</td>
<td>2,500</td>
<td>15,000</td>
</tr>
<tr>
<td>16</td>
<td>0.025</td>
<td>2,500</td>
<td>14,800</td>
</tr>
<tr>
<td>15</td>
<td>0.025</td>
<td>2,500</td>
<td>13,700</td>
</tr>
<tr>
<td>14</td>
<td>0.025</td>
<td>2,500</td>
<td>12,600</td>
</tr>
<tr>
<td>13</td>
<td>0.030</td>
<td>3,000</td>
<td>13,200</td>
</tr>
<tr>
<td>12</td>
<td>0.030</td>
<td>3,000</td>
<td>12,100</td>
</tr>
<tr>
<td>11</td>
<td>0.030</td>
<td>3,000</td>
<td>11,000</td>
</tr>
<tr>
<td>10</td>
<td>0.030</td>
<td>3,000</td>
<td>10,100</td>
</tr>
<tr>
<td>9</td>
<td>0.030</td>
<td>3,000</td>
<td>9,200</td>
</tr>
<tr>
<td>8</td>
<td>0.030</td>
<td>3,000</td>
<td>8,300</td>
</tr>
</tbody>
</table>

Conductor Color Coding. Standard color coding for cable shall be in accordance with Table 2. When permitted by the purchaser, the conductor coding may be numerals and words printed on the conductor insulation. Base colors shall be obtained by the use of colored insulation. Tracers shall be colored stripes or bands which are part of, or firmly adhered to, the surface of the insulation in such a manner as to afford distinctive circuit coding throughout the length of each wire. Tracers may be in continuous or broken lines, such as a series of dots or dashes, and shall be applied longitudinally, annularly, spirally, or in other distinctive patterns.

TABLE 2

CONDUCTORS COLORS AND SEQUENCE

<table>
<thead>
<tr>
<th>CONDUCTOR NUMBER</th>
<th>BASE COLOR</th>
<th>FIRST TRACER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Black</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>White</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Red</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Green</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Orange</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Blue</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>White</td>
<td>Black</td>
</tr>
<tr>
<td>CONDUCTOR NUMBER</td>
<td>BASE COLOR</td>
<td>FIRST TRACER</td>
</tr>
<tr>
<td>------------------</td>
<td>------------</td>
<td>--------------</td>
</tr>
<tr>
<td>8</td>
<td>Red</td>
<td>Black</td>
</tr>
<tr>
<td>9</td>
<td>Green</td>
<td>Black</td>
</tr>
<tr>
<td>10</td>
<td>Orange</td>
<td>Black</td>
</tr>
<tr>
<td>11</td>
<td>Blue</td>
<td>Black</td>
</tr>
<tr>
<td>12</td>
<td>Black</td>
<td>White</td>
</tr>
<tr>
<td>13</td>
<td>Red</td>
<td>White</td>
</tr>
<tr>
<td>14</td>
<td>Green</td>
<td>White</td>
</tr>
<tr>
<td>15</td>
<td>Blue</td>
<td>White</td>
</tr>
<tr>
<td>16</td>
<td>Black</td>
<td>Red</td>
</tr>
<tr>
<td>17</td>
<td>White</td>
<td>Red</td>
</tr>
<tr>
<td>18</td>
<td>Orange</td>
<td>Red</td>
</tr>
<tr>
<td>19</td>
<td>Blue</td>
<td>Red</td>
</tr>
<tr>
<td>20</td>
<td>Red</td>
<td>Green</td>
</tr>
<tr>
<td>21</td>
<td>Orange</td>
<td>Green</td>
</tr>
</tbody>
</table>

The color sequence may be repeated as necessary. Color code sequence applies when cable is composed of mixed sizes.

Special color coding, when specified in unpaired conductor cables, shall consist of black for all conductors except that one conductor shall be identifiable conductor in each layer.

For combination cables consisting of pairs with single conductors, color code sequence given in Table 2, Specification No. 19 - 2 shall be used for pairs, repeated as necessary.

679.5 Conductor Assembly.

A. Two Conductor Cable. Two conductor cables shall have a maximum length of lay not more than 30 times the insulated conductor diameters.

Two conductor cables shall be of the round, twisted type.

Fillers shall be used where necessary to form a two conductor round twisted cable.

B. Multi-Conductor Cables Having More Than Two Conductors. In multi-conductor cables having more than two conductors, the single
conductors shall be laid up symmetrically in layers with lay not exceeding the following:

<table>
<thead>
<tr>
<th>NUMBER OF CONDUCTORS IN CABLE</th>
<th>MAXIMUM LENGTH OF LAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>35 times insulated conductor diameter</td>
</tr>
<tr>
<td>4</td>
<td>40 times insulated conductor diameter</td>
</tr>
<tr>
<td>5 or more</td>
<td>15 times assembled core diameter</td>
</tr>
</tbody>
</table>

Each layer of conductors in the cable shall be laid in a direction opposite to that of adjacent layers. When permitted by the purchaser, uni-directional lay may be used. The outer layer shall be left hand lay.

Fillers shall be used, where necessary, to secure a uniform assembly of conductors of a firm, compact cylindrical core.

679.6 Fillers. Fillers, when used, shall be of a non-metallic moisture-resistant material which shall have no injurious effect upon the component parts of the cable.

679.7 Identification. Each shipping length of cable shall have a tape showing the name of the manufacturer and the year in which the cable is manufactured, placed over or under the tape covering the conductor assembly before the application of outer coverings. As an alternative method of identification, the above information may be applied to the outer surface of the jacket.

679.8 Cable Tape. The conductor assembly shall be covered with a spiral wrapping of a moisture resistant tape applied so as to lap at least 10 percent of its width.

679.9 Jacket. Over the taped conductor assembly there shall be applied a tightly fitting polyvinyl chloride compound jacket which shall meet the following requirements when tested in accordance with ASTM D1047 “Standard Specification for Poly(Vinyl Chloride) Jacket for Wire and Cable.”

**PHYSICAL PROPERTIES OF POLYVINYL CHLORIDE JACKET**

<table>
<thead>
<tr>
<th>INITIAL PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength</td>
</tr>
<tr>
<td>Elongation at Rupture</td>
</tr>
</tbody>
</table>
AFTER 5 DAYS IN AIR OVEN AT 100° C

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength</td>
<td>85% of original, minimum</td>
</tr>
<tr>
<td>Elongation at Rupture</td>
<td>60% of original, minimum</td>
</tr>
</tbody>
</table>

HEAT SHOCK TEST, AIR OVEN

<table>
<thead>
<tr>
<th>Condition</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour at 121° C</td>
<td>no cracks</td>
</tr>
</tbody>
</table>

HEAT DISTORTION TEST, AIR OVEN

<table>
<thead>
<tr>
<th>Condition</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour at 121° C</td>
<td>50% decrease in thickness, minimum</td>
</tr>
</tbody>
</table>

COLD BEND TEST

<table>
<thead>
<tr>
<th>Condition</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour at -40° C</td>
<td>no cracks</td>
</tr>
</tbody>
</table>

FLAME TEST

<table>
<thead>
<tr>
<th>Condition</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minutes Burning</td>
<td>1 minute</td>
</tr>
</tbody>
</table>

AFTER 4 HOURS IN AIR OVEN AT 70° C

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength</td>
<td>80% of original, minimum</td>
</tr>
<tr>
<td>Elongation of Rupture</td>
<td>60% of original, minimum</td>
</tr>
</tbody>
</table>

The nominal thickness of the jacket shall be as specified in Table 3. The average thickness shall be not less than 90% of the specified thickness. The minimum thickness shall be not less than 70% of the nominal thickness.

**TABLE 3**

<table>
<thead>
<tr>
<th>Calculated Diameter of Cable Under Jacket (Inches)</th>
<th>Jacket Thickness (Mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.425 and less</td>
<td>45</td>
</tr>
<tr>
<td>0.426 – 0.700</td>
<td>60</td>
</tr>
<tr>
<td>0.701 – 1.500</td>
<td>80</td>
</tr>
<tr>
<td>1.501 – 2.500</td>
<td>110</td>
</tr>
<tr>
<td>2.501 and larger</td>
<td>140</td>
</tr>
</tbody>
</table>

679.10 Sampling, Inspecting, and Acceptance. Inspection and tests shall be made prior to shipment and at the place of manufacture.

The manufacturer shall, when requested by the purchaser at time of placing the order, furnish the purchaser in suitable form, a certified report of the tests made on the cable to show compliance with this Item.
Tests on Entire Cable. The individual conductors of each length of completed cable shall meet the voltage and insulation resistance requirements of Section 679.4, except that the final electrical test on multiple conductor cables may be made without immersion in water. Each conductor of a multiple conductor cable shall be tested against all other conductors and shield if present.

Sample Tests. One sample for establishing conformity to this Item shall be taken from each 10,000 feet or fraction thereof, of each type and size of cable except that for the physical dimensions and the visual inspection a sample shall be taken from each reel. In case that these samples fail to meet the requirements of this Item, two additional samples shall be selected from new cable lengths and the lot shall be accepted if retests are both satisfactory. However, in case of any failure on the retest, the lot shall be rejected.

The manufacturer may re-examine rejected material and submit it for reinspection at his option.

679.11 Packing and Marking for Shipment. Reels shall be substantially constructed and in good condition. The cables shall be suitably protected. Each end of the cable shall be available for testing, properly sealed, and protected against injury. Each reel shall be plainly and permanently marked with manufacturer’s full description of the cable, giving the length of the cable on the reel, the number of conductors in the cable and the date of shipment from the factory.

679.12 Guarantee. If it is the normal trade practice for the manufacturer to furnish a guarantee for the work provided herein, the Contractor shall turn this guarantee over to the Engineer for potential dealing with the guarantor. The extent of such guarantee will not be a factor in selecting the successful bidder.

679.13 Measurement & Payment. Insulated Jacketed Traffic Signal Cable shall be measured and paid for by the linear foot for the designated cable size and International Municipal Signal Association (IMSA) cable specification.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 679
ITEM 680

STEEL MAST ARM AND STEEL STRAIN POLE ASSEMBLIES

680.1 Description. This Item will supplement the requirements found in the Standard Strain Pole Assembly Drawings for Traffic Signal Support Structures (Standard Drawing) for the design, fabrication, and delivery of single or dual steel mast arm assemblies and steel strain pole assemblies with span wires for use in mounting of traffic signals. Either assembly shall also require a 15 ft. luminaire arm as shown in the project drawings. The designs shall conform to the AASHTO Standard Specifications for Structural Supports for Traffic Signals with Luminaires and Traffic Signals.

This Item, instructions in the project drawings, and the Standard Drawings constitute the only acceptable design for the assemblies.

680.2 Mast arms. If required, shall be fabricated with a rise in the unloaded condition unless otherwise shown in the project drawings.

Fabrication and welding shall be in accordance with American National Standard Institute (ANSI) and American Welding Society (AWS), Latest Edition. All welded joints shall develop the full required strength of the member.

Shop drawings will not be required since the assemblies are to be fabricated as shown in the standard drawings. The standard drawings will also show the quantity of each pole designation to be fabricated in the Shipping Parts List table for the associated assembly. Any deviation from this standard drawing will require submission of four sets of shop drawings of the complete assembly including anchor bolts in accordance with the Item 441 "Steel Structures" of the Standard Specifications. Shop drawings, when required, are to be submitted directly to the attention of the Traffic Engineer. The Traffic Engineer will review the general design features including the number of each type of pole required, the number and length of mast arms, vertical clearance above pavement and number of structures with or without luminaires, and type of base mountings. The Traffic Engineer will then refer all four copies of the shop drawing to the Project Engineer for review and approval of the structural design features.

The assembly shall be refabricated to the design wind speed specified in the project drawings and this wind speed shall be identified permanently on a surface visible after erection of the pole base plate and mounting mast arm plate.
680.3 Anchor Bolts. Anchor bolts shall conform to the requirements in the standard drawings and shall comply with ASTM A193 “Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications” B7 or ASTM A36 “Standard Specification for Carbon Structural Steel” M55. Dimensions shall be based on the foundation size required for the arm lengths, number of arms, and design wind speed specified in the project drawings.

The anchor bolts shall have the standard nut anchorage. Nuts shall comply with the requirements of ASTM A563 “Standard Specification for Carbon and Alloy Steel Nuts” Grade A or better, heavy hex.

Two circular steel templates shall be provided for each assembly but they may be shipped without the anchor bolts attached. The lower nut shall be tack welded to the lower template. The upper template may be re-used providing it stays in place until the concrete has achieved its initial set.

Anchor bolts shall be galvanized the full length; nuts and washers shall also be galvanized.

Thread for anchor bolts shall be rolled or cut threads of unified coarse thread series except for ASTM A193 B7 bolts which shall be 8 pitch thread series. If rolled, the diameter of the unthreaded portion shall not be less than the minimum pitch diameter nor more than the maximum major diameter of the threads. Threads shall have Class 2 fit tolerances. Galvanized nuts shall be tapped after galvanized.

Threads of anchor bolts shall be coated with pipe joint compound prior to installation of upper nuts when erecting pole. After poles are plumbed and in permanent alignment, the exposed upper threads of painted bolts are to be cleaned and an additional coating of the zinc-rich paint applied to seal the bolt thread-nut joint.

680.4 Poles and Mast Arms. The shaft for the pole or mast arm may be round or octagonal and shall be tapered. Bolt slip joints are permissible in mast arms 40 feet or longer. Circumferential welds, other than at the ends of the shafts, are not permitted.

The exterior of longitudinal seam welds shall be ground or otherwise smoothed to the same appearance as other shaft surfaces. Longitudinal seam welds for pole or mast arm sections shall have 80 percent minimum penetration except longitudinal seam shall be complete penetration when within six inches of circumferential base welds. A maximum of two longitudinal seam welds may be made in pole sections and only one longitudinal seam weld is permitted in mast arms. Low hydrogen
electrodes of the equivalent in wire and flux for automatic welding, will be required for all welds. Preheat will be required for welding pole or mast arm shafts to their respective bases in accordance with American Welding Society (AWS), Latest Edition.

Material for pole or mast arm shafts shall conform to the requirements in the standard drawing and shall comply with the requirements of ASTM A1011 “Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength” Grade 50, or ASTM A572 “Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel”, or ASTM A595 “Standard Specification for Steel Tubes, Low-Carbon or High-Strength Low-Alloy, Tapered for Structural Use” Grade A, Structural Steel for Signal and Luminaires Support Structures. Material supplied under the ASTM A1011 Grade 50 or ASTM A595 Grade A specifications must meet their associated chemical and bend test requirements with the further stipulation that the materials must meet a minimum yield of 50 ksi and a minimum elongation of 18 percent in 8 inches or 23 percent in 2 inches prior to break or tube forming operations. ASTM A1011 Grade 50 material in thicknesses up to 5/16 inch is also acceptable providing it meets the above stated chemical, and mechanical test, yield, and elongation requirements.

Mill test reports and/or laboratory test certifications shall be provided to show that the materials conform to these requirements. The second arm of dual mast arm assembly shall be capable of being positioned at any angular location in respect to the first arm. A metal cap at the top of all poles shall be secured using galvanized or stainless steel set screws.

680.5 Luminaire Arm. The 15 foot luminaire arm, if shown in the project drawings, shall be as shown on the standard drawings. The connections to the pole shall be as shown on the Standard Assembly Drawing for Luminaire Support Structure and be in accordance to AASHTO Standards.


All sheared or cut edges and all other exposed edges to be painted or galvanized shall be rounded or chamfered to an approximate 1/16 inch.

Hot-Dip Galvanizing. Assemblies required to be hot-dip galvanized shall be so designed as to provide proper filling, venting, and draining during the cleaning and galvanizing operations. All parts shall be hot-dip galvanized after fabrication in accordance with ASTM A123.
All screws, nuts, bolts, washers, shims, and the full length of the anchor bolts shall be galvanized in conformance with ASTM A153 “Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware”, Class C or D, unless otherwise specified. All nuts shall be tapped after galvanizing. Any part of the mast arm assembly, from which the galvanizing has been knocked or chipped to bare metal in fabrication or transit, shall be repaired by application of galvanizing repair compounds in accordance with the manufacturer’s recommendations. The galvanizing repair shall be applied so as to provide a final assembly which is neat in appearance.

680.7 Delivery. Each mast arm assembly shall be delivered as complete unit with fittings either installed or packaged in such a manner that all parts remain with their associated major components during shipment and delivery.

The use of the standard drawings does not relieve the supplier of the responsibility for providing proper fit of mast assembly components.

The supplier shall furnish four copies of mill certificates reflecting the physical and chemical properties of the base metal of the pole and mast arm shafts, base plates, luminaire and anchor bolts. Also, four certified copies of the galvanizing test report shall be provided.

All items of a shipment shall be identified with weatherproof tag. This tag shall minimally identify manufacturer, contract number, and date and destination of shipment.

680.8 Measurement and Payment. The steel mast arm, luminaire arm and/or steel strain pole units will be measured by each unit, of the type specified on the plans. Payment for “Steel Mast Arm and Steel Strain Pole Assemblies” shall be made of the unit price bid per each unit, which price shall be full compensation for furnishing and/or installing steel mast arm, luminaire arm and/or steel strain pole assemblies by height or length as specified in the contract documents.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications.

Item 441 "Steel Structures"

END OF ITEM 680
ITEM 681

TREATED TIMBER POLES

681.1 Description. This Item shall govern for furnishing treated timber pole generally for use as signal, luminaire and electrical service support.

Poles shall be in accordance with the Latest Edition of the American National Standards Institution (ANSI) 05.1 "Specifications and Dimension for Wood Poles", except as modified herein.

Poles other than for electric service shall be ANSI Class 2 unless otherwise specified. Poles for electrical service shall be ANSI Class 4 or 5 unless otherwise specified. The length of poles will be specified in the purchase requisition or project drawings.

681.2 Material. Pole specimen shall be of long or short leaf Southern Yellow Pine with a minimum fiber stress strength of 8,000 psi. Seasoning and conditioning of poles may be either air seasoned or steam conditioned. The maximum air seasoning period shall be limited to 120 days except by permission of the engineer.

681.3 Defects. Tops and butts of poles shall be free from pith holes. Scars (cat face) or depressions in the body of the pole resulting from tree wounds wherein the process of healing has not re-established the normal cross-section of the pole will be permitted provided the deformity is not such as to impair the strength of the pole. Poles having scars greater than 1 inch in depth, within 1/10 the diameter of the pole, and pole location of scar shall be rejected unless, in the judgement of the County's representative, the strength of the pole is not impaired.

Any deviation from straightness shall not exceed 2 inches in a 5 foot (or less) section. A pole may have sweep in one plane and one direction (single sweep) provided a straight line joining the midpoint of pole at the top does not at any intermediate point, pass through the external surface of the pole. No poles with sweep in two planes (double sweep) shall be accepted.

No pole shall have more than one complete twist of spiral grain. Butt slivering due to felling shall be permitted if the distance from the outside circumference is not less than 1/4 of the butt diameter and the height is not more than 1 foot.

681.4 Manufacturer Requirements. Pole shall be cut from live timber preferably during the winter season. Poles shall be smoothly trimmed either by hand
or machine. The depth of cut shall be kept to practical minimum on the surface and in no case to be more than 1/4 inch except at knot whorls. The circumference at any point between knot whorls shall not be reduced by more than 1 inch. All work shall be done in a neat and workmanlike manner. The top side surfaces shall be free of injurious checks.

681.5 Treatment. Poles for signal and luminaire support shall be in accordance with American National Standard Institute (ANSI) Class 2, and the United States Federal Supply Service (USFSS) Specification TT-W-571 that references to the American Wood Protection Association (AWPA) standards C1 and C3 for pressure treatment.

681.6 Inspection and Delivery. Before and after treatment all poles shall be subject to inspection by the Engineer or authorized inspection agency. The inspector shall be allowed free access to all points from which materials are being produced or processed and producer shall render him whatever assistance is necessary for proper inspection of materials. Excessive splitting, or checking shall be gauged as follows:

A. A check or split which will permit a number 10 B & S (0.102" diameter) wire to be extended 3 inches into the body of the pole.

B. Checking and splitting of such size that at any point along the pole, two checks or splits occur into which a number 10 wire may be inserted by a depth of more than 7/8 inch.

Whenever there is any sign of incipient decay visible in untreated timber, and in cases where the condition of the timber is doubtful, the inspector shall insist that a section 2 inches thick, or more be cut from the butt or tip, or both ends of poles.

When there is any evidence of decay, such as softness of the wood fibers, sponginess or brownish discoloration, even though there are no definite areas of breakdown in the wood fibers, the material shall be rejected.

681.7 Measurement and Payment. The basis of payment for Treated Timber Poles shall be each by specified length as they appear on the bid sheets. Payment shall be full compensation for furnishing and/or installing of material and all other labor, tools, equipment and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 681
ITEM 683

TRAFFIC SIGNAL SUPPORTS - PEDESTAL POLES

683.1 Description. This Item shall govern for the complete signal support which includes a steel shaft extended through the base, foundation, ground rod, pole cap, and bell bottom and all other wire outlet, conduit, access door, etc., as herein specified and/or shown on the drawings.

Pedestal poles shall be the "Pedestal pole shaft extending through bases" as indicated on the drawings or mentioned in the specifications.

All pedestal pole assemblies as supplied must conform to the Standard Traffic Drawings and/or requirements in the drawings as to height, general design and finish.

The pole assembly shall be designed to support a 150 pound axial load with 11 square feet of signal head area rigidly mounted at the top of the shaft.

In addition to dead load, each assembly shall be designed to withstand wind and ice loads on the specified pedestrian signal head and sign area and on all surfaces of the support in accordance with the American Association of State Highway and Transportation Official's "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals" and other specifications of this body as may be pertinent. Unless otherwise shown on the drawings, 100 mph wind speeds shall be used for design.

Allowable unit stresses in each component of the assembly shall be as provided in the AASHTO Specification.

Pole assemblies required to be hot-dip galvanized shall be in accordance with ASTM A123 “Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products” to provide proper filling, venting and draining during the cleaning and galvanizing operations.

All parts of the same type shall be interchangeable.

683.2 Parts.

Shaft. The shaft shall be fabricated from one piece of new 4 inch diameter schedule 40 steel pipe or tubing, aluminum pipe (alloy 6061 T6), or rigid metal conduit. Do not use aluminum conduit.
The height of the shaft shall be as indicated on the drawings. All shafts shall have a cap and a bell bottom base, and the shaft shall be extended through the bases, set in an excavated hole as shown on the drawings.

A 2-1/2 inch x 1/4 inch steel strap shall be welded in accordance with the American Welding Society (Latest Edition) on the bottom pipe-end to provide extra support of the pole when set. The steel strap shall not extend beyond the outside diameter of the pipe and shall have a continuous weld to the pipe on the contacted surfaces.

683.3 Foundation.

Option 1: Concrete foundation for pedestal poles shall, as a minimum, include:

A. 4 foot - 6 inch deep by 24 inch diameter foundation, with 24 inch x 36 inch concrete head for the extended type shaft as shown on the drawings. All concrete used shall be Class “B_2” concrete.

B. Ground Rod. Shall be a minimum 5/8 inch x 8 foot long copper weld rod.

C. Hot-Dipped Galvanizing. After completion of all fabrication work the pole shall be hot-dip galvanized in accordance with ASTM A123.

Option 2: Screw anchor foundation for pedestal poles shall, as a minimum, include:

A. 8 inch schedule 40 pipe shaft length of 5 foot, with a 13 inch diameter helix (3/8 inch plate).

B. Ground Rod. Shall be a minimum 5/8 inch x 8 foot long copper weld rod.

C. Hot-Dipped Galvanizing. After completion of all fabrication work the pole shall be hot-dip galvanized in accordance with ASTM A123.

683.4 Measurement and Payment. The basis of payment for Traffic Signal Supports Pedestal Poles shall be each by specified size as they appear on the bid sheets. Payment shall be full compensation for furnishing and/or installing of material and all other labor, tools, equipment and incidentals necessary to complete the work.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 683
ITEM 686

ROAD ILLUMINATION ASSEMBLIES
(ON TRAFFIC SIGNAL POLES)

686.1 Description. This Item governs the materials, composition and quality of Light Emitting Diode (LED) luminaires used as equivalents to the 400-W, high-pressure sodium (HPS), “cobra-head” style roadway illumination light fixtures (luminaires) in conjunction with traffic signal projects as shown on the drawings. The term “assembly”, as used herein, shall constitute the complete assemblage of parts, equipment and miscellaneous items, except foundation, erected as provided in the drawings and in accordance with these Standard Specifications, forming a complete and independent lighting unit.

All materials furnished, assembled, fabricated or installed under this Item shall be of the latest design and in strict accordance with the details shown on drawings. Materials and equipment shall comply with the applicable provisions of the National Electrical Code and National Electrical Manufacturers Association Standards.

Poles and mast arms shall be designed to carry the luminaire described herein, and shall meet the applicable requirements of the Standard Traffic drawings.

686.2 Material Requirements.


Rate luminaire for operating at ambient temperature between -40 and 40°C.

Provide external label per ANSI C136.15.

Provide internal label per ANSI C136.22.

Do not place fuses in pole-mounted luminaires. Provide wall- or underpass-mounted luminaires with internal 10-amp, time-delay fuses and fuse holders.

Provide internal label or marking with date code of when fixture was manufactured.
Request approval from the County before making any changes to construction, materials, or components in the luminaire. Do not make changes to the luminaire until approved by the County.

**B. Housing.** Provide luminaire housing, lens frame, and door constructed from 96% copper-free aluminum. Provide for luminaire mounting to a 2-in. pipe arm, capable of adjustments ± 5° from level. Meet ANSI 136.31, 3.0 G vibration requirements.

Equip luminaire with a three-prong ANSI C136.10 rotatable photocell receptacle and shorting cap.

Paint luminaires light gray with initial gloss in the range of 30–60% (semi-gloss) when installing on galvanized poles. For all other poles, paint luminaires to match the color of the pole as directed. Use a thermoset powder-coat paint system. For pre-qualification, document that the coating meets the following:

1. **Exceeds a rating of six per ASTM D1654 “Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments”** after 1000 hr. of testing in accordance with ASTM B117 “Standard Practice for Operating Salt Spray (Fog) Apparatus”; and


Fabricate exposed hardware, nuts, bolts, washers, and metal parts from stainless steel or aluminum of adequate thickness as approved.

Attach a level indicator to the fixture housing. Ensure that indicator is sensitive to 1° changes in position at any point within 5° of the level position. Ensure that indicator is clearly visible from the ground up to a 50-ft. mounting height. Ensure that indication of level corresponds to level position of fixture.

Ensure weight of the luminaire is less than 60 lb. and the effective projected area is less than 1.6 sq. ft.

Provide a barrier-type terminal block secured to housing for power connection to luminaire in accordance with ANSI 136.14 and ANSI
136.37. Provide lugs with screws for wire sizes up to 6 AWG. Identify each terminal position.

C. LED Drivers. Provide luminaire with replaceable LED driver that will operate at 120 V, 240 V, or 480 V line voltages as shown in the plans. For pre-qualification, provide summary of reliability testing performed for LED driver(s). Provide LED drivers meeting the following specifications:

1. Rated case temperature suitable for operation in the luminaire at ambient temperature of -40 to +40°C;
2. Power factor (PF) of at least 0.90 at full input power at the specified voltage;
3. Rated life expectancy of 100,000 hr. at rated operating temperature inside the luminaire;
4. Reduced output power to LEDs if maximum allowable case temperature is exceeded;
5. Tolerates sustained open circuit and short circuit output conditions without damage; and
6. Potted or rated IP 66 if exposed to the environment.

D. LED Optical Assembly. Provide LED optical assembly with nominal color temperature of 4000K. For verification testing, CCT within the range of 3710K–4260K is allowable.

Provide LED optical assembly with a minimum CRI of 70.

Provide a passive thermal management system. Do not use fans or other mechanical cooling systems.

E. Surge Protective Devices. Provide luminaire with a surge protective device (SPD), in addition to driver’s internal protection, to withstand repetitive noise transients from utility line switching, nearby lightning strikes, and other interference. Provide SPD that will protect the luminaire from common mode transient peak voltages up to 10 kV (minimum) and transient peak currents up to 10 kA (minimum). Provide SPD tested in accordance with ANSI/IEEE C62.45 per ANSI/IEEE C62.41.2 Scenario I Location Category C-High for Line-Ground, Line-Neutral, and Neutral-Ground. Provide SPD listed or recognized by a NRTL to UL 1449, 3rd edition. Test luminaires at a test lab accredited by American Association for Laboratory Accreditation (A2LA) for Electrical Fast Transient (EFT) and Surge...
Immunity. Provide test reports for 120 V, 240 V and 480 V luminaires, showing the fixture can survive the following tests.

1. **Testing.** Perform Electrical Immunity Tests 1, 2 and 3, as defined by their Test Specifications, on an entire powered and connected luminaire, including any control modules housed within the luminaire but excluding any control modules mounted externally, such as a NEMA socket connected photo-control. Place a shorting cap across any such exterior connector.

Connect the luminaire to an AC power source with a configuration appropriate for nominal operation. The AC power source must have a minimum available short-circuit current of 200 A. Test the luminaire at the manufacturer-specified nominal input voltage or at the highest input voltage in the input voltage range.

Superimpose electrical immunity test waveforms on the input AC power line at a point within 6 in. (15 cm) of entry into the luminaire using appropriate high-voltage probes and a series coupler/decoupler network (CDN) appropriate for each coupling mode, as defined by ANSI/IEEE C62.45-2002. The test area for all tests must be in accordance with ANSI/IEEE C62.45-2002, as appropriate.

Prior to electrical immunity testing, perform a set of diagnostic measurements, and record the results to note the pre-test function of the luminaire after it has reached thermal equilibrium. These measurements should include at a minimum:

a. For all luminaires, Real Power, Input RMS Current, Power Factor, and THD at full power/light output; and

b. For luminaires specified as dimmable, Real Power, Input RMS Current, Power Factor, and THD at a minimum of 4 additional dimmed levels, including the rated minimum dimmed level.

Apply tests in sequential order (Test 1, followed by Test 2, followed by Test 3). If a failure occurs during Test 3, then re-apply Test 3 to a secondary luminaire of identical construction.
Following the completion of Tests 1, 2, and 3, repeat the same set of diagnostic measurements performed pre-test for all tested luminaires, and record the results to note the post-test function of the luminaire(s).

A luminaire must function normally and show no evidence of failure following the completion of Tests 1, 2, and 3 (for a single tested luminaire), or the completion of Tests 1 and 2 on a primary luminaire and Test 3 on a secondary luminaire. Abnormal behavior during testing is acceptable.

Following the completion of testing, the existence of any of the conditions listed below constitutes a luminaire failure.

a. A hard power reset is required to return to normal operation;

b. A noticeable reduction in full light output is observed (e.g., one or more LEDs fails to produce light or becomes unstable);

c. Any of the post-test diagnostic measurements exceeds by ± 10% the corresponding pre-test diagnostic measurement; and

d. The luminaire or any component in the luminaire (including but not limited to an electrical connector, a driver, a protection component, or module) has ignited evidence of melting or other heat-induced damage. Evidence of cracking, splitting, rupturing, or smoke damage on any component is acceptable.

2. Test Specifications.

NOTE: L1 is typically “HOT”, L2 is typically “NEUTRAL” and PE = Protective Earth.

a. Test 1—Ring Wave. Subject the luminaire to repetitive strikes of a “C Low Ring Wave” as defined in IEEE C62.41.2-2002, Scenario 1, Location Category C. Apply the test strikes as specified in Table 1. Prior to testing, calibrate the ring wave generator to simultaneously meet both the specified short circuit current peak and open circuit voltage peak minimum requirements. Note that this may require raising the generator charging voltage above
the specified level to obtain the specified current peak. Use calibrated current probes/transformers designed for measuring high-frequency currents to measure test waveform currents.

Compare test waveform current shapes and peaks for all strikes to ensure uniformity throughout each set of test strikes (coupling mode and polarity/phase angle), and calculate and record the average peak current. If any individual peak current in a set exceeds the average by ± 10%, check the test setup and repeat the test strikes.

**TABLE 1**

0.5 μS–100kHz RING WAVE SPECIFICATION

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST LEVEL/CONFIGURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Circuit Current Peak</td>
<td>0.5 kA</td>
</tr>
<tr>
<td>Open Circuit Voltage Peak</td>
<td>6 kV</td>
</tr>
<tr>
<td>Source Impedance</td>
<td>12 Ω</td>
</tr>
<tr>
<td>Coupling Modes</td>
<td>L1 to PE, L2 to PE, L1 to L2</td>
</tr>
<tr>
<td>Polarity and Phase Angle</td>
<td>Positive at 90° and Negative at 270°</td>
</tr>
<tr>
<td>Test Strikes</td>
<td>5 for each Coupling Mode and Polarity/Phase Angle combination</td>
</tr>
<tr>
<td>Time between Strikes</td>
<td>1 minute</td>
</tr>
<tr>
<td>Total Number of Strikes</td>
<td>5 strikes × 3 coupling modes × 2 polarity/phase angles = 30 total strikes</td>
</tr>
</tbody>
</table>

b. Test 2—Combination Wave. Subject the luminaire to repetitive strikes of a “C High Combination Wave” as defined in IEEE C62.41.2-2002, Scenario 1, Location Category C. Apply the test strikes as specified in Table 2. Prior to testing, calibrate the combination wave generator to simultaneously meet both the specified short circuit current peak and open circuit voltage peak minimum requirements. Note that this may require raising the generator charging voltage above the specified level to obtain the specified current peak. Use calibrated current...
probes/transformers designed for measuring high-frequency currents to measure test waveform currents.

Compare test waveform current shapes and peaks for all strikes to ensure uniformity throughout each set of test strikes (coupling mode and polarity/phase angle), and calculate and record the average peak current. If any individual peak current in a set exceeds the average by ± 10%, check the test setup and repeat the test strikes.

TABLE 2

1.2/50μS–8/20 μS COMBINATION WAVE SPECIFICATION

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST LEVEL/CONFIGURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2/50 μS Open Circuit Voltage Peak</td>
<td>Low: 6 kV</td>
</tr>
<tr>
<td></td>
<td>High: 10 kV</td>
</tr>
<tr>
<td>8/20 μS Short Circuit Current Peak</td>
<td>Low: 3 kA</td>
</tr>
<tr>
<td></td>
<td>High: 10 kA</td>
</tr>
<tr>
<td>Source Impedance</td>
<td>2 Ω</td>
</tr>
<tr>
<td>Coupling Modes</td>
<td>L1 to PE, L2 to PE, L1 to L2</td>
</tr>
<tr>
<td>Polarity and Phase Angle</td>
<td>Positive at 90° and Negative at 270°</td>
</tr>
<tr>
<td>Test Strikes</td>
<td>5 for each Coupling Mode and Polarity/Phase Angle combination</td>
</tr>
<tr>
<td>Time Between Strikes</td>
<td>1 minute</td>
</tr>
<tr>
<td>Total Number of Strikes</td>
<td>5 strikes × 3 coupling modes × 2 polarity/phase angles = 30 total strikes</td>
</tr>
</tbody>
</table>

c. Test 3—Electrical Fast Transient (EFT). Subject the luminaire to “Electrical Fast Transient Bursts,” as defined in IEEE C62.41.2-2002. The test area must be in accordance with IEEE C62.45-2002. Apply the bursts as specified in Table 3. Direct coupling is required; the use of a coupling clamp is not allowed.

TABLE 3

ELECTRICAL FAST TRANSIENT (EFT) SPECIFICATION
<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST LEVEL/CONFIGURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Circuit Voltage Peak</td>
<td>3 kV</td>
</tr>
<tr>
<td>Burst Repetition Rate</td>
<td>2.5 kHz</td>
</tr>
<tr>
<td>Burst Duration</td>
<td>15 mS</td>
</tr>
<tr>
<td>Burst Period</td>
<td>300 mS</td>
</tr>
<tr>
<td>Coupling Modes</td>
<td>L1 to PE, L2 to PE, L1 to L2</td>
</tr>
<tr>
<td>Polarity</td>
<td>Positive and Negative</td>
</tr>
<tr>
<td>Test Duration</td>
<td>1 minute for each Coupling Mode and Polarity combination</td>
</tr>
<tr>
<td>Total Test Duration</td>
<td>1 minute × 3 coupling modes × 2 polarities = 6 minutes</td>
</tr>
</tbody>
</table>

F. Warranty. The manufacturer will replace failed luminaires, when non-operable due to defect in material or workmanship, within ten years of installation with a luminaire that meets all specifications, delivered to the project location. Photocells are subject to the warranties of their respective manufacturers.

The warranty must cover maintained integrity and functionality of:

1. Luminaire housing, wiring, and connections;
2. LED light source(s)—negligible light output from more than 10% of the LED packages constitutes luminaire failure; and
3. LED driver(s).

The warranty period will begin 90 days after date of manufacture as shown on internal label.

Provide documentation of warranty service procedures, including forms, manufacturer contact information, and shipping addresses.

G. Calculation of Light Loss Factor (LLF). For pre-qualification, submit calculations per IES TM-21 predicting lumen maintenance at the luminaire level using In Situ Temperature Measurement Testing (ISTMT) and LM-80 data. Meet all of the conditions below.

1. The LED light source(s) have been tested according to LM-80. Provide verification from the LED or luminaire.
manufacturer that the LM-80 report corresponds to the LEDs in the luminaire being tested.

2. The LED drive current specified by the luminaire manufacturer is less than or equal to the appropriate drive current specified in the LM-80 test report.

3. The LED light source(s) manufacturer prescribes/indicates a temperature measurement point (TS) on the light source(s).

4. For the hottest LED light source in the luminaire, the temperature measured at the TS during ISTMT is less than or equal to the appropriate temperature specified in the LM-80 test report for the corresponding drive current or higher, within the manufacturer’s specified operating current range.

The ISTMT laboratory must meet at least one of the following requirements:

1. Be approved by OSHA as a Nationally Recognized Testing Laboratory (NRTL) or recognized as a participant in UL’s Client Data Test Program;

2. Be approved through an OSHA NRTL data acceptance program or OSHA Satellite Notification and Acceptance Program (SNAP); or

3. Be accredited for ANSI/UL 1598 or CSA C22.2 No. 250.0-08, including Sections 19.7 and 19.10–16, by an accreditation organization that is an ILAC-MRA Signatory.

Conduct the ISTMT using the same configuration of luminaires submitted, or another luminaire from the same product family having:

1. The same or lower nominal CCT;

2. The same or higher nominal drive current;

3. The same or greater number of LED light source(s);

4. The same or lower percentage driver loading and efficiency; and

5. The same or smaller size luminaire housing.
Install luminaire as defined by ANSI/UL 1598 (hardwired luminaires).

Include in the ISTMT report:

1. Photos of thermocouple locations and luminaire in testing position;
2. Ambient test temperature;
3. LED temperature;
4. Maximum LED current; and
5. Full description of luminaire used in test.

Calculate LLF for each fixture configuration using the submitted ISTMT data, LM-80 data, and Energy Star TM-21 calculator.

1. Provide documentation of in situ temperature at 25°C ambient for the luminaire rating submitted for approval;
2. Calculate the lumen depreciation at 70,000 hr. at the documented in situ temperature at 25°C ambient using the Energy Star TM-21 calculator;
3. LLF = Manufacturer's documented lamp lumen depreciation (LLD) factor per TM-21 calculations at 25°C at 70,000 hr. × 0.90 Luminaire Dirt Depreciation; and
4. Total light loss factor is not to exceed 30% system depreciation (0.70) over 70,000 hr.

Calculated LLF will be used for design purposes and to determine if luminaire meets the performance specification.

H. Performance Requirements. For each type of luminaire specified, submit a photometric file in LM-63 format (i.e., filename.ies) and test report of the luminaire generated from LM-79 tests of an actual luminaire in a NVLAP-accredited test lab. Document that the luminaire was tested according to IES LM-79. The Department will verify the performance of the luminaire in a computer simulation using the following criteria in AGI32 Roadway Optimizer.

400 Watt HPS Equivalent:
1. **Layout.**
   
a. LLF as calculated in Section 11011.8.G;
   
b. Fixtures mounted level perpendicular to the roadway at 50-ft. mounting height with 8-ft. arms, on one side of the roadway;
   
c. Fixtures spaced at 270 ft.;
   
d. Setback 15 ft. from outside edges of main lanes;
   
e. Grid points spaced according to IESNA RP-8 for a roadway with four 12-ft. lanes.

2. **Test Criteria for Passing.**
   
a. Minimum > 0.20 footcandle;
   
b. Average > 0.60 footcandle;
   
c. Average/minimum ratio < 3.0:1;
   
d. IESNA TM-15-11 BUG rating with an Uplight value of U0.

686.3 **Submittal.** Shop drawings shall be submitted directly to the Harris County Engineering Department, Traffic Signal Maintenance Section. Harris County Engineering Department, Traffic Signal Maintenance Section will review the general design features of the Road Illumination Assemblies.

686.4 **Construction Methods.**

A. General. The installation as a whole shall be carried out in conformance with the requirements stated herein and as shown on the drawings, and shall present a neat and workmanlike finished appearance.

B. Installing Fixtures. The installation of all luminaires shall conform to the recommendations of the manufacturer and, unless otherwise specified, shall be mounted in a level position.

C. Wire and Cable Installation. All conductor cables shall be installed in continuous lengths, without splices, from terminal to terminal. Terminals for lighting shall be located in the luminaire housing and the controller cabinet only, or as indicated on the drawings.
Measurement and Payment. Road Illumination Assemblies shall be paid for by each assembly installed, including all mounting hardware required.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specification

Item 680 “Steel Mast Arm & Steel Strain Pole Assemblies”

END OF ITEM 686
ITEM 687

FLASHER ASSEMBLY INSTALLATION

687.1 Description. This Item shall govern for the furnishing of all labor, materials, tools, equipment, tests, adjustments and all other incidentals necessary to install school zone flasher assemblies and warning flasher assemblies.

687.2 General. All bidders shall visit the job site prior to bidding, only if drawings are made available, in order to acquaint themselves with all jobsite conditions and problems, if any, and all other factors that may affect the bid. Any discrepancy between drawings and specifications shall be resolved prior to bidding.

The Contractor shall clean the job site of all debris, loose excess excavated material, etc. accumulated as a result of work performed under this contract. The Contractor shall exercise care in working around the area not to infringe on or mutilate property. The Contractor shall be responsible for any such infringement or mutilation. It is the Contractor's responsibility to restore the construction area to its original condition prior to final acceptance and payment. The Contractor shall remove any excess excavated material from the jobsite.

All trades are to work in cooperation with one another, and all trades, when necessary and/or as standard procedure, shall construct preliminary grounds for work to be performed by succeeding trades. It is the General Contractor's responsibility to see that all work is properly coordinated and executed.

Any Contractor having any questions concerning this project should contact Harris County (713) 881-3210.

687.3 Materials and Equipment. All materials and equipment furnished for installation under this contract shall be new and unused, unless otherwise specified. The Contractor shall install all school zone flashing signals in accordance with this Item, any and all applicable special specifications or special provisions associated with this project, and in accordance with referenced Harris County specifications and details as indicated below.

A. Solar School Zone Flasher Systems. Reference Harris County Specifications, Items 624, 649, 683, 688, 689, and 690 (Polycarbonate).

All control equipment shall conform to appropriate ITE and NEMA Specifications and shall be furnished and installed in accordance with the drawings and specifications.

687.4 Permits, Codes, Etc. The Contractor shall be responsible for obtaining permits and inspections by regulatory bodies and shall work with Harris County in obtaining power to the system from the local power utility company and notify Harris County 48 hours prior to connecting the system to the local power utility company lines.

All required meter service assemblies shall be installed by the Contractor as required by the local power utility company at the Contractor's expense, unless otherwise specified and/or shown on the construction drawings.

All wiring throughout this system shall be in strict accordance with the National Electrical Code, all local applicable codes and shall also comply with all requirements of CenterPoint Energy, in order that service may be obtained from them. All costs for code compliance are to be included in the bid for this contract.

All construction will be in accordance with the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways", (TMUTCD), and in accordance with the specifications and drawings.

687.5 All items installed under this Item, having a manufacturer's guarantee shall be installed by or under the direction of the manufacturer or his certified agent. The Contractor shall follow the manufacturer's installation procedures for all equipment furnished by Harris County Engineering Department. It is the Contractor's responsibility to procure the installation procedures before bidding the project.

687.6 Barricades and Construction Signs. The Contractor shall furnish and install permanent and/or portable construction signs on all approaches to the project as shown on the drawings and as required by TMUTCD and Harris County Specification Items 670 and 671. All required construction signs shall be installed and in place when the Contractor is on the jobsite.

Closing of lanes for construction shall be done in strict accordance with the TMUTCD and as shown on the drawings. Prior to closing any section of roadway to traffic, the Contractor shall furnish and install barricades and warning signs in accordance with the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways", (TMUTCD), and in accordance with Harris County Specification Items 670 and 671.
687.7 Responsibility for Damage or Claims. (Also see Paragraphs 3.01 "Indemnification" and 4.01 "Laws to be Observed" of "Harris County General Conditions for Roads, Bridges and Related Work ".)

The Contractor shall hold harmless the County and its representatives from all suits, actions, or claims of any character filed as a result of injuries or damages sustained by any person or property due to neglect in safeguarding the work, the use of unacceptable materials in the execution of the contract, or any act of omission by the Contractor or his Sub-Contractors. The Contractor shall not be released from responsibility until the contract has been completed and all work accepted. Money due the Contractor under and by virtue of his contract may be retained by the County or his surety may be held until such claims have been settled and suitable evidence to that effect furnished to the County.

Unless otherwise set forth in these Standard Specifications, the Contractor shall receive no direct compensation for furnishing, erecting, and maintaining the necessary barricades, lights, flares, signs, or for any other incidentals necessary for the good and proper safety, convenience, and direction of traffic during the period prior to final inspection and acceptance by the County.

687.8 Operation and Maintenance Responsibilities. The Contractor shall accept responsibility for operation and maintenance of the flasher system beginning on the date work commences on the project through the date of final acceptance and payment of the project. Operation and maintenance responsibilities shall include, as a minimum, initiating emergency response for evaluation and, if necessary, for emergency repair operations, on the job site a maximum of 4 hours after notification by Harris County of a reported system failure or malfunction. The Contractor shall pursue emergency response and repair operations with all haste in order that flashers down time will be kept to absolute minimum. In the event the Contractor fails to respond within 4 hours, Harris County reserves the right to pursue the repair operations and forward all associated bills for providing this service to the Contractor for reimbursement. Harris County will also inform the Contractor’s bonding company of these incidents.

687.9 Guarantee. Excluding lamps, the Contractor’s acceptance of this contract guarantees all workmanship performed and/or materials and/or equipment furnished and installed shall be warranted for a period of two year from date of final acceptance and payment for the project. All LED lamps
furnished and installed by the Contractor shall be guaranteed for workmanship and performance for a period of no less than five years from the date of final acceptance and payment for the project. All incandescent lamps furnished and installed by the Contractor shall be guaranteed for workmanship and performance for a period of no less than 180 days from the date of final acceptance and payment for the project, excluding lamps. When warranty repairs are required, the Contractor shall initiate emergency repair service operations on the job site a maximum of 4 hours after notification by Harris County of system failure or malfunction. The Contractor shall pursue repair operations with all haste in order that signal down time will be kept to absolute minimum. In the event the Contractor fails to respond to a request for warranty repairs within 4 hours, Harris County will pursue the repair operations and forward the bills to the Contractor for reimbursement and inform his bonding company. Vandal damage and damage due to automobile accidents or acts of nature shall not be included under Contractor's guarantee. The Contractor shall sign the inspection sheet on all warranty calls.

687.10 Substitute Materials. Set forth in these Standard Specifications are definite models, materials, etc.; however, items of equal appearance, durability, performance and design will be accepted upon approval of Harris County. The successful bidder is required to submit to the Harris County Engineering Department, Traffic Signal Maintenance, engineering brochures and information on all materials he desires to furnish and install which are of different manufacturer or model number than specified herein. The submittal is for approval or disapproval by the Engineer. In the event approval is not obtained, the specified items shall not be furnished and installed. The submittals shall be furnished not later than 2 days after bid opening. It is the Contractor's responsibility to verify these locations prior to commencing work and to insure that these locations do not result in conflicts with and/or damage to existing utilities. To this end, the Contractor shall, as a minimum, contact the Lone Star Notification Center at (713) 223-4567 in Houston and 1-800-669-8344 outside of Houston and Texas One Call at 1-800-245-4545 a minimum of 72 hours before commencing any work in the construction area. It is the Contractor's responsibility to physically locate any electrical, communications, sewer, water, gas, of other utilities and to adjust the location of any foundations(s) as necessary to avoid damage to any existing utilities.

687.11 Field Test. All flasher assemblies installed by the Contractor shall be field tested. The contract shall not be considered complete until all the flasher assemblies have been field tested for 10 consecutive days without failure and/or malfunction, and to the satisfaction of Harris County. Should a failure and/or malfunction occur within the 10 day test period, the test
period shall be extended until the flasher assemblies have operated successfully for 10 consecutive days.

687.12 Special Notes.

A. A pre-construction meeting shall be scheduled by the County after award of contract, and prior to commencement of construction. The Contractor or his authorized representative will be required to attend.

B. All work in this contract shall be performed between the hours of 8:30 a.m. and 4:30 p.m., Monday through Friday, unless prior authorization has been obtained from the Engineer.

C. Contractor shall notify Harris County at (713) 881-3210 a minimum of 24 hours prior to commencement of work so that an inspector may be assigned.

D. The "Service Outlet Location and Data Statement" for these flashers will be supplied to the Contractor upon receipt from local power utility company.

E. All flashing beacon heads shall be wrapped with burlap or an approved equal cover so that signal faces cannot be seen from the time of installation until placed into operation.

F. The Contractor shall inform the Harris County at (713-881-3210) a minimum of 48 hours prior to placing a flasher into operation. Turn-ons shall be scheduled for Monday through Thursday during off-peak traffic periods only.

687.13 Miscellaneous.

A. Submittals. Harris County Engineering Department, Traffic Signal Maintenance Section will supply the Contractor with the drawings of the proposed improvements. Upon receipt of the drawings, the Contractor shall within two calendar days furnish the County with a copy of purchase orders, invoices, etc., with the estimated date of delivery.

B. Time for Installation. The Contractor will have five calendar days to install flashers from the time they receive their materials.

C. Contract Duration. This contract shall be completed when the maximum expenditure is met. It is anticipated that this will occur within the designated period from the date of the purchase order.
D. Units Assemblage. The Contractor shall be required to assemble the items that are supplied to manufacture's specifications or inspector's satisfaction.

E. Lane Closure(s). Lane Closure(s) shall be addressed with lane closure details, which will be provided to the declared winning bid.

F. Sign Removal. Sign removal is incidental to the installation of flashers and new signs.

G. Pedestal Pole. Poles shall be installed in accordance with drawings and Item 683 “Traffic Signal Supports Pedestal Poles”.

687.14 Measurement and Payment. The measurement and payment shall be by the lump sum bid or unit price bid as they appear on the bid sheets for the completed contract, which bids shall be for full compensation for all costs of labor, materials, tools, equipment, test, adjustments, and all other incidentals necessary to construct the complete traffic signal system, excluding all other items shown in the bid sheets in accordance with the specifications and drawings and to the satisfaction of the Engineer.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires drawings that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications

Item 624 “Aluminum Signs”
Item 649 “Wide Angle Prismatic Retroreflective Sheeting for Traffic Control Signs (Diamond Grade)”
Item 670 “Barricades”
Item 671 “Traffic Control”
Item 677 “Electrical Conduits for Traffic Signal Installation”
Item 679 “Insulated Jacketed Traffic Signal Cable”
Item 683 “Traffic Signal Supports – Pedestal Poles”
Item 688 “Flasher Assemblies”
Item 689 “Twelve Inch LED Traffic Signal Lamp Unit”
Item 690 “Traffic Signal Heads”

END OF ITEM 687
ITEM 688

FLASHER ASSEMBLIES

688.1 Description. This Item shall govern for furnishing materials, equipment and all other incidentals necessary to assemble complete school zone flasher assemblies (school zone pager flasher assemblies) and warning flasher assemblies.

All materials and equipment furnished for installation under this contract shall be new and unused, unless otherwise specified.

Any Contractor having any questions concerning this project should contact Harris County at (713) 881-3210.

The Contractor shall submit all brochures for all materials.

688.2 The AC Operation. Units shall include the following components for the AC School Zone Pager Flashing Signals per flasher assembly:

<table>
<thead>
<tr>
<th>QTY (UNIT 1)</th>
<th>UNIT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EACH</td>
<td>4 1/2'' OD x 19' Galvanized Steel Pole</td>
</tr>
<tr>
<td>2</td>
<td>EACH</td>
<td>12'' Yellow Polycarbonate Single Section Housing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Less Lenses and gasket)</td>
</tr>
<tr>
<td>2</td>
<td>EACH</td>
<td>12'' Yellow LED Optical Assemblies, AC Voltage</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>1 1/4'' Weatherhead</td>
</tr>
<tr>
<td>10</td>
<td>LF</td>
<td>1 1/4'' x 10' Rigid Galvanized Conduit</td>
</tr>
<tr>
<td>25</td>
<td>EACH</td>
<td>3/4'' Stainless Steel Strap</td>
</tr>
<tr>
<td>13</td>
<td>EACH</td>
<td>3/4'' Stainless Steel Strap Buckles</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>1 1/4'' Offset Nipple</td>
</tr>
<tr>
<td>5</td>
<td>EACH</td>
<td>1 1/4'' Locknut</td>
</tr>
<tr>
<td>5</td>
<td>EACH</td>
<td>1 1/4'' Fiber Bushing</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>1 1/4'' Hub (For Service Disconnect)</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>Service Disconnect</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>20 Amp Single Pole Breaker</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>Lightning Arrestor</td>
</tr>
<tr>
<td>3</td>
<td>EACH</td>
<td>1 1/4'' x Close Nipple</td>
</tr>
</tbody>
</table>
### PARTS FOR ELECTRICAL FLASHER - AC OPERATION

<table>
<thead>
<tr>
<th>QTY (UNIT 1)</th>
<th>UNIT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>EACH</td>
<td>Cabinet Mount assembly. (PELCO SE-1100)</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>Flasher Cabinet Assembly, Complete (NO TIME CLOCK FOR WARNING FLASHERS)</td>
</tr>
<tr>
<td>13</td>
<td>EACH</td>
<td>3/4&quot; Single Hole Mount for Strapping, with Bolt</td>
</tr>
<tr>
<td>4</td>
<td>EACH</td>
<td>1 1/2&quot; x 12&quot; Aluminum Nipple</td>
</tr>
<tr>
<td>4</td>
<td>EACH</td>
<td>1 1/2&quot; Aluminum Cross</td>
</tr>
<tr>
<td>4</td>
<td>EACH</td>
<td>1 1/2&quot; Aluminum Collared Nipple</td>
</tr>
<tr>
<td>4</td>
<td>EACH</td>
<td>1 1/2&quot; Locking Ring</td>
</tr>
<tr>
<td>8</td>
<td>EACH</td>
<td>1 1/2&quot; Short Rosette Cap</td>
</tr>
<tr>
<td>4</td>
<td>EACH</td>
<td>1 1/2&quot; Hub Plate</td>
</tr>
<tr>
<td>50</td>
<td>LF</td>
<td>#4 Wire</td>
</tr>
<tr>
<td>15</td>
<td>LF</td>
<td>#12, 2-conductor</td>
</tr>
<tr>
<td>10</td>
<td>LF</td>
<td>#8, Bare Copper Grounding Wire</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>Sign - See Attached Drawing</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>Ground Rod (8ft)</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>Ground Rod Clamp</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>Split Bell Base</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>Pole Cap</td>
</tr>
</tbody>
</table>

A. Controller Cabinet. The battery cabinet shall be manufactured of sheet aluminum with a minimum thickness of 0.125 inches, or cast aluminum alloy. The cabinet shall be sized to provide adequate space for two group 29 batteries. The cabinet shall have louvers for ventilation and to prevent the accumulation of gasses. There shall also be rubber mats installed on the bottom of the cabinets and two 1/8” drain holes located in the bottom at opposite corners.

The door and its opening shall encompass and constitute the entire area of the face of the cabinet. It shall be hinged via a continuous hinge, which shall be riveted to the door and to the cabinet. The door shall be tightly secured via a latching device, which pulls the door snugly against a neoprene gasket affixed to the cabinet body forming a weather-tight seal. The latching device shall be equipped with a standard police door-locking device.

The cabinet shall be equipped with the necessary hardware to provide right top and bottom mountings to a pole with band on post.
hubs, or 4-1/2 inch O.D. pole clamps as specified in the invitation for bids.

688.3 The DC Operation. Units shall include the following components for the DC Flashing Signals per flasher assembly:

<table>
<thead>
<tr>
<th>QTY (UNIT 1)</th>
<th>UNIT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EACH</td>
<td>4 1/2&quot; OD x 19' Galvanized Steel Pole</td>
</tr>
<tr>
<td>2</td>
<td>EACH</td>
<td>12&quot; Yellow Polycarbonate Single Section Housing (Less Lenses and gasket)</td>
</tr>
<tr>
<td>2</td>
<td>EACH</td>
<td>12&quot; Yellow LED Optical Assemblies, DC Voltage</td>
</tr>
<tr>
<td>25</td>
<td>LF</td>
<td>3/4&quot; Stainless Steel Strap</td>
</tr>
<tr>
<td>12</td>
<td>EACH</td>
<td>3/4&quot; Stainless Steel Strap Buckles</td>
</tr>
<tr>
<td>2</td>
<td>EACH</td>
<td>1 1/2&quot; x 20&quot; Offset Nipple</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>1 1/4&quot; Hub (For Service Disconnect)</td>
</tr>
<tr>
<td>2</td>
<td>EACH</td>
<td>1 1/2&quot; Aluminum Ell (SE-0457)</td>
</tr>
<tr>
<td>2</td>
<td>EACH</td>
<td>1 1/2&quot; Threaded Tee's(SE-0458)</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>1 1/2&quot; Sign Clamp (SH-0208) Comes in pairs</td>
</tr>
<tr>
<td>2</td>
<td>EACH</td>
<td>Cabinet Mount assembly. (PELCO SE-1100)</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>Flasher Cabinet Assembly, Complete (NO TIME CLOCK FOR WARNING FLASHERS)</td>
</tr>
<tr>
<td>13</td>
<td>EACH</td>
<td>3/4&quot; Single Hole Mount for Strapping, with Bolt</td>
</tr>
<tr>
<td>6</td>
<td>EACH</td>
<td>1 1/2&quot; x 12&quot; Aluminum Nipple</td>
</tr>
<tr>
<td>4</td>
<td>EACH</td>
<td>1 1/2&quot; Aluminum Cross</td>
</tr>
<tr>
<td>4</td>
<td>EACH</td>
<td>1 1/2&quot; Aluminum Collared Nipple</td>
</tr>
<tr>
<td>4</td>
<td>EACH</td>
<td>1 1/2&quot; Locking Ring</td>
</tr>
<tr>
<td>8</td>
<td>EACH</td>
<td>1 1/2&quot; Short Rosette Cap</td>
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<td>LF</td>
<td>#8, Bare Copper Grounding Wire</td>
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<td>EACH</td>
<td>Sign – See Attached Drawing</td>
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<td>1</td>
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<td>Ground Rod (8ft)</td>
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<tr>
<td>1</td>
<td>EACH</td>
<td>Ground Rod Clamp</td>
</tr>
<tr>
<td>1</td>
<td>EACH</td>
<td>Split Bell Base</td>
</tr>
<tr>
<td>2</td>
<td>EACH</td>
<td>55 Watt Solar Panel</td>
</tr>
</tbody>
</table>
## PARTS FOR SOLAR FLASHER - DC OPERATION

<table>
<thead>
<tr>
<th>QTY (UNIT 1)</th>
<th>UNIT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EACH</td>
<td>Charging Regulator, 12 VDC</td>
</tr>
<tr>
<td>2</td>
<td>EACH</td>
<td>Batteries, Gel filled 12 VDC</td>
</tr>
</tbody>
</table>
| 1            | EACH | Solar Array Cap Mounting Assembly" Top of Pole Kit"

A. The Regulator/Charger unit is a solid state device, which shall regulate the photovoltaic (PV) module electrical output to prevent battery overcharge. It shall be encapsulated for environmental protection. LED or LCD indicators shall be provided so that battery condition and/or amount of charge/discharge to or from the battery can be quickly determined.

The unit shall be supplied with a color-coded harness and a complete wiring diagram. Wires shall be a minimum 16 gauge stranded. Termination of the harness wiring to components mounted to pedestal poles, photovoltaic module, and signal beacons shall be accomplished via connectors. Female connectors shall be terminated for ease of installation and male connectors are to be supplied with each harness.

Battery terminals shall be 3/8 inch diameter round crimp terminals. Flasher termination shall be spade terminals. Regulator/charger terminations shall be spade terminals. The harness shall be installed in the controller cabinet using chassis tie downs and riveted to the harness bracket. The harness shall have spiral tubing to protect wires from the control cabinet to the door.

The flashing operation of the unit shall be initiated and terminated by toggle switch.

The flasher shall be:

1. 12 volts D. C.
2. Solid-state with no relays or electro-mechanical devices.
3. 2-circuit with 50% duty cycle (per circuit) and shall provide 55 flashes per minute (±5 flashes per minute) to each circuit in accordance with M.U.T.C.D. standards.

B. Photovoltaic Modules. The photovoltaic module shall provide 12 VDC and be capable of recharging the system to full capacity, after 6 hours of continuous operation, in 3 hours +/- .5 hours during optimum sun conditions in December. The crystalline silicon solar module shall consist of cells that are permanently encapsulated...
between a tempered glass cover and layers of ethylene vinyl acetate (EVA) pottant with a polyvinyl fluoride (PVF) and aluminum foil back sheet to provide a moisture free environment. The module frame shall be made from extruded aluminum alloy and adequately sized to attach the desired number and size of solar panels. The mounting bracket shall have no less than (4) 3/4 inch stainless steel bolts, lock washers, and hex head c, nuts to secure the PV module to the frame. An ultra violet (UV) resistant, weatherproof junction box providing wire termination for up to #8 A WG wiring shall be provided with the PV module.

The photovoltaic module mounting assembly shall be constructed of galvanized steel (ASTM A153 “Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware” Class A) or aluminum, of adequate design and strength to provide a means of securely attaching the PV module frame to a pole at a permanent angle of 45 to 50 degrees. The pole mounting hardware shall accommodate poles ranging from a minimum 4-1/2 inch O.D. steel pole to a wood pole. The bracket shall be capable of 360 degree horizontal orientation with a means of locking the bracket at an inscribed angular position about the pole. Contractor shall supply proper equipment to ensure due south positioning and angle of tile of solar panels.

C. Battery. The manufacturer shall furnish the required number of batteries to meet this Item. The batteries shall be group 29, sealed, gel lead acid batteries. The batteries shall be 12-volt D.C. nominal and have minimum storage capacity of 105 ampere-hours. The deep cycle marine battery shall be maintenance free with internal c venting. The batteries shall be sized to allow twelve (12) days autonomy.

D. Battery Cabinet. The battery cabinet shall be manufactured of sheet aluminum with a minimum thickness of 0.125 inches, or cast aluminum alloy. The cabinet shall be sized to provide adequate space for two group 29 batteries. The cabinet shall have louvers for ventilation and to prevent the accumulation of gasses. There shall also be rubber mats installed on the bottom of the cabinets and two 1/8” drain holes located in the bottom at opposite corners.

The door and its opening shall encompass and constitute the entire area of the face of the cabinet. It shall be hinged via a continuous hinge, which shall be riveted to the door and to the cabinet. The door shall be tightly secured via a three point latching device, which pulls the door snugly against a neoprene gasket affixed to the cabinet body forming a weather-tight seal. The three point latching
device shall be equipped with a locking device that is operated by a number two Carbon Key.

The cabinet shall be equipped with the necessary hardware to provide right top and bottom mountings to a pole with band on post hubs, or 4-1/2 inch O.D. pole clamps as specified in the invitation for bids.

A Harris County approved single battery/control cabinet may be used in place of the separate battery and control cabinets.

E. Warranty. Photovoltaic modules shall have a limited warranty for a minimum period of 10 years. The balance of the equipment described herein shall be warranted for 3 years from the date of completion.

F. Testing. Solar-powered flasher assemblies shall meet or exceed all applicable TMUTCD and/or ITE Standards and these Standard Specifications. In addition to testing or pre-shipment samples, complete testing of school zone flasher assemblies may be required at any time prior to acceptance.

G. Documentation Requirements. Each solar-powered flasher assembly shall be provided with two each of the following documentation.

1. Complete accurate schematic diagrams.

2. Complete parts list including names of vendors for parts not identified by universal part numbers.

3. Complete set of operator manuals.

688.4 Guarantee. The Contractor, by accepting this contract, guarantees all workmanship, materials and equipment performed or furnished and installed under this Item for a period of two year from date of completion and shall, at his entire expense and within said term of guarantee, repair, replace or adjust all faulty, broken, or maladjusted materials and/or equipment furnished and installed under this Item. All L.E.D. lamps shall be warranted for 5 years. The Contractor shall initiate emergency repair service operations on the job site a maximum of 4 hours after notification by Harris County of system failure or malfunction, and the Contractor shall pursue repair operations with all haste in order that signal down time will be kept to absolute minimum. In the event the Contractor fails to respond within 4 hours, Harris County will pursue the repair operations and forward the bills to the Contractor for reimbursement and inform his bonding company. Vandal damage and damage due to automobile accidents or
acts of nature shall not be included under Contractor's guarantee. **Contractor shall sign inspection sheet on all warranty calls.**

688.5 Substitute Materials. Set forth in these Standard Specifications are definite models, materials, etc. of particular manufacturer; however, items of equal appearance, durability, performance and design will be accepted upon approval of the Engineer. The successful bidder is required to submit to the County Engineer's Office, Traffic Signal Maintenance Section, engineering brochures and information on all materials he desires to furnish and install which are of different manufacturer or model number specified herein. The submittal is for approval or disapproval by the Engineer. In the event approval is not obtained, the specified items shall not be furnished and installed. The submittals shall be furnished not later than 2 days after bid opening.

688.6 Control Components. All electronic components within the cabinet shall be mounted to the back panel. The electronic components shall be easily installed or removed with simple hand tools.

Constructed so that each component may be readily replaced if needed.

The Operation units shall include the following components for all the School Zone Flasher Assemblies per system: a low profile disc antenna, a three-point latch for Cabinet Door Assembly (solar), and a 19’ pole.

688.7 Solid State Time Clock. This section of the Item describes the minimum acceptable requirements for an electronic time clock that can automatically change the operation of a traffic signal at predetermined times.

The time clock shall have a day program for each day of the week.

The day program shall have at least six on and six off events per day. Each of these events shall consist of a time in hours and minutes and an output state (on or off). An on/off event shall control a clock output that activates a single pole, double throw relay circuit. "On" and "Off" shall refer to the normally open contact of the relay.

The time clock shall have 10 special event day program. Each special event day program shall be designated by the date in month, day, and year format. Each special event day program shall consist of all the same elements as a day program.

The time clock shall have a holiday feature that will slap a period specified by a starting date and an ending date. The starting and ending dates shall be entered in month/day of month format. If the ending date is earlier than the starting date then the slap period shall be from the starting date to the
ending date of next year (e.g. December 24 to January I). There shall be a minimum of 10 separate holiday programs.

The time clock shall have a digital time-of-day display in hours and minutes of 12 or 24 hour periods. A 12 hour clock shall have an AM-PM indicator. It shall also have a display, which clearly indicates the day of the week. The month and year shall be programmable but need not be displayed except when programming.

The display shall be visible from the face of the time clock, and each display light shall have a minimum size of 0.11 inches. Liquid Crystal Displays (LCD) are acceptable. The LCD's shall be visible over a temperature range from -10°C to + 74°C. All displays shall have a rated minimum lifetime of 10 years.

On/off events shall be easily programmable from the face of the clock via pushbuttons or keyboard entry. The time clock shall also be able to accept an upload program from a computer via RS-232 Port. The clock shall be able to be set to the correct time of day to the nearest minute.

A separate indicator shall be provided to indicate whether the output is on or off.

The output shall have manual on/off control independent of the time clock programming.

The output shall remain in the last state programmed until the next programmed event changes the output state or the output is changed by the manual on/off control or if the current day program is disabled.

The time clock shall automatically switch to and from daylight savings time. This feature shall be enabled or disabled manually by keyboard entry.

The Time clock shall be capable of operating using either a 120 volt A.C. or 12 volt D.C. power supply.

Using an A.C. power supply, the time clock shall operate over a voltage range of 95 to 135 volts A.C. The nominal voltage shall be 120 volts A.C. at an operating frequency of 60 Hz +/- 3.0 Hz. The time-base shall be derived from the 60 Hz line frequency during normal operation. The time clock shall be designed to operate as specified at any ambient temperature range from -34°C to + 75°C. Normal operation accuracy shall be equal to the 60 Hz line frequency.
Using a D.C. power supply, the clock shall operate over a voltage range of 9.5 to 14.5 volts D.C. and maintain an accuracy of 0.02% over the entire ambient temperature range from -34°C to +74°C.

The time clock shall have a power backup capacitor, which shall power the timer for at least 48 continuous hours during the loss of A.C. power. During loss of power, the time clock shall generate its own internal time-base. The clock accuracy while operating on the internal time-base shall be within 0.02% over the entire ambient temperature range from -34°C to +74°C.

During back-up operation, all displays and outputs shall be disabled.

The time clock shall operate correctly and accurately regardless of mounting orientation.

The entire time clock shall be completely wired and equipped with an AMF 206036-1 (16 pin 206037-1 (16 pin female) connector. Each wire of the adapter cable shall be No. 18 AWG stranded copper 24 inches long. The connectors shall have pin and color assignments as follows:

<table>
<thead>
<tr>
<th>PIN</th>
<th>FUNCTION</th>
<th>ADAPTOR-CABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A.C. Positive</td>
<td>Black</td>
</tr>
<tr>
<td>2</td>
<td>A.C. Neutral</td>
<td>White</td>
</tr>
<tr>
<td>3</td>
<td>Chassis Ground</td>
<td>Green</td>
</tr>
<tr>
<td>4</td>
<td>Relay I Normally Open</td>
<td>Red</td>
</tr>
<tr>
<td>5</td>
<td>Relay I Normally Closed</td>
<td>Yellow</td>
</tr>
<tr>
<td>10</td>
<td>Relay I Common</td>
<td>White / Yellow</td>
</tr>
<tr>
<td>11</td>
<td>D.C. Positive</td>
<td>White / Red</td>
</tr>
<tr>
<td>12</td>
<td>D.C. Negative</td>
<td>White / Black</td>
</tr>
</tbody>
</table>

The output relay shall have a normally open, normally closed and common terminal, and these terminals shall be clearly identified. The relay contact shall be rated at a minimum of 10 Amps, resistive load, at either 12 volts D.C. or 120 volts A.C.

The time clock shall be enclosed in a dust resistant housing. The housing door shall expose all adjustments when it is open. The housing shall have an inverted "T" screw hole mount. The bottom two holes shall be 2-5/16 inches apart from center to center. The top hole shall be 5-3/4 inches from its center perpendicular to the line connecting the bottom holes at their centers. The top hole shall be 1 to 1-1/2 inches from the top of the box.
The maximum overall outside dimension of the clock’s housing shall be 10-1/4 inches high by 6-1/4 inches wide by 7-1/2 inches deep.

The time clock shall be completely solid state with the exception of the output relay.

A power loss indication shall be provided. The indication shall be activated upon restoration of A.C. power, or activated only if the A.C. power interruption is of sufficient length to allow the capacitor to discharge or adversely affect the time keeping and memory. The indication shall be reset with a pushbutton switch or by keyboard activation.

When A.C. power is restored, the clock shall resume operation with the event that would be currently in effect had there been no power failure.

All components shall be amply rated with regard to heat dissipating capacity and rated voltage so that with maximum ambient temperature and maximum applied voltage, material shortening of life or shift in value shall not occur. The design life of the components under 24 hours per day operating conditions in their circuit application shall not be less than 10 years.

Components shall be mounted on printed circuit boards. All printed circuit boards shall be made from NEMA grade-10 epoxy glass or equivalent, with two ounces or more copper track. Any wire jumpers included on circuit boards shall be placed in plated through holes that are specifically designed to contain them. Jumpers that are tack soldered to circuit traces or are added to correct board layout errors are not acceptable.

The time clock shall be designed so that the printed circuit boards can be taken apart without desoldering.

All components shall be mounted in such a way that replace anyone defective component can be accomplished using only simple tools.

All components (including transistors, resistors, diodes, capacitors, and integrated circuits) shall be available to Harris County through at least two Contractors of solid state devices. Successful bidders may be required to supply a list of sources for those components which Harris County cannot verify the existence of multiple vendors.

The time clock shall provide a fuse and a transient protection device such as a variator, on the incoming power line to protect the time clock from line voltage surges as described in NEMA Standards Publication TS 1-1989, paragraph TS 1-2.1.8.
The vendor shall provide one spare set of proprietary components including IC’s and programmed PROM’s for every ten time clocks purchased with a minimum of one set per order.

All IC’s with 14 or more pins and all proprietary components shall be mounted in high reliability, high contact force sockets. The sockets shall have thermoplastic bodies meeting Ut Specification 94V-O. Any other IC sockets supplied shall also meet the above requirements.

The clock adapter cable shall be delivered neatly wired into the cabinet.

688.8 Warranty. Photovoltaic modules shall have a limited warranty for a minimum period of 10 years. The balance of the equipment described herein shall be warranted for 3 years from the date of completion.

688.9 Testing. Flasher and school zone flasher assemblies shall meet or exceed all applicable Texas M.U.T.C.D. and/or I.T.E. Standards and these Standard Specifications. In addition to testing or pre-shipment samples, complete testing of school zone flasher or flasher assemblies may be required at any time prior to acceptance.

688.10 Documentation Requirements. Each flasher assembly shall be provided with two each of the following documentation.

   A. Complete accurate schematic diagrams.
   B. Complete parts list including names of vendors for parts not identified by universal part numbers.
   C. Complete set of operator manuals.

688.11 Special Equipment and Materials

   A. Lightning Arrestor. Shall be 2 pole, 3 wire, 175v per pole for 120/240 service. Lightning arrestor shall be installed on the main disconnect box (Joslyn J9200-10, General Electric 9L15ECB001, or approved equal).

   B. Main Breaker. Shall be a minimum 20 amp breaker for the flasher.

   C. Hardware. All hardware used in this construction shall be galvanized; all conduits shall be galvanized rigid steel conduits as per Item 677 “Electrical Conduits for Traffic Signal Installation”. All junction boxes and/or condulets shall have a cover and gasket and shall be located approximately 24 inches above natural ground for accessibility as shown on the drawings.
D. Signal Cables. All traffic signal cable shall be copper insulated jacketed cable in accordance with Item 679 “Insulated Jacketed Traffic Signal Cable”. The number and size of conductors shall be as directed by the manufacturer to service the required signals and according to the National Electric Code or as shown on the drawings. All wires for luminaires shall be minimum 2 conductor #12 wire.

688.12 Signal Heads. All flashing beacons (2 per sign) shall be 12 inch Yellow Polycarbonate amber lenses with visor hood, band-on mounting or approved equal, designed according to Item 690 “Traffic Signal Heads”. Beacons to flash alternately (bouncing ball type).

The number and size of conductors shall be as directed by the manufacturer to service the required signals and according to the National Electric code or as shown on the drawings.

688.13 Pedestal Pole. Poles shall be 19 feet x 4-1/2 inch O.D. pedestal poles and shall be designed in accordance with the drawings.

688.14 School Zone Signs. Shall be school zone signs (24 inches x 48 inches) as shown on drawings.

688.15 Warning Signs. Shall be “Slow When Flashing” signs (48 inches x 48 inches) or as shown on drawing sheet(s).

688.16 Signs. All required construction signs and regulatory signs shall be in accordance with the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways" as shown on the drawings.

688.17 Other Specifications Requirements. Harris County with Mutual Contractor approval reserves the right to extend the quantity by up to 100 percent within 18 months from the date of Purchase Order, at the same price, terms and conditions. For additional quantities Harris County will issue a work order to the Contractor with the number of School Zone Pager System Flasher Assembly (not less than 4 School Zone Pager System Flasher Assembly per shipment) and the delivery schedule shall be 45 calendar days from work order date for 4 School Zone Pager System Flasher Assembly and 60 calendar days. The School Zone Pager System Flasher Assembly shall be shipped with all components contained within the assembly.

688.18 Test and Acceptance of ITS Assembly. The Contractor shall setup and demonstrate to Harris County the system 5 calendar days from the date of award. A Factory Representative shall be present with Harris County to inspect and test the system.
688.19 Basis of Payment. The basis of payment shall be lump sum bid or unit price bid as they appear on the bid sheets for the completed contract, which bids shall be for full compensation for all costs of labor, materials, tools, equipment, tests, adjustments, and all other incidentals necessary to construct the complete traffic signal system according to specifications and drawings and to the satisfaction of the Engineer.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires drawings that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications

Item 677 “Electrical Conduits for Traffic Signal Installation”
Item 679 “Insulated Jacketed Traffic Signal Cable”
Item 690 “Traffic Signal Heads”

END OF ITEM 688
ITEM 689

TWELVE INCH LED TRAFFIC SIGNAL LAMP UNIT

689.1 Description. This Item shall govern for the minimum acceptable design and performance requirements for a 12 inch (300 mm) light emitting diode (LED) traffic signal lamp unit for use in various Traffic Signal Head Assemblies.

689.2 Units of Measurements. The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

689.3 Material Producer List. The Harris County Engineering Department maintains the Material Producer List (MPL) of all materials conforming to the requirements of this Item. Materials appearing on the MPL, need no further sampling or testing unless deemed necessary by the Engineer.

689.4 Bidders’ and Suppliers’ Requirements. The Engineer will purchase or allow on projects only those products listed by manufacturer and product code or designation shown on the MPL.

Use of pre-qualified product does not relieve the Bidder of the responsibility to provide product that meets this Item. The Engineer may inspect or test material at any time and reject any material that does not meet the specifications.

689.5 Pre-Qualification Procedure.

A. Pre-Qualification Request. Prospective producers interested in submitting their product for evaluation must submit a written request to:

Harris County Engineering Department
10555 Northwest Freeway, Suite 140, Houston, TX 77092
Attn: Traffic Signal Maintenance

B. Pre-Qualification Samples. Ship two samples of each color indication and type from a normal production run of each LED traffic signal lamp unit model requesting acceptance to:

Harris County Engineering Department
10555 Northwest Freeway, Suite 140, Houston, TX 77092
Attn: Traffic Signal Maintenance
Provide additional samples when directed by the Engineer.
All products submitted for pre-qualification tests must be at no cost to the Engineer.

Provide the following with pre-qualification samples:

1. Manufacturer name and contact information
2. Brand and model number of LED traffic signal lamp unit
3. LED Manufacturer’s recommended drive current and degradation curves
4. One schematic diagram for each LED traffic signal lamp unit model being evaluated, along with any necessary installation instructions
5. Copy of the manufacturer’s International Organization for Standardization ISO 9000 certification, or Latest Edition, (including date)
6. Copy of the manufacturer’s quality assurance (QA) testing procedures
7. Letter from the manufacturer confirming compliance to this Item
8. Testing procedures explaining compliance to this Item, in addition to the I.T.E. tests
9. Letter confirming participation from ETL/INTERTEK LED Traffic Signal Modules Certification Program; confirming each LED traffic signal lamp unit model’s compliance with this Item, including Section 689.7 as well as the latest pertinent I.T.E standards.
10. Manufacturer’s written warranty against defects in materials, design and workmanship for LED traffic signal lamp units for a period of 60 months after installation

C. Sampling and Testing. The Engineer will connect all samples submitted to the Engineer’s ITS Traffic Signal Control Cabinet and will test to I.T.E. Vehicle Traffic Control Signal Heads (VTCSH) environmental standards. All LED units must be operational at the conclusion of the test and must not cause Conflict Monitor
(MMU/CMU) trip conditions in the controller/cabinet during testing.

During the environmental testing, the Engineer may evaluate the samples for chromaticity and intensity after 8 hours of soaking at −40°F (−40°C) and 165°F (74°C), at low (80 VAC) and high (135 VAC) voltages.

The Engineer will conduct destructive testing to determine that the units are in conformance with the catastrophic LED failure clause.

D. Evaluation. The Engineer will return to the submitting party a letter of confirmation or rejection for each model submitted. For each rejected model, TSM will issue a test report along with the letter of rejection.

1. Qualification. If approved for use by the Engineer, the product will be included in the MPL. Any deviation in product design after testing and approval from the Engineer constitutes a new model which must be resubmitted for acceptance.

If a manufacturer determines there is reason to remove a model from the MPL, they must submit a letter to the Engineer identifying the problem in writing. The Engineer will remove the model without prejudice. Once the problem has been resolved to the Engineer's satisfaction, the manufacturer may apply for re-qualification for the new model.

All submitted materials become the property of the County.

2. Failure. Products not qualified under this Item may not be furnished on County projects and must be corrected of all deficiencies before reconsideration for qualification.

If products fail to meet any of the specification requirements, the producer may not resubmit for pre-qualification until one year from original evaluation date. The Engineer may waive this time limit if provided with documentation from an independent testing facility stating the product meets all requirements. The Engineer will enforce the one year time limit if, after retesting, the product again fails any of the specification requirements.

Costs of sampling and testing are normally borne by the County; however, the costs of sampling and testing products
failing to conform to the requirements of this Item are borne by the contractor or supplier. This cost will be assessed at the rate established by the Engineer and in effect at the time of testing for each recurring non-compliant submittal.

Amounts due to the County will be deducted from monthly or final estimates on contracts or from partial or final payments on direct purchases by the County.

E. Disqualification. The following conditions are cause for immediate removal from the MPL:

1. A problem is found to exist with a LED traffic signal lamp unit (e.g. unsafe failure condition or excessive failure rate)
2. Excessive complaints about a manufacturer’s compliance to Section 689.8
3. Manufacturer deviates LED traffic signal lamp units from pre-qualified units without prior testing and approval from the Engineer.

If the Engineer removes a model from the MPL for cause other than manufacturer’s recommendation, the manufacturer may not resubmit for approval for a minimum of one year.

The Engineer may reinstate a model on the MPL under a different model number, if all problems identified have been corrected, and the new model no longer exhibits the same. The Engineer must approve of the new model as a successful replacement.

F. Periodic Evaluation. The Engineer may perform random sample testing on shipments, to be completed within 30 days after delivery.

The Engineer will perform optical testing with the module mounted in a standard traffic signal section, but without a visor or hood attached to the section or housing. The quantity of each model in the shipment will determine the number of modules tested. The sample size will conform to ANSI/ASQC Z1.4. The Engineer will determine the sampling parameters used for the random sample testing. All parameters of the specification may be tested on the modules. Acceptance or rejection of the shipment will conform to ANSI/ASQC Z1.4 for randomly sampled shipments.

689.6 Material Requirements.
A. General Requirements. All LED traffic signal lamp units must conform to the Latest Edition of the Institute of Transportation Engineers (I.T.E.) Vehicle Traffic Control Signal Heads – Light Emitting Diode (LED) Vehicle Arrow Traffic Signal Supplement standard, the I.T.E Vehicle Traffic Control Signal Heads – Light Emitting Diode (LED) Circular Signal Supplement standard, and this Item. In the case of conflicts between standards and specifications, the latest County specifications will govern.

The LED traffic signal lamp unit must be designed as a retrofit replacement for existing signal lamps and will not require any special tools for installation. The 12 inch retrofit replacement LED traffic signal lamp unit must fit into existing traffic signal housings without modifications.

Installation of a retrofit replacement LED traffic signal lamp unit into existing signal housing must only require removal of the existing lens, reflector, and incandescent lamp; fitting of the new unit securely in the housing door; and connecting to existing electrical wiring or terminal block by means of simple connectors.

For proper orientation of the LED traffic signal circular lamp unit prominent and permanent directional marking(s), i.e. an “UP arrow” or equivalent, for correct indexing and orientation must exist on the unit. LED traffic signal arrow lamp units when required shall be omni-directional only with permanent markings, i.e. “Suitable for mounting in any direction” or equivalent.

Each LED traffic signal lamp unit shall have the manufacturer's name, trademark, model number, serial number, lot number, month and year of manufacture, and required operating characteristics, including rated voltage, power consumption, and volt-ampere, permanently marked on the back of the module. Serial Number schemes that clearly identify the date of manufacture will be considered.

Each LED traffic signal lamp unit shall have a symbol indicating module type and color. Symbol must be an inch in diameter. Color must be written out in 0.50 inch high letters next to the symbol.

Each LED traffic signal lamp unit shall have a certification label from ETL/INTERTEK LED, which provides ongoing verification of production to pertinent standards.

Any deviation to product design after testing and approval from the Engineer will constitute a new model and must have a new model number. The new model must be submitted for acceptance. Failure to adhere to this requirement will be grounds for automatic removal from the MPL until the Engineer approves an alternative solution. Random testing of average production LED traffic signal lamp units will be conducted to ensure compliance with this Item.

B. Physical and Mechanical Requirements. The LED traffic signal lamp unit must be a single, self-contained device, not requiring on-site assembly for installation into existing traffic signal housing.

The assembly and manufacturing process for the LED traffic signal lamp unit must ensure that all internal LEDs and electronic components are adequately supported to withstand mechanical shock and vibration from high winds and other sources.

Each LED traffic signal lamp unit must be comprised of a UV stabilized polymeric outer shell, multiple LED light sources, and a regulated power supply. LEDs must be mounted on a printed circuit board/heat sink assembly.

C. Optical and Light Output Requirements. The LEDs must be manufactured using AlInGaP (Aluminum-Indium-Gallium-Phosphide) technology and/or InGaN (Indium-Gallium-Nitride) LEDs. The AlGaAs (Aluminum-Gallium-Arsenic) LEDs will not be allowed.

Designs that require the LEDs to be operated at currents greater than the LED manufacturer’s published recommended drive current will not be allowed.

Each LED traffic signal lamp unit must meet minimum laboratory light intensity values and light output distribution as described in I.T.E. Vehicle Traffic Control Signal Heads (VTCSH) - LED Supplements for a minimum period of 60 months, based on normal use in traffic signal operation over an operating temperature range of −40°F (−40°C) to 165°F (74°C).

Measured chromaticity coordinates of LED traffic signal lamp units must conform to the chromaticity requirements detailed in the I.T.E.
VTCSH LED Circular Signal Supplement, Section 4.2: Chromaticity, or in the I.T.E. VTCSH LED Vehicle Arrow Traffic Signal Supplement, Section 4.2: Chromaticity, for circular or arrow indications respectfully for a minimum period of 60 months.

LED lamp units shall be non-tinted, with an incandescent appearance and meeting the criteria of this Item.

LED traffic signal lamp units tested or submitted for testing must be representative of typical production units. Perform optical testing with LED units mounted in standard traffic signal sections without visors or hoods attached to the signal sections.

A copy of the lab test report from an NRTL for each LED traffic signal lamp model must include light intensity values at each I.T.E. specific distribution test point (balls supplement Table 1 or 2, for arrow supplement Table 4). The lab report must document current, voltage, and total harmonic distortion (THD) for each test point. The power factor (PF) associated with each model must be documented.

D. Electrical Requirements. Each LED traffic signal lamp unit must incorporate a regulated power supply engineered to electrically protect the LEDs and maintain a safe and reliable operation. The power supply must provide capacitor filtered DC regulated current to the LEDs per the LED manufacturer specification. The power supply must be designed so that the failure of an individual component or any combination of components cannot cause the signal to be illuminated after source power is removed.

LED traffic signal lamp units must be operationally compatible with all cabinet designs.

Under normal operating conditions, the LED lamp unit must operate without inhibiting any Conflict Monitor (MMU/CMU) monitoring features.

If a 20 mA alternating current or less is applied to the unit, the voltage read across the 2 leads must be 15 VAC or less.

Arrow and circular LED traffic signal lamp units must be designed to sense a loss of light output due to catastrophic LED failure and react in compliance with the failed state impedance provision of the I.T.E. VTCSH Circular Signal Supplement, Section 5.7. LED Arrow indications must trip the Conflict Monitor (MMU/CMU) after no more than 15 percent to 25 percent LED loss occurs. The LED unit must
always be recognizable as an arrow indication for any loss less than this trip condition.

Two, captive, color coded, 600 V, 18 AWG minimum jacketed wires, 3 feet or 1 meter long, conforming to the National Electric Code, rated for service at 22°F (105°C), are to be provided for an electrical connection.

The LED traffic signal lamp units must have on-board circuitry including voltage surge protection, to withstand high-repetition noise transients and low-repetition high-energy transients as stated in NEMA Standard TS 2-2003, Section 2.1.8, except voltage must be 2000 V instead of 1000 V. The circuitry must also be able to withstand high-repetition low-energy transients as stated in NEMA Standard TS 2-2003, Section 2.1.6.

E. Environmental Requirements. Environmental requirements must meet or exceed I.T.E. VTCSH LED Standard Supplements.

The LED traffic signal lamp units must be rated for use in the ambient operating temperature range of −40°F (−40°C) to 165°F (74°C).

The LED traffic signal lamp units must be dust and moisture tight to protect all internal LED and electrical components.

The LED traffic signal lamp units must consist of a housing that is a sealed, watertight enclosure to eliminate dirt contamination and allow for safe handling in all weather conditions. Perform moisture resistance testing on LED signal modules in conformance with the requirements in the I.T.E. VTCSH LED Standard Supplements. Evidence of internal moisture after testing will be cause for rejection.

F. Production Testing Requirements. A quality assurance (QA) program must be in place at the manufacturer’s facility to ensure product reliability.

Each new LED traffic signal lamp unit must be energized at the manufacturer’s facility for a minimum of 24 hours at nominal operating voltage (120 VAC RMS) at room temperature in order to ensure electronic component reliability prior to shipment.

689.7 Documentation Requirements. Provide each LED traffic signal lamp unit with, as a minimum, the following documentation:
A. Complete and accurate installation wiring guide

B. Contact name, address, telephone number and email address or webpage for the representative, manufacturer, or distributor for warranty repair

C. If requested by the purchaser, the bidders must supply schematics for all electronics

D. LED Manufacturer’s recommended drive current and degradation curves

E. Compliance letter specified in Section 689.8

F. Certification document specified in Section 689.8

G. Bidders must submit a copy of a test report, certified by an NRTL, stating that the LED traffic signal lamp model submitted meets or exceeds the latest I.T.E. VTCSH LED Supplemental Standards. The NRTL report must include documentation of tests and verification of compliance to the additional provisions of this standard. Tests performed by the independent lab must follow all the instructions documented in the latest I.T.E. VTCSH circular signal supplement or latest I.T.E. VTCSH arrow supplement as it pertains to the product being tested. The I.T.E. criteria in Section 6 Quality Assurance must be documented in the submitted test report.

Manufacturers must be certified to International Organization for Standardization ISO 9000, or Latest Edition.

689.8 Warranty Requirements. Manufacturer must comply with all requirements of the following warranty. Failure to comply with the requirements of this warranty is cause for the manufacturer/supplier to be removed from the MPL.

The manufacturer/provider must submit a letter of compliance indicating understanding and willingness to abide by the provisions of this Item. The manufacturer/provider must provide name and telephone number of the person to contact regarding potential claims under the provisions of this warranty. Address the compliance letter to:

Harris County Engineering Department
10555 Northwest Freeway, Suite 140, Houston, TX 77092
Attn: Traffic Signal Maintenance
The LED traffic signal lamp units must be warranted against any failure due to design, workmanship, material defects, and loss of intensity for 60 months of field operation. Units must meet or exceed minimum requirements of this Item for a minimum of 60 months of field operation.

Repair or full replacement will be required if a LED traffic signal lamp unit fails to operate as specified under normal operating conditions. Provide repaired or replaced units at no cost to the Engineer. Repaired units will inherit the remainder of the failed unit’s warranty. Replaced units will be warranted for 60 months of field operation.

Should a lamp unit fail with no visible damage to electronic/electrical components, (not including fuses or components designed to act as a fuse) or wiring, the unit is considered to have failed under normal operating conditions. A blown fuse or a component acting as a fuse, without any other permanent failure to electrical, electronic components will be considered to have failed under normal operating conditions. Natural phenomena (e.g. lightning) are not acceptable as excusable unit failures without visible damage.

Repair or replace LED traffic signal lamp units within 15 business days after receipt of failed LED units. All shipping costs will be borne by the vendor or manufacturer.

The manufacturer/provider must submit a certification document with each lot or shipment stating that the LED lamp units provided meet all the requirements of this Item.

The certification document must show individual lot numbers and manufacturer dates.

The Engineer reserves the right to select a sample from the field during the warranty period and perform evaluation tests to determine extended compliance and/or deterioration of the LED traffic signal lamp unit. Any model that shows deterioration of unit causing the unit to fail the evaluation tests during the warranty period will be automatically removed from the MPL, and the submitting party may be held legally responsible for all damages.

689.9 Measurement and Payment. LED traffic signal lamp units when supplied as part of a traffic signal head assembly, will not be paid for directly, but shall be incidental to assemblies defined by Item 690 “Traffic Signal Heads” and/or Item 691 “Twelve- Inch Signal Head with Programmable Visibility of Signal Faces”, any pertinent Special Provisions and Standard Drawings (if applicable).
LED traffic signal lamp units when supplied individually shall be paid for by each type and color required.

There are line code(s), description(s), and unit(s) for this Item.

**NOTE:** This Item requires other Standard Specifications

Item 690 “Traffic Signal Heads”
Item 691 “Twelve- Inch Signal Head with Programmable Visibility of Signal Faces”

END OF ITEM 689
ITEM 690

TRAFFIC SIGNAL HEADS

690.1 Description. This Item shall govern the minimum design and requirements for adjustable face aluminum or polycarbonate functional requirements for traffic control signal heads and signal heads hardware.

690.2 General. The traffic control signal heads shall be in accordance with the Latest Edition of Institute of Transportation Engineers (ITE) Technical Report No. 1, except as noted below. The Contractor shall supply written certification of compliance from the manufacturer.

Each traffic signal face shall consist of a number of signal sections rigidly fastened together in such a manner as to present a continuous pleasing appearance. Assembled signal sections shall not exhibit light leakage.

The traffic signal head shall consist of a system of one or more signal faces installed and illuminated in a definite sequence by a remote timing device, which shall indicate to traffic approaching the signal face the right of way at the intersection or giving warning of existence of a hazardous condition, thus facilitating an orderly movement of traffic through the intersection.

Structural requirements for aluminum and polycarbonate materials are described in Section 690.4.

Unless otherwise specified in the drawings, the material for the mounting attachments shall be cast aluminum alloy.

The signal, including one or more LED modules, shall be sectional in construction, requiring one section for each module.

The design of the signal shall be such, that with the aid of simple tools and addition of standard signal fittings; these signal assemblies with the addition of standard bracket assemblies will assemble into two-way, three-way, four-way and horizontal signal head configurations.

690.3 Standard Signal Face & Heads. Signal face and signal arrangement shall be as shown in the drawings; and conform to the Latest Edition of the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways".

The "Standard Signal Face" shall consist of three or more LED modules, each mounted in an individual housing case.
All housing cases of each of the multiple-way signal heads shall be rigidly attached, at top and bottom, to 1-1/2 inch (38mm) (inside diameter) tubular supporting arms radiating from hubs at the vertical central axis of the head and rigidly attached thereto in a manner that will assure permanent alignment of the separate housings. The hub shall be designed to conform to the type of mounting attachment specified in the drawings and provisions shall be made for carrying the leads from each housing enclosed in the supporting arms to a single outlet in the mounting attachment. All units of the assembled head shall be of adequate strength for the purpose intended and shall be constructed of materials not affected by continuous exposure to corrosive atmospheres, particularly salt air.

A metal spacer in place of the bottom pipe bracket will be acceptable for multiple-way span-wire and mast-arm mounted signal heads.

Signal Faces to be installed vertically or horizontally on mast arms shall be mounted by the appropriate and necessary hardware as approved by Harris County. Any signal heads to be installed vertically or horizontally on the signal pole shall likewise be mounted by hardware as approved by Harris County.

Unless otherwise called for in the drawings, all supporting arm assemblies shall have threaded connections, not welded, and shall be assembled with full threaded crosses, not elbows.

690.4 Housings. The Polycarbonate resin material with sides, top, and bottom integrally molded. The housing shall be injection molded from ultraviolet and heat stabilized flame retardant, permanently colored polycarbonate resins. The housing shall at least 0.125 inches (3.18 mm) thick anywhere on the housing and shall be internally ribbed so as to produce the strongest possible assembly consistent with light weight. The terminal block shall either be securely mounted or integrally molded into the housing (see Section 690.4, Paragraph 11).

The silicon aluminum alloy traffic signal housing cases, also designated herein as optical-unit housings, if required in the drawings, shall be die cast of a silicone aluminum alloy by a process imparting a smooth homogeneous finish. Casting shall be accurately formed and free from pouring faults, sponginess, cracks, blowholes, or other defects affecting their strength and appearance.

All visors shall be of a silicon aluminum alloy and may be of cast material or of sheet metal having a minimum thickness of 1/16 inch (1.6 mm).
The signal housing cases, fittings, and accessories shall be of noncorrosive, rust resistant material capable of withstanding constant exposure to sunlight and corrosive atmospheres, including salt air, and shall provide adequate strength for the purpose of which it is utilized.

Provision shall be made for accommodation of the particular type of mounting specified and attachment of doors, optical units, and other such accessories as may be specified for the particular installation. All traffic signal housing cases, together with doors, lenses, and mounting attachments shall comprise a dust and moistureproof housing for the LED module, connecting wiring, and terminal block. The housing cases shall be of such construction as to assure permanent alignment of the lens in the traffic signal face. Design of door, housing, and visor shall be such that no light is visible in the profile view of the traffic signal face.

Traffic control signal housing cases shall be of the sectional adjustable expandable type. The assembled housings for each signal face shall consist of three or more individual sections, each designed for housing a single complete LED module. Individual signal sections shall be rigidly attached to form a single "Signal Face" either with at least four machine screws between each section or by the three bolt and two washer method. Complete signal faces shall provide positive locked positioning when used with serrated brackets, mast arm, or span wire fittings.

The top and bottom of each signal section shall be provided with a serrated ring surrounding a two inch diameter hole, such that positive locking of signal faces can be accomplished when mounted with serrated ring.

The serrated ring at the top of each signal shall be raised 0.128 inches above the surrounding body and rib plane to prevent water trapped between signal sections or falling on top of a signal from entering into the housing.

Portions of cases providing for attachment to supporting arms shall be molded with large bosses for the supporting arms. Each housing case shall be so attached to its supporting arm that it will be adjustable by rotation about its vertical axis in such a manner that any pair of adjacent cases may be adjusted individually to give indications in two directions as close as 15 degrees apart and may be rigidly clamped in any position throughout the range of adjustment. Provision shall be made for carrying the traffic signal leads enclosed in the mounting attachment.

Both the top and bottom of each traffic signal housing case shall be provided with an opening of two inches (50 mm) in diameter to accommodate 1-1/2 inch (38 mm) pipe brackets. A locking ring shall be
integrally cast or molded around the bottom opening. Around the top opening shall be either an integrally cast or molded locking ring or a separate splined locking ring designed to fit into notches. The locking rings shall have a minimum of 46 evenly spaced teeth and shall be so designed that the top and bottom rings will mate to provide a perfectly aligned signal head with flush connection between the outer circumference of the sections.

Threaded metal inserts shall be provided in a walled off portion of each signal for terminal block mounting. It shall be possible to place and insulating cover over the terminal block that will match the wall surrounding the terminal block.

Any open end of an assembled beacon face housing shall be plugged with an ornamental cap and gasket.

**690.5 Housing Door.** The housing door of each traffic signal housing shall be a one piece polycarbonate resin material or die cast in a silicon aluminum alloy with an approximate 12 inch (300 mm) diameter circular opening for the lens as specified. The door must be of the same material as the housing. The housing door shall be at least 0.125 inches (3.18 mm) thick anywhere on the housing door.

A. Silicon Aluminum Alloy Door. The door shall be provided with hinges and lugs for attachment to the main body casting, so spaced as to hold the door in perfect alignment when closed. The door shall be securely gasketed to the traffic signal housing with a weatherproof gasket.

B. Polycarbonate Resin Door. The door shall be attached to the housing by means of two stainless steel hinge pins.

Two stainless steel wing screws shall be installed on the side of the door to provide for opening and closing the door without the use of tools. Wing screws shall have a flat-bearing surface or stainless steel flat washer to prevent gouging of the housing door by the wing screws. Wing screws shall remain captive in the housing door when the door is open.

**690.6 Visors.** Each traffic signal housing door shall be equipped with an easily detachable standard tunnel or full circle visor (unless otherwise indicated). The visor shall be a polycarbonate resin or a silicon aluminum alloy to match the housing and door. The visor shall be rigidly attached to the door with stainless steel screw type connections in a manner that will prevent the leakage of light and moisture throughout the periphery of attachment.
Unless otherwise called for in the drawings, the visor on the front of each door shall:

A. Be circular in section;

B. Have a downward tilt of 2 to 8 degrees;

C. Encompass approximately 300 degrees of the lens;

D. Extend outward from the face of the lens a minimum of 9-1/2 inches (240 mm) for 12 inch (300 mm) diameter lens (measured at its outer visible circumference);

E. Be of such design that the encircled portion of the lens will not be visible in the profile view of the traffic signal face; and,

F. Be open at the bottom so as to prevent the accumulation of snow and dirt

Visors shall be easily removed and replaced without damage to visor or signal head.

690.7 Terminal Blocks. Each optical unit shall be wired to a two-post terminal block located in that signal section. The terminal block in the top or red signal section shall have a six-post terminal block. All sections of the signal face assembly shall be wired to the six-post terminal ready for field installation. All terminal blocks shall be securely mounted in an accessible position and shall be of weatherproof molded construction, equipped with identified terminals. Binding screws shall be provided for the field and interior wires.

If specified, and/or shown in the drawings, a Terminal Compartment shall be provided for the side of pole-mounted signal heads in addition to the signal face assembly terminal block specified above. The terminal compartment shall be located as called for in the item description and drawings.

The Terminal Compartment shall be equipped with a readily accessible moistureproof cover and weatherproof molded-construction connector block with identified terminals for signal and field wires. Separate terminals shall be provided for the interior wires and the field wires. In addition to the interior wires required above, the supplier is also required to furnish and install all other leads necessary to connect the terminal block of the multiple section face to the terminal block in the Terminal Compartment. Each lead shall be brought to a separate terminal in the Terminal Compartment except that the commons from one housing can all
be brought to the same terminal in the Terminal Compartment. The color coding on leads from the individual optical units shall be maintained from the lamp holder to the individual terminals in the signal head Terminal Compartment except that the commons from each housing shall be grouped and carried to one terminal. The wiring shall be so arranged that any one optical unit can be individually illuminated through connections to terminals in the Terminal Compartment.

The Terminal Block installed in the Terminal Compartment shall be equipped with Pressure-Type Connectors having a minimum capacity of two No. 12 AWG solid-copper conductors per connector and shall be provided with barriers and rated for 25 amperes, 250-volt service. This multiple-connector terminal block is to be equipped with a minimum of twelve sets of connectors, with separate terminals for the interior and the fieldwire connections. Any variations from the above requirements will be covered in the Standard Traffic drawings.

Use of Terminal Compartments containing terminal blocks does not eliminate the requirement for terminal blocks specified above.

690.8 Mounting Attachments. All mounting attachments shall be cast aluminum specified in the drawings.

Provision shall be made for carrying the signal leads enclosed in the mounting attachment. The mounting attachment together with supporting arms and assembled housings, shall comprise a dust-and-moisture-proof enclosure for optical units and lead wiring.

690.9 Traffic Signal Hardware. Horizontal Signal Head Span Wire Hardware Kit. The hardware shall be in accordance with drawing number 1, which is part of this specification. All hardware shall be packaged in the same box.

Horizontal Signal Mid Mast Arm Kit. The hardware shall be in accordance with drawing number 2, which is part of this specification. All hardware shall be packaged in the same box.

Horizontal Signal End Mast Arm Kit. The hardware shall be in accordance with drawing number 3, which is part of this specification. All hardware shall be packaged in the same box.

Vertical Signal Kit. The hardware shall be in accordance with drawing number 4, which is part of this specification. All hardware shall be packaged in the same box.

690.10 Material & Colors (Polycarbonate Signal Faces and/or Signal Heads Only). All material used in construction of major traffic signal components shall
be polycarbonate resin. This material shall withstand 70 foot-pounds (95 Joules) of impact without fracture or permanent deformation.

Material for hardware shall be cast aluminum of adequate strength for the intended purpose.

The color of the completed traffic signals shall be Federal Yellow with the exception of the underside of the visors which shall be painted a flat black. The yellow color shall be completely impregnated in the resin material.

690.11 Paint & Painting (Metal Signal Faces and/or Signal Heads). Before shipment, all exposed metal surfaces except for the inside of the visors of the assembled traffic signal head shall be given two coats, separately baked on, of high grade highway yellow enamel. The inside of the visors shall be provided with two coats of high grade dull black finish paint.

Any variation in color of enamel will be covered in the Item Description.

690.12 Guarantee. The signal shall be guaranteed against imperfections in workmanship or material for a period of 2 years from date of completion.

690.13 Measurement and Payment. Traffic Signal Heads shall be paid by each signal head assembly installed, including all required mounting hardware.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires drawings that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications

Item 689 “Twelve Inch LED Traffic Signal Lamp Unit”

END OF ITEM 690
ITEM 691

TWELVE INCH SIGNAL HEAD
WITH PROGRAMMABLE VISIBILITY OF SIGNAL FACES

691.1 Description. This Item shall govern 12 inch adjustable programmable limiting traffic signal heads which shall permit the visibility zone of the indication to be determined optically.

The head shall employ no louvers or hoods to obtain this programmable limitation, however, if required, hoods shall be provided to eliminate extraneous light falling on the lens.

The projected indication may be selectively visible or veiled anywhere within 15 degrees of the optical axis.

691.2 Optical System. The optical system shall consist of the following basic components:

A. Lamp

B. Lamp Collar

C. Optical Limiter-Diffuser

D. Objective Lens

All other minor components necessary for the full utilization of the programmable head shall be provided.

The lamp shall be a LED module with no greater than 25 watt rating. The lamp shall have an average rated life of at least 5 years. Each supplied lamp shall be red, yellow or green as specified in design drawings.

The optical limiter shall provide an accessible imaging surface at focus on the optical axis for objects 900 to 1200 feet distance. It shall permit an effective veiling mask to be variously applied as determined by the desired visibility zone.

The objective lens shall be a high resolution planar incremental lens. The lens shall be symmetrical in outline so that it may be rotated to any 90 degree orientation about the optical axis.

The optical system shall accommodate projection of diverse, selected indicia to separate portions of the roadway such that only one indication
will be simultaneously apparent to any viewer. The projected indication shall conform to ITE transmittance and chromaticity standards.

691.3 Construction. Signal housings shall be die-cast conforming to the latest ITE specification alloy and tensile requirements. The exterior of the signal housing, lamp housing and mounting flanges shall be finished with two coats of separately baked on high quality enamel paint. The exterior color of the signal head with the exception of the inside of the visors shall be Federal Yellow unless otherwise specified on the drawings. The inside of the visors shall be painted a dull black.

Hinges and latch pins shall be stainless steel.

All access openings not otherwise utilized for mounting hardware or other purposes shall be sealed with weather resistant rubber gaskets so that the resulting housing shall be moisture and dust proof.

The complete signal head shall consist of three or more individual sections, as shown on the drawings. The lens to be furnished likewise shall be as shown on the drawings. Heat resistant tape or other masking material shall be provided in sufficient quantity to adequately tape or mask all sections as specified. Lamps as specified shall be provided for each required signal section so that each signal head will be a complete unit.

Lamp fixture shall comprise a separately accessible housing and integral lamp support, ceramic socket and self-aligning, quick release lamp retainer. Each signal section shall include a terminal block for screw-type attachment of lead wires. Concealed No. 18 stranded and coded copper wire shall interconnect all sections to permit field connection within any section.

691.4 Mounting and Installation. The signal shall mount to standard 1-1/2 inch fittings as a single section, multiple sections or in combination with other signals. The fittings shall be provided with the signal head and shall be mounted as indicated on the drawings. The signals shall be mountable with ordinary tools and capable of being serviced with no tools.

691.5 Guarantee. It is normal trade practice for the manufacturer to furnish a guarantee for the work provided herein. The Contractor shall turn this guarantee over to the Engineer for potential dealing with the guarantor. The extent of such guarantee will not be a factor in selecting the successful bidder.

691.6 Measurement and Payment. Programmable Traffic Signal Heads shall be paid by each signal head assembly installed, including all required mounting hardware.
There are line code(s), description(s) and unit(s) for this Item.

END OF ITEM 691
ITEM 692

PEDESTRIAN SIGNAL HEAD

692.1 Description. This Item shall govern the minimum acceptable requirements for a pedestrian signal head with housing and doors made of die cast aluminum alloy or polycarbonate resin material.

692.2 General. The design, material, and construction of the pedestrian signal heads shall be in accordance with the requirements for the LED type signal set forth in the latest "Adjustable Face Pedestrian Signal Head Standard" of the Institute of Traffic Engineers.

These signals may be used alone or in conjunction with traffic signals in a complete assembly.

692.3 Design Requirements for the Housing Case and Door. The front of the signal shall be approximately square and no larger than necessary to accommodate the message.

The signal head shall be a one piece assembly constructed of die cast aluminum alloy, or molded polycarbonate. Polycarbonate housing cases shall be a minimum of .250 inches thick and shall be ribbed for strength. Polycarbonate cases and doors shall have ultraviolet inhibitors to reduce deterioration due to exposure to light. Openings in the top and bottom of the signal head shall accommodate a standard 1-1/2" (38mm) bracket arm.

The signal head shall contain 1 four point terminal with the two common points wired together by the supplier. The terminal block shall accommodate AWG 12 field wires.

The assembly shall provide a dustproof and weatherproof enclosure and shall provide easy access to all components.

All gaskets shall be continuous neoprene gaskets.

Aluminum doors shall be a one-piece corrosion resistant, aluminum alloy casting with two hinged lugs cast at the bottom and two latch slots cast at the top of each door. Two stainless steel wing screws or wing nuts shall be used to open and close the door. Latching or unlatching the door shall not require tools.

Polycarbonate doors shall be one piece and shall be a minimum of 0.250 inches thick with two hinged lugs at the bottom and two latch slots at the
top of each door. Two stainless steel wing screws or wing nuts shall be used to open and close the door. Latching or unlatching the door shall not require tools.

692.4 Each signal head shall be furnished with a flush "egg-crate" type visor with diagonal and horizontal louvers to eliminate sun phantom. The visor may be part of a one piece door/visor assembly.

692.5 Mounting Attachments. The type of mounting attachments shall be traditional unless otherwise specified.

Traditional Mounting (option which must be specified by purchaser). All mounting attachments shall be of adequate strength for the purpose intended and shall be constructed of materials not affected by continuous exposure to corrosive atmospheres, particularly salt air. Provisions shall be made for carrying the signal leads enclosed in the mounting attachment. The mounting attachments together with supporting arms and assembled housings, shall comprise a dust and moisture proof enclosure for optical units and lead wiring. Mounting attachments shall be of the design shown on the attached drawings or as described on the item description.

All bracket arms shall be fabricated from 1-1/2 inch (38mm) diameter aluminum pipe.

Threaded crosses shall be used to make all joints in the bracket assemblies. All segments of these crosses that are not attached to a bracket arm shall be plugged with an ornamental plug and a gasket.

692.6 Paint/Painting. All exposed metal surfaces of the assembled pedestrian traffic signal head with mounting attachments shall be given (2 coats of high grade Federal Yellow enamel as used by the manufacturer of the signal equipment. Each coat shall be separately baked. Powder coating is acceptable.

692.7 Shipment and Delivery. Each pedestrian signal head shall be delivered completely assembled and wired without the lamp installed. Each signal head shall be ready for immediate installation.

Each signal head assembly shall be individually packaged. The crate and the signal head shall be tagged showing manufacturer, type, and catalog number. The crate tag shall also display the requisition or contract numbers on which the item was delivered.
692.8 Measurement and Payment. Pedestrian Signal Heads shall be paid by each signal head assembly installed, including all required mounting hardware.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 692
ITEM 694

LED SIGN LIGHTS FOR TRAFFIC SIGNALS

694.1 Description. This Item shall govern for the minimum requirements for a traffic signal sign and sign light and mounting brackets to be used with horizontal and vertical traffic signals.

694.2 Horizontal Sign Light Housing. The housing of the sign light shall be of 1/16 inch aluminum rolled and crimped on the backside under edge of the housing, crimped and bent upward on the forward edge to allow a drip drain. This crimp is to be approximately 45 degrees with the front portion of the housing. Approximately 3 inches from the top, the housing shall be crimped forward so as to give the proper reflector surface to throw light passing forward from the lamp back onto the sign hanging below.

The end plates of the structures shall be 1/8 inch or larger sheet aluminum for rigidity. These end plates shall be drilled or knockouts placed in them for 1/2 inch grommet type connectors.

At each end of the housing there shall be a bracket for mounting the lamp sockets so as to place the center of the lamp socket approximately 3-3/4 inch below the top of the housing. The exact positioning of the lamp socket shall depend on the front angle of the housing for the proper reflective angles to place the maximum amount of light on the sign hanging below. These brackets shall be so constructed that the wiring from the signal cable to the sign may be made up on a terminal block.

694.3 Finish. The outside of the sign light shall be finished with two coats of Federal Yellow gloss and the inside with two coats of white gloss.

694.4 Sign Light Dimensions. The horizontal sign light shall be approximately 48 inches long so as to mount under a three section 12 inch signal without extending beyond the mounting hardware of the signal assembly.

Four holes shall be drilled in the rear wall of the housing approximately 26 inches apart, plus or minus 1/4 of an inch in the horizontal dimension and 3-1/2 inches apart in the vertical dimension. This will allow it to be used with an 8 or 12 inch signal type assembly. These holes shall be of sufficient size to accommodate 1/4 inch bolts.

The vertical sign light shall be approximately 12 inches long so as to mount on top of the proposed sign.
694.5 Brackets. Each horizontal sign light shall come equipped with two brackets of 1/8 inch aluminum stock, 1-1/4 inch wide, 24 inches long, with a pipe bend on one end for a 1-1/2 inch pipe so that the bracket may be placed around the pipe and a 1/4 inch bolt and nut placed through corresponding holes and tightened down so as to give a tight fit. Besides the two holes for tightening to the assembly, there shall be the two holes for mounting a 12 inch maximum dimension sign.

The holes shall be located at the following dimensions from the bottom of the bracket: 1-1/4, 10-1/4 inches, 12 inches and the remaining hole depending on the holes drilled in the rear of the sign light, but approximately 3-3/4 inches from the third hole. These brackets shall be furnished with two coats of Federal Yellow gloss. The purpose of the brackets will be to hang from the top crossbar of the horizontal signal down the back of the signal and thus place the sign light approximately underneath the signal when it is mounted on the brackets. These brackets shall be malleable enough to allow bending around any manufacturer’s signal.

694.6 Electrical Requirements for a Traffic Signal LED Sign Lamp. The LED Sign Lamp shall meet the same requirements as the 60 Watt Fluorescent Lamp (F48T12-High Output).

A. Average Rated Life - 12000 Hours
B. Initial Lumens at 25C – 4050
C. Mean Lumens at 25C – 3281
D. Approximate Length – 48 inches
E. Base – Recessed Double Contact
F. Diameter – 1.59 inches

694.7 Signs. "ONE WAY" sign shall be according to Texas Manual on Uniform Traffic Control Devices (TMUTCD) R6-1, and shall be a white arrow, (right or left as specified), on a black horizontal rectangle with the words "ONE WAY" centered in the arrow, made out of reflective material conforming to Item 649 “Wide Angle Prismatic Retroreflective Sheeting For Traffic Control Signs (Diamond Grade)".

Horizontal “LEFT TURN SIGNAL” sign shall be a 48 inch x 12 inch sign, and shall be white with black letters with the words “LEFT TURN SIGNAL” as shown in drawings, made out of reflective material conforming to Item
649 “Wide Angle Prismatic Retroreflective Sheeting for Traffic Control Signs (Diamond Grade)”.

Vertical “LEFT TURN SIGNAL” sign shall be a 24 inch x 30 inch sign, and shall be white with black letters with the words “LEFT TURN SIGNAL” as shown in drawings, made out of reflective material conforming to Item 649 “Wide Angle Prismatic Retroreflective Sheeting for Traffic Control Signs (Diamond Grade)”.

694.8 Photoelectric Control. All sign lights shall be connected to one photoelectric cell. Location of the photoelectric cell shall be on the electrical service pole or as shown on drawings.

694.9 Guarantee. It is normal trade practice for the manufacturer to furnish a guarantee for the work provided herein. The Contractor shall turn this guarantee over to the Engineer for potential dealing with the guarantor. The extent of such guarantee will not be a factor in selecting the successful bidder.

694.10 Measurement and Payment. Sign lights shall not be paid for directly, but shall be included in the bid item for Item 690 “Traffic Signal Heads” or Item 691 “Twelve Inch Signal Head with Programmable Visibility of Signal Faces” except when included in an equipment procurement contract by the County.

There are line code(s), description(s), and unit(s) for this Item (for equipment procurement contracts only).

NOTE: This Item requires drawings that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications

Item 690 “Traffic Signal Heads”
Item 691 “Twelve Inch Signal Head with Programmable Visibility of Signal Faces”

END OF ITEM 694
ITEM 696

LOW PROFILE CONCRETE BARRIER

696.1 Description. This Item shall govern for furnishing and installing precast Low Profile Concrete Barrier (LPCB) at the locations shown on the plans, for moving the precast barrier from one location and placing the barrier in a new location and removing upon completion of work.

696.2 Materials. All materials shall conform to the pertinent requirements of the following Items:

A. Item 421 “Structural Concrete”
B. Item 440 “Reinforcing Steel”
C. Item 442 “Metals for Structures”
D. Item 526 “Membrane Curing”

A hardware assembly is defined as being sufficient hardware for one complete connection between two traffic-barrier sections, including all required bolts, nuts, washers, structural-steel shapes and/or dowels.

LPCB Type (1) and (2) shall be designed and fabricated in compliance with the standard detail drawings of the Texas Department of Transportation (TxDOT) “Low Profile Concrete Barrier”.

When the Contractor elects to furnish LPCB that has been constructed prior to this contract, he shall submit written certification that the barrier sections substantially conform to the requirements herein specified.

When the Contractor cannot verify that the barrier sections were constructed in compliance with the requirements herein specified, the Engineer may accept the barrier for use as a temporary barrier only, if:

A. the barrier sections substantially meet typical cross-sectional dimension requirements shown on the TxDOT standard drawings of LPCB Type (1) & (2).
B. the barrier sections are acceptable to the Engineer in regard to there being no evidence of structural damage such as major spalling or cracking; and
C. the general condition of both the barrier sections and their connectors is acceptable to the Engineer.

In the event that previously constructed barrier has steel channel connectors for which the top flange protrudes outside the projected concrete surface of the barrier, the Contractor shall bevel each end of the top flange on a 30 degree bevel, with the 30 degrees being measured from the web.

696.3 Installation. It shall be the Contractor’s responsibility to furnish low profile concrete barrier including end treatment and hardware assembly for use on the project. Barriers shall be installed in accordance with the requirements of the “Texas Manual on Uniform Traffic Control Devices”, Item 671 “Traffic Control” and information herein. When barriers are no longer required on the project, they shall be removed. Upon removal of the LPCB at the completion of work, all LPCB, incidentals and hardware assemblies will remain the property of the Contractor.

696.4 Defects and Breakage of Barrier. Concrete traffic barrier damaged in the process of fabricating, curing, handling or placing shall be repaired or replaced as directed by the Engineer. All replacements and repairs shall be made at the Contractor’s expense.

696.5 Damage and Loss of Hardware. Hardware damaged or lost in the process of handling, placing, removing or resetting shall be repaired or replaced as directed by the Engineer. All replacement and repairs shall be made at the Contractor’s expense.

696.6 Measurement. This Item will be measured along the bottom face of the barrier by the linear foot, based on the nominal lengths of the barrier sections as shown on the plans.

696.7 Payment. The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for the “Low Profile Concrete Traffic Barrier” including end treatment and hardware assembly and shall include all manipulations, labor, tools, equipment and incidentals necessary to complete the work; and described as follows:

A. Furnish and install low profile concrete barrier.

B. Relocate low profile concrete barrier.

C. Remove low profile concrete barrier.
There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires drawings (TxDOT standards) that are downloadable on TxDOT’s website.

NOTE: This Item requires other Standard Specifications

Item 421 “Structural Concrete”
Item 440 “Reinforcing Steel”
Item 442 “Metals for Structures”
Item 526 “Membrane Curing”
Item 671 “Traffic Control”

END OF ITEM 696
ITEM 698

TEMPORARY POLYETHYLENE WATER-FILLED BARRIER

698.1 Description. This Item shall govern for the furnishing, installing, moving, replacing, maintaining, and removing upon completion of work all temporary plastic water-filled barrier sections.

698.2 General. Temporary barrier shall be approved by the Federal Highway Administration (FHWA).

All temporary barrier sections shall be of a Jersey barrier type design.

Each barrier section shall have the capability of interlocking with other barrier sections when installed in a row through the use of independent clevis devices at the top of the barrier and a built-in male/female coupling at the bottom of the barrier. Each barrier section shall have ports for ground mounting.

Each barrier section shall be capable of easily and securely accommodating sign posts.

Each barrier section shall have 2 drain plugs located on opposite sides of the barrier to ensure the separation of workers from traffic when draining barrier sections.

Each barrier section shall have forklift holes to allow fully filled sections to be lifted and relocated.

Barrier sections shall be colored either orange or white. When installed in a row, the sequence of colors shall be 4 white, 1 orange unless otherwise specified in the drawings.

698.3 Materials. Heavy duty, low density polyethylene with ultraviolet (UV) light inhibitors, rotationally molded to a uniform thickness of no less than 8 mm.

698.4 Dimensions. Barrier type shall be as designated in the construction drawings.

Type A. Length: 72 inches long x 24 inches wide at base. Height: 42 to 46 inches. Weight: approximately 130 lbs. empty, 1650 lbs. filled.
Type B. Length: 72 inches long x 18 inches wide at base. Height: 28 to 34 inches. Weight: approximately 95 lbs. empty, 1200 lbs. filled.

698.5 Construction Methods.

All barrier shall be installed in accordance with the requirements of the "Texas Manual on Uniform Traffic Control Devices" (TMUTCD) and Item 671 “Traffic Control”.

698.6 Responsibility for Damage or Claims. (Also see Paragraphs 3.01 “Indemnification” and 4.01 “Laws to be Observed” of "Harris County General Conditions for Roads, Bridges and Related Work").

The Contractor shall hold harmless the County and its representatives from all suits, actions, or claims of any character brought on account of injuries or damages sustained by any person or property as a consequence of negligence in safeguarding the work or through the use of unacceptable materials in the execution of the contract or as a result of any act of omission by the said Contractor. He shall not be released from said responsibility until the contract has been completed and all work accepted. So much of the money due the said Contractor under and by virtue of his contract may be retained by the County or his survey may be held until such claims have been settled and suitable evidence to that effect furnished to the County.

All temporary barriers shall be checked daily to ensure they are properly located as shown in the approved traffic control plan drawings.

698.7 Measurement & Payment. This Item shall be measured and paid for by the contract unit price bid per linear foot of barrier used, furnished, installed, relocated during construction and removal.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 671 “Traffic Control”

END OF ITEM 698
ITEM 699

LED PEDESTRIAN TRAFFIC SIGNAL LAMP UNIT

699.1 Description. This Item shall govern for the design and performance requirements for a light emitting diode (LED) traffic signal lamp unit for use in various Pedestrian Signal Head Assemblies.

699.2 Units of Measurements. The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

699.3 Material Producer List. The Harris County Engineering Department (hereinafter referred to as the “Department”) maintains the Material Producer List (MPL) of all materials conforming to the requirements of this Item. Materials appearing on the MPL, need no further sampling or testing unless deemed necessary by the Department.

699.4 Bidders’ and Suppliers’ Requirements. The Department will purchase or allow on projects only those products listed by manufacturer and product code or designation shown on the MPL.

Use of pre-qualified product does not relieve the Bidder of the responsibility to provide product that meets this Item. The Department may inspect or test material at any time and reject any material that does not meet the specifications.

699.5 Pre-Qualification Procedure.

A. Pre-Qualification Request. Prospective producers interested in submitting their product for evaluation must submit a written request to:

Harris County Engineering Department
6922 Katy Road, Houston, TX 77024
Attn: Traffic Signal Maintenance

B. Pre-Qualification Samples. Ship two samples from a normal production run of each LED pedestrian signal lamp unit model requesting acceptance to:

Harris County Engineering Department
6922 Katy Road, Houston, TX 77024
Attn: Traffic Signal Maintenance
Provide additional samples when directed by the Department.

All products submitted for pre-qualification tests must be at no cost to the Department.

Provide the following with pre-qualification samples:

1. Manufacturer name and contact information
2. Brand and model number of LED pedestrian signal lamp unit
3. LED Manufacturer’s recommended drive current and degradation curves
4. One schematic diagram for each LED pedestrian signal lamp unit model being evaluated, along with any necessary installation instructions
5. Copy of the manufacturer’s International Organization for Standardization ISO 9000 certification, or Latest Revision, (including date)
6. Copy of the manufacturer’s quality assurance (QA) testing procedures
7. Letter from the manufacturer confirming compliance to this Item
8. Testing procedures explaining compliance to this Item, in addition to the I.T.E. tests
9. Letter confirming participation in a third party traffic signal certification program conducted by an independent Nationally Recognized Testing Laboratory (NRTL); including reports confirming each LED traffic signal lamp unit model’s compliance with this Item, including Section 699.7 as well as the latest pertinent I.T.E. standards.
10. Completed checklist detailing the page and paragraph in the laboratory report where I.T.E. and Department compliance has been tested
11. Manufacturer’s written warranty against defects in materials, design and workmanship for LED pedestrian signal lamp units for a period of 60 months after installation

C. Sampling and Testing. The Department will connect all samples
submitted to the Department’s ITS Traffic Signal Control Cabinet and will test to I.T.E. Pedestrian Traffic Control Signal Indicators (PTCSI): Light Emitting Diode (LED) Signal Modules environmental standards. All LED units must be operational at the conclusion of the test and must not cause Conflict Monitor (MMU/CMU) trip conditions in the controller/cabinet during testing.

During the environmental testing, the Department may evaluate the samples for chromaticity and intensity after 8 hours of soaking at −40°F (−40°C) and 165°F (74°C), at low (80 VAC) and high (135 VAC) voltages.

The Department will conduct destructive testing to determine that the units are in conformance with the catastrophic LED failure clause.

D. Evaluation. The Department will return to the submitting party a letter of confirmation or rejection for each model submitted. For each rejected model, TSM will issue a test report along with the letter of rejection.

1. Qualification. If approved for use by the Department, the product will be included in the MPL.

   Any deviation in product design after testing and approval from the Department, constitutes a new model which must be resubmitted for acceptance.

   If a manufacturer determines there is reason to remove a model from the MPL, they must submit a letter to the Department identifying the problem in writing. The Department will remove the model without prejudice. Once the problem has been resolved to the Department’s satisfaction, the manufacturer may apply for re-qualification for the new model.

   All submitted materials become the property of the Department.

2. Failure. Products not qualified under this Item may not be furnished on Department projects and must be corrected of all deficiencies before reconsideration for qualification.

   If products fail to meet any of the specification requirements, the producer may not resubmit for pre-qualification until one year from original evaluation date. The Department may waive this time limit if provided with documentation from an
independent testing facility stating the product meets all requirements. The Department will enforce the one year time limit if, after retesting, the product again fails any of the specification requirements.

Costs of sampling and testing are normally borne by the Department; however, the costs of sampling and testing products failing to conform to the requirements of this Item are borne by the Contractor or Supplier. This cost will be assessed at the rate established by the Director of the Department and in effect at the time of testing for each recurring non-compliant submittal.

Amounts due to the Department will be deducted from monthly or final estimates on contracts or from partial or final payments on direct purchases by the Department.

E. Disqualification. The following conditions are cause for immediate removal from the MPL:

1. A problem is found to exist with a LED pedestrian signal lamp unit (e.g. unsafe failure condition or excessive failure rate)

2. Excessive complaints about a manufacturer’s compliance Section 699.8

3. Manufacturer deviates LED pedestrian signal lamp units from pre-qualified units without prior testing and approval from the Department

If the Department removes a model from the MPL for cause other than manufacturer’s recommendation, the manufacturer may not resubmit for approval for a minimum of one year.

The Department may reinstate a model on the MPL under a different model number, if all problems identified have been corrected, and the new model no longer exhibits the same. The Department must approve of the new model as a successful replacement.

F. Periodic Evaluation. The Department may perform random sample testing on shipments, to be completed within 30 days after delivery.

The Department will perform optical testing with the module mounted in a standard traffic signal section, but without a visor or hood attached to the section or housing. The quantity of each
model in the shipment will determine the number of modules tested. The sample size will conform to ANSI/ASQC Z1.4. The Department will determine the sampling parameters used for the random sample testing. All parameters of the specification may be tested on the modules. Acceptance or rejection of the shipment will conform to ANSI/ASQC Z1.4 for randomly sampled shipments.

699.6 Material Requirements.

A. General Requirements. All LED pedestrian signal lamp units must conform to the Latest Edition of the Institute of Transportation Engineers I.T.E. *PTCSI: Light Emitting Diode (LED) Signal Modules*, and this Item. In the case of conflicts between standards and specifications, the latest County specifications will govern.

The LED pedestrian signal lamp unit must be designed as a retrofit replacement for existing signal lamps and will not require any special tools for installation. The retrofit replacement LED pedestrian signal lamp unit must fit into existing pedestrian signal housings without modifications.

Installation of a retrofit replacement LED pedestrian signal lamp unit into existing signal housing must only require removal of the existing lens, reflector, and incandescent lamp; fitting of the new unit securely in the housing door; and connecting to existing electrical wiring or terminal block by means of simple connectors.

Each LED pedestrian signal lamp unit shall have the manufacturer's name, trademark, model number, serial number, lot number, month and year of manufacture, and required operating characteristics, including rated voltage, power consumption, and volt-ampere, permanently marked on the back of the module. Serial Number schemes that clearly identify the date of manufacture will be considered.

Each LED pedestrian signal lamp unit shall have a label detailing complete and accurate installation guidelines.

Each LED pedestrian signal lamp unit shall have a label certifying compliance to the latest I.T.E. *PTCSI: Light Emitting Diode (LED) Signal Modules* standard, including standard title and date.

Each LED pedestrian signal lamp unit shall have a label from a Nationally Recognized Testing Laboratory (NRTL) indicating participation in a third party traffic signal certification program which provides ongoing verification of production to pertinent standards.
Any deviation to product design after testing and approval from the Department will constitute a new model and must have a new model number. The new model must be submitted for acceptance. Failure to adhere to this requirement will be grounds for automatic removal from the MPL until the Department approves an alternative solution. Random testing of average production LED pedestrian signal lamp units will be conducted to ensure compliance with this Item.

B. Physical and Mechanical Requirements. The LED pedestrian signal lamp unit must be a single, self-contained device, not requiring on-site assembly for installation into existing pedestrian signal housing. The assembly and manufacturing process for the LED pedestrian signal lamp unit must ensure that all internal LEDs and electronic components are adequately supported to withstand mechanical shock and vibration from high winds and other sources.

Each LED pedestrian signal lamp unit must be comprised of a UV stabilized polymeric outer shell, multiple LED light sources, and a regulated power supply. LEDs must be mounted on a printed circuit board/heat sink assembly.

C. Optical and Light Output Requirements. The LEDs must be manufactured using AlInGaP (Aluminum-Indium-Gallium-Phosphide) technology and/or InGaN (Indium-Gallium-Nitride) LEDs. The AlGaAs (Aluminum-Gallium-Arsenic) LEDs will not be allowed.

Designs that require the LEDs to be operated at currents greater than the LED manufacturer’s published recommended drive current will not be allowed.

Each LED pedestrian signal lamp unit must meet minimum laboratory light intensity values and light output distribution as described in I.T.E. PTCSI: Light Emitting Diode (LED) Signal Modules for a minimum period of 60 months, based on normal use in traffic signal operation over an operating temperature range of −40°F (−40°C) to 165°F (74°C).

Measured chromaticity coordinates of LED pedestrian signal lamp units must conform to the chromaticity requirements detailed in the I.T.E. PTCSI: Light Emitting Diode (LED) Signal Modules for a minimum period of 60 months.

LED pedestrian signal lamp units tested or submitted for testing must be representative of typical production units. Perform optical testing with LED units mounted in standard traffic signal sections
without visors or hoods attached to the signal sections.

A copy of the lab test report from an NRTL for each LED pedestrian signal lamp model must include light intensity values at each I.T.E. specific distribution test points. The lab report must document current, voltage, and total harmonic distortion (THD) for each test point. The power factor (PF) associated with each model must be documented.

D. Electrical Requirements. Each LED pedestrian signal lamp unit must incorporate a regulated power supply engineered to electrically protect the LEDs and maintain a safe and reliable operation. The power supply must provide capacitor filtered DC regulated current to the LEDs per the LED manufacturer specification. The power supply must be designed so that the failure of an individual component or any combination of components cannot cause the signal to be illuminated after source power is removed.

LED pedestrian signal lamp units must be operationally compatible with TS1, TS2 cabinet designs, 170 cabinet designs and ITS cabinet designs (comply with TEES Chapters 3 and 6). Under normal operating conditions, the LED lamp unit must operate without inhibiting any Conflict Monitor (MMU/CMU) monitoring features.

If a 20 mA alternating current or less is applied to the unit, the voltage read across the 2 leads must be 15 VAC or less. LED pedestrian signal lamp units must be designed to sense a loss of light output due to catastrophic LED failure and react in compliance with the failed state impedance provision of the I.T.E. PTCSI: Light Emitting Diode (LED) Signal Modules.

Three captive, color coded, 600 V, 18 AWG minimum jacketed wires, 3 feet or 1 meter long, conforming to the National Electric Code, rated for service at 22°F, are to be provided for an electrical connection.

The LED pedestrian signal lamp units must have on-board circuitry including voltage surge protection, to withstand high-repetition noise transients and low-repetition high-energy transients as stated in NEMA Standard TS 2-2003, Section 2.1.8, except voltage must be 2000 V instead of 1000 V. The circuitry must also be able to withstand high-repetition low-energy transients as stated in NEMA Standard TS 2-2003, Section 2.1.6.

E. Environmental Requirements. Environmental requirements must
meet or exceed *I.T.E. PTCSI: Light Emitting Diode (LED) Signal Modules*.

The LED pedestrian signal lamp units must be rated for use in the ambient operating temperature range of −40°F (−40°C) to 165°F (74°C).

The LED pedestrian signal lamp units must be dust and moisture tight to protect all internal LED and electrical components.

The LED pedestrian signal lamp units must consist of a housing that is a sealed, watertight enclosure to eliminate dirt contamination and allow for safe handling in all weather conditions. Perform moisture resistance testing on LED signal modules in conformance with the requirements in the *I.T.E. PTCSI: Light Emitting Diode (LED) Signal Modules*. Evidence of internal moisture after testing will be cause for rejection.

F. Production Testing Requirements. A quality assurance (QA) program must be in place at the manufacturer’s facility to ensure product reliability.

Each new LED pedestrian signal lamp unit must be energized at the manufacturer’s facility for a minimum of 24 hours at nominal operating voltage (120 VAC RMS) at room temperature in order to ensure electronic component reliability prior to shipment.

699.7 Documentation Requirements. Provide each LED pedestrian signal lamp unit with, as a minimum, the following documentation:

A. Complete and accurate installation wiring guide

B. Contact name, address, telephone number and email address or webpage for the representative, manufacturer, or distributor for warranty repair

C. If requested by the purchaser, the bidders must supply schematics for all electronics

D. LED Manufacturer’s recommended drive current and degradation curves

E. Compliance letter specified in Section 699.8

F. Certification document specified in Section 699.8

G. List containing all LED signal module serial numbers anticipated for
H. Bidders must submit a copy of a test report, certified by an NRTL, stating that the LED pedestrian signal lamp model submitted meets or exceeds the *I.T.E. PTCSI: Light Emitting Diode (LED) Signal Modules* standard. The NRTL report must include documentation of tests and verification of compliance to the additional provisions of this standard. Tests performed by the independent lab must follow all the instructions documented in the latest *I.T.E. PTCSI: Light Emitting Diode (LED) Signal Modules* as it pertains to the product being tested. The I.T.E. criteria in Section 6 Quality Assurance must be documented in the submitted test report.

Manufacturers must be certified to International Organization for Standardization ISO 9000, or Latest Revision, (including date)

699.8 Warranty Requirements. Manufacturer must comply with all requirements of the following warranty. Failure to comply with the requirements of this warranty is cause for the manufacturer/supplier to be removed from the MPL.

The manufacturer/provider must submit a letter of compliance indicating understanding and willingness to abide by the provisions of this Item. The manufacturer/provider must provide name and telephone number of the person to contact regarding potential claims under the provisions of this warranty. Address the compliance letter to:

Harris County Engineering Department  
6922 Katy Road, Houston, TX 77024  
Attn: Traffic Signal Maintenance

The LED pedestrian signal lamp units must be warranted against any failure due to design, workmanship, material defects, and loss of intensity for 60 months of field operation. Units must meet or exceed minimum requirements of this Item for a minimum of 60 months of field operation.

Repair or full replacement will be required if a LED pedestrian signal lamp unit fails to operate as specified under normal operating conditions. Provide repaired or replaced units at no cost to the Department. Replaced units will inherit the remainder of the failed unit’s warranty. Replaced units will be warranted for 60 months of field operation.

Should a lamp unit fail with no visible damage to electronic/electrical components, (not including fuses or components designed to act as a fuse) or wiring, the unit is considered to have failed under normal operating conditions. A blown fuse or a component acting as a fuse, without any other permanent failure to electrical, electronic components
will be considered to have failed under normal operating conditions. Natural phenomena (e.g. lightning) are not acceptable as excusable unit failures without visible damage.

Repair or replace LED pedestrian signal lamp units within 15 business days after receipt of failed LED units. All shipping costs will be borne by the vendor or manufacturer.

The manufacturer/provider must submit a certification document with each lot or shipment stating that the LED lamp units provided meet all the requirements of this Item. The certification document must show individual lot numbers and manufacturer dates.

The Department reserves the right to select a sample from the field during the warranty period and perform evaluation tests to determine extended compliance and/or deterioration of the LED pedestrian signal lamp unit. Any model that shows deterioration of unit causing the unit to fail the evaluation tests during the warranty period will be automatically removed from the MPL, and the submitting party may be held legally responsible for all damages.

699.9 Measurement and Payment. LED pedestrian signal lamp units when supplied as part of a pedestrian signal head assembly, will not be paid for directly, but shall be incidental to assemblies defined by Item 692 “Symbolic Pedestrian Signal Head”, any pertinent Special Provisions and Standard Drawings (if applicable).

LED pedestrian signal lamp units when supplied individually shall be paid for by each type required.

There are line code(s), description(s), and unit(s) for this Item (equipment procurement contracts only).

NOTE: This Item requires other Standard Specifications

Item 692 “Symbolic Pedestrian Signal Head (Incandescent Type)”

END OF ITEM 699
700 ITEMS

- 700 – Notice of Intent
- 713 – Reinforced Filter Fabric Barrier
- 719 – Inlet Protection Barriers
- 724 – Stabilized Construction Access
- 725 – General Source Control (SWPPP)
- 730 – Concrete Truck Washout Structures
- 741 – Inlet Protection Barrier (for Stage II Inlets, Gravel Bags)
- 750 – Rock Filter Dams
- 751 – SWPPP Inspection and Maintenance
ITEM 700

NOTICE OF INTENT (NOI)

700.1 Description. The Contractor shall implement, inspect, and maintain the Storm Water Pollution Prevention Plan shown in the plans and project manual. Certification of a Notice of Intent (NOI) in accordance with Part II.E.3 of the TPDES General Permit No. TXR150000 is required. The Contractor, as a primary operator, as defined by the TPDES General Permit, shall certify at least one NOI.

To process the NOI applications the following procedures will be observed:

A. Harris County Construction Programs Division will receive the original copy of Harris County’s completed (except for the payment) TCEQ NOI application that has been signed by the County Judge, along with the Contractor’s P.O.

B. Construction Programs Division notifies the Contractor to complete his/her NOI application and to make his/her payment along with Harris County’s payment for its NOI application.

C. The Contractor completes his/her NOI application and payment online.

D. The Contractor completes an on-line form of payment, for Harris County’s NOI fee.

E. The Contractor provides the following items to the Construction Programs Division:
   1. a copy his/her submitted NOI application,
   2. his/her payment voucher and processed permit, and
   3. Harris County’s payment voucher.

700.2 Measurement and Payment. The Contractor’s and Harris County’s Notice of Intent (NOI) application fees shall be paid for per each fee, as required, per the bid item provided with quantity of 2.

There are line code(s), description(s), and unit(s) for this Item.

END OF ITEM 700
ITEM 713

REINFORCED FILTER FABRIC BARRIER

713.1 Description. This Item shall govern for furnishing, installing, and removing temporary erosion protection and sediment control reinforced filter fabric barrier in accordance with these Standard Specifications and construction drawings, and as directed by the Engineer. The reinforced filter fabric barrier consists of geotextile fabric supported by a net reinforced fence stretched across and attached to supporting posts or frame and entrenched. This work shall be performed during construction operations and prior to final stabilization to control erosion and sedimentation.

713.2 Materials. Geotextile fabric (filter fabric) shall consist of long-chain synthetic polymers composed of at least 95 percent by weight of polyolefins in a woven fabric. The geotextile fabric shall meet or exceed the following specifications:

| TABLE 1 |
|------------------|---------|-----------------|-----------------|
| SILT FENCE GEOTEXTILE FABRIC PROPERTIES | REQUIREMENTS UNSUPPORTED SILT FENCE |
| | Units | Supported Silt Fence | Geotextile Elongation ≥50% | Geotextile Elongation <50% |
| Grab Strength | | | |
| Machine Direction | Lbs. | 90 | 123 | 123 |
| X-Machine Direction | Lbs. | 90 | 100 | 100 |
| Permittivity | Sec⁻¹ | 0.05 | 0.05 | 0.05 |
| Apparent Opening Size (Max. Average Roll Value) | Mm/sieve | 0.6/30 | 0.6/30 | 0.6/30 |
| Ultraviolet Stability (Retained Tensile Strength) | % | 70 after 500 hrs exposure | 70 after 500 hrs exposure | 70 after 500 hrs exposure |

NOTES:
1. Table 1 adapted from AASHTO M 288 Geotextile Specification for Highway Applications Table 6. Temporary Silt Fence Property Requirements.
2. All numeric values in Table 1 except Apparent Opening Size (AOS) represent minimum average roll values (MARV). Values for AOS represent maximum average roll values.
Geotextile fabric shall contain stabilizers and/or inhibitors to make the fabric resistant to deterioration resulting from exposure to sunlight or heat. Geotextile fabric shall be resistant to commonly encountered soil chemicals, mildew, rot, and insects. Geotextile fabric shall be free of defects or flaws that affect its physical and/or filtering properties. Geotextile fabric shall provide an expected useable life comparable to the anticipated construction period.

Fence posts shall be either steel or hardwood, essentially straight, with a minimum length of 4 feet. Hardwood posts shall be 2 inch x 2 inch minimum, or equivalent. Metal posts shall be either studded T or U steel type with a minimum weight of 1.28 lbs. per linear foot. Fin anchors shall be used to resist post movement as directed by the Engineer.

Net reinforced fence shall be 2 inch wide by 4 inch high welded wire fabric mesh, 14 gauge minimum. The mesh support height shall be the equivalent height, or greater, of the geotextile fabric to be attached. Plastic grid mesh or other support mesh may be substituted for welded wire mesh as approved by the Engineer.

Attachment of net reinforced fence and geotextile fabric shall be with wire ties, staples, or rings. Wire ties shall be 14 gauge minimum, staples shall be no. 9 wire minimum with a 1/2 inch minimum crown length, and rings shall be galvanized, or as approved by the Engineer.

A prefabricated unit with geotextile fabric, posts, and wire mesh meeting the minimum specifications in this Item may be used in lieu of a constructed filter fabric barrier.

Construction Methods. No clearing and grubbing or rough cutting, other than as specifically directed by the Engineer to allow for soil testing, surveying and installation of erosion protection and sediment control measures, shall be permitted until sediment control and erosion protection systems are in place.

Reinforced filter fabric barriers shall be so installed that the surface runoff will percolate through the system and allow sediment to be retained and accumulated, and may be used in conjunction with a rock filter dam (Item 750) at the outfall of a detention pond. Reinforced filter fabric barrier shall not be used as the sole best management practice at the outfall of a detention pond. Reinforced filter fabric barriers shall be installed at the locations shown on the construction drawings and in accordance with the Standard Civil Drawing or as directed by the Engineer. Reinforced filter fabric barriers shall be constructed in accordance with an approved schedule that clearly describes the timing during the construction process that the various erosion control measures will be implemented. Reinforced
filter fabric barriers shall be installed so as surface runoff will percolate through the system and allow sediment to be retained and accumulated.

Posts shall be driven to a minimum depth of 1 foot into the ground. Posts shall be a minimum of 18 inches above the ground. Posts shall be placed with a maximum spacing of 6 feet and be installed on a slight angle toward the anticipated runoff.

Trenches shall be dug along the uphill side of the fence to anchor at least 8 inches of the filter fabric to prevent underflow. The trench shall be a 6 inch x 6 inch square, or a 4 inch deep V-trench.

Net reinforced fence shall be attached to the posts. Attachment shall be at the top and mid-section. Additional ties or staples shall be added to secure the net reinforced fence to the posts as directed by the Engineer.

Geotextile fabric shall be placed against the side of the trench with approximately 2 inches across the bottom in the upstream direction. Using wire ties or rings, the geotextile fabric shall be attached to the net reinforced fence. The fabric shall be attached at the top and mid-section. The horizontal spacing of the attachment shall be every 24 inches, or less. Additional ties, rings, or staples shall be added to secure fabric to the net reinforced fence or posts as directed by the Engineer.

Geotextile fabric shall be provided in continuous rolls and cut to the length of the barrier, so as to minimize joints. When joints of two sections of fabric are necessary, the fabric shall be spliced together only at a support post. The fabric shall be overlapped a minimum of 6 inches at a post, folded, and secured at six or more places. Splices in concentrated flow areas will not be permitted.

Geotextile fabric shall be attached at the end posts at a minimum of four locations. Geotextile fabric shall be entrenched and attached to the posts so as a minimum of 18 inches of the fabric is above the ground. The trench then shall be backfilled and hand tamped as approved by the Engineer.

Contractor shall inspect the reinforced filter fabric barriers at least once every week or as directed by the Engineer. The Contractor shall remove irregularities which will impede normal flow. Erosion protection and sediment control systems shall be maintained by the Contractor until final stabilization. Damage caused to erosion protection and sediment control systems shall be repaired immediately. (Note: Maintenance for Item 713 is paid for under Item 751 “SWPPP Inspection and Maintenance”)
The Contractor is responsible for removal and proper disposal of sediment and debris from the reinforced filter fabric barrier system and as directed by the Engineer. Sediment and debris shall not be allowed to flush into the storm sewer system, waterways, and jurisdictional wetlands, or onto adjacent properties. Sediment deposits shall be removed before they reach one-third of the height of the reinforced filter fabric barrier.

Uncontaminated sediment can be placed at the project spoil site protected by a reinforced filter fabric barrier or, if properly handled, spread out to supplement fill requirements. The Engineer will designate how the sediment deposits are to be handled. Uncontaminated sediment shall not be placed in waterways or jurisdictional wetlands, unless as approved by the Engineer. If sediment has been contaminated, then it shall be disposed of in compliance with current local, State and Federal Regulations. Offsite disposal shall be the responsibility of the Contractor.

After final stabilization and at the direction of the Engineer, the Contractor, when required, shall be responsible for removing all erosion protection and sediment control systems that are not permanent, from the project.

713.4 Quality Assurance. The Contractor is responsible for the control of the quality of materials incorporated into the construction and the quality of completed construction. The County will engage materials engineering services to provide quality assurance testing and inspection to assist the Engineer in determining the acceptability of materials and completed construction. Quality assurance services provided by the County do not relieve the Contractor of his responsibility for quality control. The Materials Engineer shall not have control of the means, methods, techniques, sequences or procedures of construction selected by the Contractor.

713.5 Measurement. When paid for separately as a pay item, measurement for reinforced filter fabric barrier shall be by the linear foot, complete in place, measurement being made along the centerline of the top of the barrier.

715.6 Payment. Payment for reinforced filter fabric barrier shall include and be full compensation for all labor, equipment, materials, supervision and all incidental expenses for the construction of this Item, complete in place, where 60 percent of the total unit cost shall be for furnishing and installing all materials. Thus, 40 percent of the total unit cost shall be for the removal and disposal of erosion protection and sediment control systems: reinforced filter fabric barrier, after final stabilization, at the end of the project.

There are line code(s), description(s), and unit(s) for this Item.
NOTE: This Item requires a Standard Civil Drawing that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications.

Item 751 “SWPPP Inspection and Maintenance”

END OF ITEM 713
ITEM 719

INLET PROTECTION BARRIERS

719.1 Description. This Item shall govern for furnishing, installing, and removing temporary erosion protection and sediment control inlet protection barriers in accordance with these Standard Specifications and construction drawings, and as directed by the Engineer. The inlet protection barrier consists of a geotextile fabric (filter fabric) supported by a net reinforced fence structure and constructed around a storm drain inlet, catch basin, or culvert. An alternative design of the inlet protection barrier, as approved by the Engineer, consists of fiber rolls placed around a frame, staked in place (or weighted down with clean gravel bags), and constructed around a storm drain inlet, catch basin or culvert. This work shall be performed during construction operations and prior to final stabilization to control erosion and sedimentation.

719.2 Materials. Geotextile fabric (filter fabric) shall consist of long-chain synthetic polymers composed of at least 95 percent by weight of polyolefins in a woven fabric. The geotextile fabric shall meet or exceed the following specifications shown in Table 1:

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>SILT FENCE GEOTEXTILE FABRIC PROPERTIES</th>
<th>REQUIREMENTS</th>
<th>UNSUPPORTED SILT FENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Units</td>
<td>Supported Silt Fence</td>
<td>Geotextile Elongation ≥50%</td>
</tr>
<tr>
<td>Grab Strength</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine Direction</td>
<td>Lbs.</td>
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<td>123</td>
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<tr>
<td>X-Machine Direction</td>
<td>Lbs.</td>
<td>90</td>
<td>100</td>
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<tr>
<td>Permittivity</td>
<td>Sec^{-1}</td>
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<td>0.05</td>
</tr>
<tr>
<td>Apparent Opening Size (Max. Average Roll Value)</td>
<td>Mm/sieve</td>
<td>0.6/30</td>
<td>0.6/30</td>
</tr>
<tr>
<td>Ultraviolet Stability (Retained Tensile Strength)</td>
<td>%</td>
<td>70 after 500 hrs exposure</td>
<td>70 after 500 hrs exposure</td>
</tr>
</tbody>
</table>

NOTES:
1. Table 1 adapted from AASHTO M 288 Geotextile Specification for Highway Applications Table 6. Temporary Silt Fence Property Requirements.
2. All numeric values in Table 1 except Apparent Opening Size (AOS) represent minimum average roll values (MARV). Values for AOS represent maximum average roll values.
Geotextile fabric shall contain stabilizers and/or inhibitors to make the fabric resistant to deterioration resulting from exposure to sunlight or heat. Geotextile fabric shall be resistant to commonly encountered soil chemicals, mildew, rot, and insects. Geotextile fabric shall be free of defects or flaws that affect its physical and/or filtering properties. Geotextile fabric shall provide an expected useable life comparable to the anticipated construction period.

Posts shall be either steel or hardwood, essentially straight, with a minimum length of 4 feet. Hardwood posts shall be 2 inch x 2 inch minimum, or equivalent. Metal posts shall be either studded T or U steel type with a minimum weight of 1.28 lbs. per linear foot. Fin anchors shall be used to resist post movement as directed by the Engineer.

Support beams shall be either steel or hardwood essentially straight. Hardwood support beams shall be 2 inch x 2 inch minimum, or equivalent. Metal support beams shall be either studded T or U steel type with or minimum weight of 1.28 lbs per linear foot, or as approved by the Engineer.

Net reinforced fence shall be 2 inch wide by 4 inch high welded wire fabric mesh, 14 gauge minimum. The mesh support height shall be the equivalent height, or greater, of the geotextile fabric to be attached. Plastic grid mesh or other support mesh may be substituted for welded wire mesh as approved by the Engineer.

Attachment of net reinforced fence and geotextile fabric shall be with wire ties, staples, or rings. Wire ties shall be 14 gauge minimum, staples shall be no. 9 wire minimum with a 1/2 inch minimum crown length, and rings shall be galvanized, or as approved by the Engineer.

A prefabricated unit with geotextile fabric, posts, supports, and wire mesh meeting the minimum specifications in this Item may be used in lieu of a constructed inlet protection barrier.

Fiber roll material for inlet protection barrier alternative design shall be as approved by the Engineer.

Construction Methods. No clearing and grubbing or rough cutting, other than as specifically directed by the Engineer to allow for soil testing, surveying and installation of erosion protection and sediment control measures, shall be permitted until sediment control and erosion protection systems are in place.

Inlet protection barriers shall be installed at the locations shown on the construction drawings and in accordance with the Standard Civil Drawing or as directed by the Engineer. Inlet protection barriers shall be
constructed in accordance with an approved schedule that clearly describes the timing during the construction process that the various erosion control measures will be implemented. Inlet protection barriers shall be installed so as surface runoff will percolate through the system and allow sediment to be retained and accumulated.

Posts shall be driven to a minimum depth of 1 foot into the ground. Posts shall be a minimum of 18 inches above the ground. Posts shall be placed with a maximum spacing of 4 feet. Horizontal support beams shall be securely attached from post to post and no higher than the top of the filtering material.

Trenches shall be dug along the upstream side of the barrier to anchor at least 8 inches of the geotextile fabric to prevent underflow. The trench shall be a 6 inch x 6 inch square, or a 4 inch deep V-trench.

Net reinforced fence shall be attached to the posts. Attachment shall be at the top and mid-section. Additional ties or staples shall be added to secure the net reinforced fence to the posts as directed by the Engineer.

Geotextile fabric shall be placed against the side of the trench with approximately 2 inches across the bottom in the upstream direction. Using wire ties or rings, the geotextile fabric shall be attached to the net reinforced fence. The fabric shall be attached at the top and mid-section. The horizontal spacing of the attachment shall be every 24 inches, or less. Additional ties, rings, or staples shall be added to secure fabric to the net reinforced fence or posts as directed by the Engineer. Geotextile fabric shall be entrenched and attached to the posts so as a minimum of 18 inches of the fabric is above the ground.

Geotextile fabric shall be provided in continuous rolls and cut to the length of the barrier, so as to minimize joints. When joints of two sections of fabric are necessary, the fabric shall be spliced together only at a support post. The fabric shall be overlapped a minimum of 6 inches at a post, folded, and secured at six or more places.

After the geotextile fabric has been securely attached, the trench shall be backfilled and hand tamped as approved by the Engineer.

For inlet protection barriers with reinforced filter fabric, if the immediately adjacent surface is a hard packed surface, the geotextile fabric shall extend outward away from the inlet protection barrier and upstream along the hard packed surface for at least 12 inches and be weighed down continuously along the perimeter of the structure with at least 4 inches of clean gravel or nylon gravel filled bags

The Contractor shall inspect the inlet protection barriers at least once every week or as directed by the Engineer. The Contractor shall remove
irregularities which will impede normal flow. Erosion protection and sediment control systems shall be maintained by the Contractor until final stabilization. Damage caused to erosion protection and sediment control systems shall be repaired immediately. (Note: Maintenance for Item 719 is paid for under Item 751 “SWPPP Inspection and Maintenance”)

The Contractor is responsible for removal and proper disposal of sediment and debris from the inlet protection barrier system and as directed by the Engineer. Sediment and debris shall not be allowed to flush into the storm sewer system, waterways, and jurisdictional wetlands, or onto adjacent properties. Sediment deposits shall be removed before they reach one-third of the height of the inlet protection barrier.

Uncontaminated sediment can be placed at the project spoil site or, if properly handled, spread out to supplement fill requirements. The Engineer will designate how the sediment deposits are to be handled. Uncontaminated sediment shall not be placed in waterways or jurisdictional wetlands, unless as approved by the Engineer. If sediment has been contaminated, then it shall be disposed of in compliance with current local, State and Federal Regulations. Offsite disposal shall be the responsibility of the Contractor.

After final stabilization and at the direction of the Engineer, the Contractor, when required, shall be responsible for removing all erosion protection and sediment control systems that are not permanent, from the project.

719.4 Quality Assurance. The Contractor is responsible for the control of the quality of materials incorporated into the construction and the quality of completed construction. The County will engage materials engineering services to provide quality assurance testing and inspection to assist the Engineer in determining the acceptability of materials and completed construction. Quality assurance services provided by the County do not relieve the Contractor of his responsibility for quality control. The Materials Engineer shall not have control of the means, methods, techniques, sequences or procedures of construction selected by the Contractor.

719.5 Measurement. When paid for separately as a pay item, measurement shall be by the unit, for each inlet protection barrier, complete in place.

719.6 Payment. Payment for each unit of an inlet protection barrier shall include and be full compensation for all labor, equipment, materials, supervision and for all incidental expenses for the construction of these items, complete in place, where 60 percent of the total unit cost shall be for the furnishing and installing all material. Thus, 40 percent of the total unit cost shall be for the removal of erosion protection and sediment control systems: inlet protection barriers, after final stabilization, at the end of the project.
There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires a Standard Civil Drawing that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications

Item 751 “SWPPP Inspection and Maintenance”

END OF ITEM 719
724.1 Description. This Item shall govern for furnishing and installing temporary erosion protection and sediment control stabilized construction access, utilized during construction operations and prior to final stabilization, in accordance with these Standard Specifications and construction drawings, and as directed by the Engineer.

724.2 Materials. Geotextile fabric shall consist of a woven monofilament or spunbond nonwoven fibers consisting of long-chain synthetic polymers composed of at least 95 percent by weight of polyolefins. Geotextile fabric shall equal or exceed the following average roll values or as directed by the Engineer:

A. Minimum average roll value.
   1. Elongation $\geq 50\%$.
   2. Grab Strength – 200 pounds.
   3. Puncture Strength – 75 pounds.
   4. UV Stability (retained strength) – 50% after 500 hours of exposure.

B. Maximum average roll value.
   1. Apparent Opening Size (AOS) – 0.6 mm/#30 US sieve.

Geotextile fabric shall be resistant to commonly encountered soil chemicals, mildew, rot, insects, and deterioration resulting from exposure to sunlight or heat. Geotextile fabric shall provide an expected useable life comparable to the anticipated construction period.

Aggregate for the construction access shall consist of crushed stone, gravel, or furnace slag, or combination thereof. The aggregate shall be open graded with a size of 2 inches to 5 inches with no material diameter less than 2 inches and no material diameter greater than 5 inches. Aggregate particles shall be composed of clean, hard, durable materials free from adherent coatings, salt, alkali, dirt, clay, loam, shale, soft or flaky materials or organic and injurious matter. Prior to installation, all exposed metal, including reinforcing steel and wire mesh, shall be cut off flush with the surface of the crushed concrete. The depth of the aggregate shall not be less than 8 inches.
Aggregate shall be cubic or rounded form, not elongated, flat, shapes. Spalls, fragments, and chips shall not exceed 5 percent by weight.

724.3 Construction Methods. No clearing and grubbing or rough cutting, other than as specifically directed by the Engineer to allow for soil testing, surveying and installation of erosion protection and sediment control measures, shall be permitted until sediment control and erosion protection systems are in place.

Stabilized construction access shall be installed at the locations shown on the construction drawings and in accordance with the Standard Civil Drawing or as directed by the Engineer. Stabilized construction access shall be constructed in accordance with an approved schedule that clearly describes the timing during the construction process that the various erosion control measures will be implemented. Stabilized construction access shall be installed so as to prevent tracking or flowing of sediment from the construction site.

The construction access location shall be graded to provide sufficient drainage away from the proposed stabilized area. The separation geotextile fabric shall be placed to the width and length of the construction access. Aggregate shall be placed on the underlying separation geotextile fabric to the width and length of the fabric and to the specified depth, with the depth being no less than 8 inches. The separation geotextile fabric may be omitted only as approved by the Engineer.

When necessary, equipment, truck, and vehicle wheels shall be cleaned to remove sediment prior to entrance onto public right-of-way. When washing is required, the construction access shall be graded to drain into a sediment trap or sediment basin. The sediment trap or sediment basin for the washing area shall be the size and location shown on the construction drawings or as directed by the Engineer.

Details for stabilized construction access are shown on the drawing that is incorporated into the Standard Civil Drawings. Stabilized construction access shall be at least 14 feet wide for one way traffic and 20 feet for two way traffic and shall be sufficient for all ingress and egress unless as approved by the Engineer due to site conditions. Length of the stabilized area shall be as shown on the construction drawings, but not less than 50 feet, unless approved by the Engineer due to site conditions.

The Contractor shall provide stabilized construction access for project related access roads, parking areas, and other on-site vehicle transportation routes. Stabilization of these areas shall have the same
aggregate and thickness requirements as the stabilized construction access unless shown otherwise on the construction drawings.

Gravel bags, boards, reinforced filter fabric fence, or similar methods shall be used in combination with the stabilized construction access to prevent sediment from entering public right-of-way, storm sewer system, jurisdictional wetlands, and waterways.

The Contractor shall provide periodic top dressing, with additional aggregate, to maintain the required access roadway depth. The Contractor shall be responsible for repairing and cleaning out damaged areas used to trap sediment. All sediment and aggregate tracked or washed into public right-of-way, storm sewer system, jurisdictional wetlands or waterways shall be removed immediately.

The Contractor shall inspect the stabilized construction access at least once every week or as directed by the Engineer. Damage caused to stabilized construction access shall be repaired immediately. Stabilized construction access shall be maintained by the Contractor until construction staging requires removal or upon final stabilization of the construction site. Upon removal of the stabilized construction access, the area shall be graded as per the construction drawings and stabilized with vegetation, or other. (Note: Maintenance for Item 741 is paid for under Item 751 “SWPPP Inspection and Maintenance”)

If an equipment or vehicle washing area is necessary, The Contractor is responsible for removal and proper disposal of sediment and debris from the sediment trap or basin. Sediment and debris shall not be allowed to flush into the storm sewer system, waterways, jurisdictional wetlands, or onto adjacent properties. Sediment deposits shall be removed before they reach 1/3 of the depth of the sediment trap or basin.

Uncontaminated sediment can be placed at the project spoil site or, if properly handled, spread out to supplement fill requirements. The Engineer will designate how the sediment deposits are to be handled. Uncontaminated sediment shall not be placed in waterways or jurisdictional wetlands, unless as approved by the Engineer. If sediment has been contaminated, then it shall be disposed of in compliance with current local, State and Federal Regulations. Offsite disposal shall be the responsibility of the Contractor.

After final stabilization and at the direction of the Engineer, the Contractor, when required, shall be responsible for removing all erosion protection and sediment control systems that are not permanent, from the project.
724.4 Quality Assurance. The Contractor is responsible for the control of the quality of materials incorporated into the construction and quality of completed construction. The County will engage materials engineering services to provide quality assurance testing and inspection to assist the Engineer in determining the acceptability of materials and completed construction. Quality assurance services provided by the County do not relieve the Contractor of his responsibility for quality control. The Materials Engineer shall not have control of the means, methods, techniques, sequences or procedures of construction selected by the Contractor.

724.5 Measurement. When paid for directly as a pay item, measurement for stabilized construction access shall be by the square yard, complete and in place.

724.6 Payment. Payment for stabilized construction access shall include and be full compensation for all labor, equipment, materials, supervision and for all incidental expenses for the construction of these items, complete in place, where 60 percent of the total unit cost shall be for the furnishing and installing materials including excavation. Thus, 40 percent of the total unit cost shall be for the removal of erosion protection and sediment control systems: stabilized construction access, after final stabilization, at the end of the project. Construction and maintenance of sediment traps or basins associated with the stabilized construction access for the purpose of washing equipment or vehicles prior to egress to public right-of-way shall be considered incidental to stabilized construction access.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires a Standard Civil Drawing that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications.

Item 751 “SWPPP Inspection and Maintenance”

END OF ITEM 724
ITEM 725

GENERAL SOURCE CONTROLS (SWPPP)

725.1 Description. This Item shall govern for erosion protection and sediment control related practices which shall be utilized during construction operations.

725.2 Materials. Topsoil shall conform to Item 160 “Topsoil”.

The Contractor is required to inform the Engineer of the location of the pit or pits from which the material is to be taken. Harris County shall have the right to have an independent testing laboratory test the material to determine if it meets these Standard Specifications.

725.3 Construction Methods. No clearing and grubbing or rough cutting, other than as specifically directed by the Engineer to allow for soil testing and surveying, shall be permitted until sediment control and erosion protection systems are in place.

The Contractor shall prohibit equipment and vehicles from maneuvering on areas outside of dedicated rights of way and easements for construction. Damages caused by construction traffic to erosion and sedimentation control systems shall be repaired immediately.

Topsoil for Erosion and Sedimentation Control Systems:
When topsoil is called for as a component of another item, Contractor shall conduct erosion control practices during topsoil operation. When applying topsoil, Contractor shall maintain erosion and sediment control systems, such as swales, berms, dikes, and sediment basins. Contractor shall place the topsoil to the lines and grades and to the depths shown on the construction plans.

After the areas to receive topsoil have been brought to grade and immediately prior to dumping and spreading the topsoil, the subgrade shall be loosened by discing or by scarifying to a depth of at least 2 inches, to permit bonding of the topsoil to the subsoil. Contractor shall compact by passing a bulldozer up and down the slope, tracking over the entire surface area of the slope to create horizontal erosion control slots. When grading, filling, and applying topsoil around trees, Contractor shall maintain the existing grade within the drip line of trees, unless otherwise indicated.

Topsoil shall be material free of clay, rock or gravel larger than 2 inches in any dimension, debris, waste, vegetation and other deleterious matter.
Drainage fill shall be selected stone or gravel, graded to pass a 3 inch sieve and retained on a 1 inch sieve.

No sod, seed, or other vegetation shall be placed on soil that has been treated with soil sterilants until sufficient time has elapsed to permit dissipation of toxic materials.

Protection of Trees in Construction Area:
Contractor shall employ protective measures to avoid damage to existing trees to be retained on the project site. Heavy equipment, vehicular traffic, and stockpiles of construction materials, including topsoil, are not permitted within 3 feet of the dripline of any tree to be retained. Specimen trees shown on the construction plans shall be boxed or fenced for protection. Contractor shall water those trees indicated to be preserved, as required, to maintain their healthy growth during the course of construction operations. Contractor shall protect tree root systems from damage due to noxious materials in solution caused by runoff or spillage during mixing and placement of construction materials or drainage from stored materials.

When called for in the construction plans, tunneling under the root system for the installation of utility lines shall be accomplished by hand digging. Contractor shall not allow exposed roots to dry before permanent backfill is placed. Tree trunks, exposed roots, and limbs of the trees designed to be retained which are damaged during construction operations will be cared for as prescribed by an arborist certified by the International Society of Arboriculture (ISA), at the expense of the Contractor. The Contractor shall extend the pruning operation to restore the natural shape of the entire tree. Main lateral roots, taproots, or old main branches shall not be cut or pruned. The Contractor shall cut branches and roots with sharp pruning instruments. He shall not break or chop branches and roots. Cuts over 1/2 inch in size shall be painted with tree pruning compound. Tree pruning compound shall be waterproof, antiseptic, elastic, and free of kerosene, coal tar, creosote and other substances harmful to trees.

Dust Control:
Control dust blowing and moving on construction sites and roads for erosion and sediment control, to prevent exposure of soil surfaces, to reduce on and off site property damage, to prevent health hazards, and to prevent hazardous sight conditions. Control dust blowing by utilizing one or more of the following methods:

A. Mulches bound with natural or chemical binders such as Soiltac®, Terratack®, or equal, as approved by the Engineer.

B. Temporary or permanent vegetative cover.
C. Spray-on adhesive, such as Soil Master®, PennzSuppress®, Soil Sement®, or equal, on mineral soils when not used by traffic and as approved by the Engineer.

D. Tillage to roughen surface and bring clods to the surface.

E. Irrigation by water sprinkling.

F. Barriers using solid board fences, snow fences, burlap fences, crate walls, bales of hay, or similar materials.

Dust control methods shall be implemented immediately whenever dust can be observed blowing on the project site.

Equipment Maintenance and Repair:
Maintenance and repair of construction machinery and equipment shall be confined to areas specifically designated for that purpose. Designated areas shall be located, designed, and maintained so as oils, gasoline, grease, solvents, and other potential pollutants cannot be washed into the storm sewer system or any other receiving stream. Contractor shall not allow oils, gasoline, waste fluids, and other potential pollutants to spill onto the soil or seep into the ground and groundwater. Adequate waste disposal receptacles shall be provided for liquid waste, as well as solid waste. Proper spill response measures and materials will be the responsibility of the Contractor. Designated maintenance areas shall be inspected and properly maintained daily. (Note: Maintenance for Item 725 is paid for under Item 751 “SWPPP Inspection and Maintenance”)

On a site where designated equipment maintenance and repair areas are not feasible, care shall be taken during each individual repair or maintenance operation to prevent spills of potential pollutants. All applicable local, State and Federal Regulations shall be followed for the proper handling, storage, and waste disposal of oils, gasoline, grease, solvents, and other designated potential pollutants associated with the maintenance and repair of construction machinery and equipment.

Waste Collection and Disposal:
A plan shall be implemented for the collection and disposal of on site general trash, as well as construction debris. Disposal of waste materials shall be in compliance with current local, State and Federal Regulations. Trash and debris shall not be allowed to overflow its receptacle or accumulate for excessively long periods of time. Receptacles shall be located where they will least likely be affected by storm water runoff. Trash and construction debris shall not be burned on the project right-of-way.
Special provisions shall be made for the collection and disposal of liquid, toxic, or hazardous materials.

Sanitary Facilities:
Adequate sanitary facilities shall be provided for workers. Sanitary collection and disposal shall be in compliance with current local, State and Federal Regulations.

Vehicle Washing:
Construction equipment and vehicles, such as concrete trucks, shall be washed in designated areas only, as approved by the Engineer. These designated wash areas shall be designed and maintained such as to prevent runoff from leaving the site, as well as preventing the runoff from entering a storm sewer system or into a watercourse. The designated areas shall be located where the wash water will evaporate or infiltrate directly into the ground and where runoff can be collected in a temporary holding or seepage basin. Wash areas shall not be located immediately adjacent to a storm sewer system or other watercourse or near a designated jurisdictional wetland. Concrete waste shall be permitted to dry in a controlled pit, sump, or other, and the waste shall be removed from the project site.

Storage of Construction Materials and Chemicals:
Storage of chemicals, cements, solvents, paints, pesticides, herbicides, fuels, or other potential pollutants shall be stored so that they will not be in contact with storm water runoff or cause potential leachate to the soil or groundwater. These items shall not be stored adjacent to a storm sewer system or other watercourse. Storage and use shall be in compliance with current local, State and Federal Regulations, as well as manufacturer's guidelines.

Contractor shall have a spill response program which addresses spills of construction related hazardous and toxic materials.

Demolition Areas:
Demolition projects usually generate large amounts of dust with significant concentrations of heavy metals and other toxic pollutants. Dust control techniques shall be used to limit the transport of the airborne pollutants. Water or slurries used to control dust shall not be allowed to flow into the storm sewer system or other watercourse.

Street Cleaning:
Street cleaning, such as sweeping, vacuuming, or shoveling, shall be provided along project area roadways where erosion have deposited or construction traffic have tracked sediments, mud, or debris. Contractor shall inspect the roadways daily, and perform the cleaning on a daily
basis, if necessary. Washing or flushing of sediments, mud, or debris into adjacent drainage systems is prohibited.

Dewatering:
The pumping of ponded storm water, or other waters, from the project site directly into an adjacent watercourse or storm sewer system shall not be permitted unless the water has been pretreated through a sediment basin or other method, and as approved by the Engineer.

Pesticides, Herbicides, and Fertilizers:
Contractor shall only use pesticides, herbicides, and fertilizers on the construction site as indicated in the construction specifications and plans or as approved the Engineer. Pesticides, herbicides, and fertilizers shall be stored, used, applied, and disposed of in accordance with manufacturer’s guidelines and with local, state, and federal regulations. Contractor shall not dispose of the pesticide, herbicide, and fertilizer wastes, and containers, on site or in the storm sewer system or other watercourse.

725.4 Measurement and Payment. No separate payment shall be made for this Item. The work performed under this Item shall be paid for and considered incidental to Item 751 “SWPPP Inspection and Maintenance”.

There are no line codes for this Item.

NOTE: This Item requires other Standard Specifications.

Item 160 “Topsoil"
Item 751 “SWPPP Inspection and Maintenance”

END OF ITEM 725
ITEM 730

CONCRETE TRUCK WASHOUT STRUCTURES

730.1 Description. This Item shall govern for furnishing, installing and removing concrete washout structures. The description for maintenance is included in this Item, but payment for maintenance is part of Item 751 “SWPPP Inspection and Maintenance”.

730.2 Submittals. Concrete truck washout structure shall be used per Standard Civil Drawing.

Submit site plan showing location(s) of concrete truck washout structure(s) for approval.

Submit plan for disposal of both concrete truck washout water and solid concrete wastes for approval.

730.3 Concrete Truck Washout Structure. Refer to the Standard Civil Drawing detail for “Concrete Truck Washout Structure”, with sandbags.

730.4 Placement. Do not locate concrete washout structures within 50 feet of storm drain inlets, open drainage facilities or watercourses.

Locate away from construction traffic or access areas to prevent disturbance or tracking.

730.5 Construction. Install a sign adjacent to each temporary concrete washout structure to inform concrete equipment operators to utilize the proper facilities. See Detail sheets for sign dimensions.

Detail – “Below Grade Concrete Truck Washout Structure with Sandbags”.

A. Construct temporary concrete truck washout structures below grade with a minimum length and width of 10 feet. Construct and maintain concrete truck washout structures in sufficient quantity and size to contain all liquid and concrete waste generated by washout operations.

B. Remove rocks and other debris in soil base of structure that might tear or puncture the plastic lining.

C. Provide plastic lining material which is a minimum of 10 mil thick polyethylene sheeting. Sheeting shall be free of holes, tears or other defects that compromise the impermeability of the lining. Install lining seams in accordance with manufacturers' recommendations.
D. Provide sandbags to hold plastic lining in place.

E. Install 15 feet by 35 feet by 8 inches thick granular fill truck parking pad underlain with geotextile per Item 724 “Stabilized Construction Access”.

F. Install orange safety fence around three sides of the structure as shown on the drawing detail.

730.6 Maintenance. Once concrete wastes are washed into the designated structure and allowed to harden, break up the concrete, remove and dispose in accordance with approved submittal.

Inspect lining integrity and level in concrete washout structure before each rainfall to prevent overtopping due to rainfall and daily during periods of daily rainfall and, at a minimum, once every week.

Repair or replace damaged lining or other damaged or missing parts of the washout structure immediately.

Maintain level in washout structure(s) to provide adequate holding capacity with a minimum freeboard of 12 inches.

Existing washout structure(s) must be cleaned, or new washout structure(s) constructed and ready for use once the washout structure is 75 percent full. Contractor is responsible for any concrete washed out in other location. (Note: Maintenance for Item 730 is paid for under Item 751 “SWPPP Inspection and Maintenance”)

730.7 Removal of Concrete Washout Structures. Once concrete washout structures are no longer required, as determined by the Engineer, remove and dispose the hardened concrete and concrete washout water per the approved submittal.

730.8 Material Disposal. Dispose materials used to construct truck washout structure(s) and granular fill parking pad(s) in compliance with current local, State and Federal Regulations.

Remove unusable, objectionable or excess material from the construction work area. Dispose of such material in compliance with current local, State and Federal Regulations.

Disposal of material in the 100-year flood plain without permits is prohibited.

Disposal of material in wetlands or other environmentally sensitive areas without permits is prohibited.
Material disposed of without permits shall be removed and properly disposed of at no cost to the County. Restore the site at no cost to the County.

730.9 Site Restoration. Compact clean fill in pit up to surrounding grade.

Backfill and repair all holes, depressions or other ground disturbances caused by the construction and removal of the concrete washout structure(s).

Restore concrete washout structure area to match surrounding grade and vegetation.

730.10 Measurement. Measurement is as noted as lump sum. No separate measurement will be made for maintenance or removal of accumulated washout structure wastes.

730.11 Payment. Payment is lump sum, for the duration of the project. Payment shall include and be full compensation for all labor, equipment, materials, supervision and for all incidental expenses for the installation of concrete washout structures, complete in place, where 60 percent of the total cost shall be for the furnishing and installation with embankment and excavation. Thus, 40 percent of the total cost shall be for the removal of concrete truck washout structures, after final stabilization, at the end of the project.

No separate payment will be made for maintenance or removal of accumulated washout structure wastes, per this Item. Removal of the concrete washout structure and site restoration is a part of the cost bid for the concrete washout structure. For the Below Grade Concrete Washout Structure shown on the Standard Civil Drawing detail, the sandbags and geotextile are incidental to the cost of the concrete truck washout structure.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires a Standard Civil Drawing that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications.

Item 724 “Stabilized Construction Access”
Item 751 “SWPPP Inspection and Maintenance”.

END OF ITEM 730
ITEM 741

INLET PROTECTION BARRIER
(FOR STAGE II INLETS, GRAVEL BAGS)

741.1 Description: This Item shall govern for furnishing, installing, and removing temporary erosion protection and sediment control gravel bag inlet protection barrier for a stage II inlet in accordance with these Standard Specifications and construction drawings, and as directed by the Engineer. Gravel bag inlet protection barriers for stage II inlets are geotextile fabric bags filled with clean gravel and placed around a stage II inlet, such as a curb inlet. This work shall be performed during construction operations and prior to final stabilization to control erosion and sedimentation.

741.2 Materials: Bags shall consist of geotextile fabric (filter fabric) made of long-chain synthetic polymers composed of at least 95 percent by weight of polyolefins in a woven fabric. The geotextile fabric shall meet or exceed the following specifications shown in Table 1:

<table>
<thead>
<tr>
<th>SILT FENCE GEOTEXTILE FABRIC PROPERTIES</th>
<th>REQUIREMENTS UNSUPPORTED SILT FENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Units Supported Silt Fence</td>
</tr>
<tr>
<td>Grab Strength</td>
<td>lbs.</td>
</tr>
<tr>
<td>Machine Direction</td>
<td>lbs.</td>
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<tr>
<td>X-Machine Direction</td>
<td>lbs.</td>
</tr>
<tr>
<td>Permittivity</td>
<td>sec⁻¹</td>
</tr>
<tr>
<td>Ultraviolet Stability</td>
<td>%</td>
</tr>
</tbody>
</table>

NOTES:
1. Table 1 adapted from AASHTO M 288 Geotextile Specification for Highway Applications Table 6. Temporary Silt Fence Property Requirements.
2. All numeric values in Table 1 except Apparent Opening Size (AOS) represent minimum average roll values (MARV). Values for AOS represent maximum average roll values.
Geotextile fabric shall contain stabilizers and/or inhibitors to make the fabric resistant to deterioration resulting from exposure to sunlight or heat. Geotextile fabric shall be resistant to commonly encountered soil chemicals, mildew, rot, and insects. Geotextile fabric shall be free of defects or flaws that affect its physical and/or filtering properties. Geotextile fabric shall provide an expected useable life comparable to the anticipated construction period.

The bag size shall be as follows:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>18 to 24 inches</td>
</tr>
<tr>
<td>Width</td>
<td>12 to 18 inches</td>
</tr>
<tr>
<td>Thickness</td>
<td>6 to 8 inches</td>
</tr>
</tbody>
</table>

The bag shall be filled with open-graded gravel and weigh 50 to 75 pounds. The gravel shall be free from adherent coatings, salt, alkali, dirt, clay, or organic and injurious matter.

Nylon rope shall be used to secure the closure of the gravel filled bag.

Construction Methods: Gravel bag inlet protection barrier for a stage II inlet shall be installed at the locations shown on the construction drawings and in accordance with the Standard Civil Drawing or as directed by the Engineer. Inlet protection barrier for a stage II inlet shall be constructed in accordance with an approved schedule that clearly describes the timing during the construction process that the various erosion control measures will be implemented. Inlet protection barrier for a stage II inlet shall be installed so as surface runoff will percolate through the system and allow sediment to be retained and accumulated.

Gravel bags for the inlet protection barrier shall be placed so as the gravel bags are placed on each side of the curb inlet along the gutter line and continuously along the back of the curb inlet. Gravel bags shall not be placed so as the throat of the inlet is blocked. Gravel bags shall be placed in a row with ends tightly abutting the adjacent bag.

The Contractor shall inspect the gravel bag inlet protection barrier at least once every week or as directed by the Engineer. The Contractor shall remove irregularities which will impede normal flow. Erosion protection and sediment control systems shall be maintained by the Contractor until final stabilization. Damage caused to erosion protection and sediment control systems shall be repaired immediately. (Note: Maintenance for Item 741 is paid for under Item 751 “SWPPP Inspection and Maintenance”)
The Contractor is responsible for removal and proper disposal of sediment and debris from the inlet protection barrier system and as directed by the Engineer. Sediment and debris shall not be allowed to flush into the storm sewer system, waterways, jurisdictional wetlands, or onto adjacent properties. Sediment deposits shall be removed before they reach one-third of the height of the gravel bags.

Uncontaminated sediment can be placed at the project spoil site or, if properly handled, spread out to supplement fill requirements. The Engineer will designate how the sediment deposits are to be handled. Uncontaminated sediment shall not be placed in waterways or jurisdictional wetlands, unless as approved by the Engineer. If sediment has been contaminated, then it shall be disposed of in compliance with current local, State, and Federal Regulations. Offsite disposal shall be the responsibility of the Contractor.

After final stabilization and at the direction of the Engineer, the Contractor, when required, shall be responsible for removing all erosion protection and sediment control systems that are not permanent, from the project.

741.4 Quality Assurance. The Contractor is responsible for the control of the quality of materials incorporated into the construction and the quality of completed construction. The County will engage materials engineering services to provide quality assurance testing and inspection to assist the Engineer in determining the acceptability of materials and completed construction. Quality assurance services provided by the County do not relieve the Contractor of his responsibility for quality control. The Materials Engineer shall not have control of the means, methods, techniques, sequences or procedures of construction selected by the Contractor.

741.5 Measurement. Inlet protection barrier for a stage II inlet shall be measured as “each”, complete in place all necessary gravel bags to protect against erosion and control sediment.

741.6 Payment. Payment for a gravel bag inlet protection barrier for a stage II inlet shall include and be full compensation for all labor, equipment, materials, supervision, and all incidental expenses for construction of this Item, where 60 percent of the total unit cost shall be for the furnishing and installing all materials. Thus, 40 percent of the total unit cost shall be for the removal and disposal of erosion protection and sediment control systems: inlet protection barrier, after final stabilization, at the end of the project.

There are line code(s), description(s), and unit(s) for this Item.
NOTE: This Item requires a Standard Civil Drawing that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications.

Item 751 “SWPPP Inspection and Maintenance”

END OF ITEM 741
ITEM 750

ROCK FILTER DAMS

750.1 Description. This Item shall govern for furnishing and installing temporary erosion protection and sediment control rock filter dams utilized during construction operations and prior to final stabilization in accordance with these Standard Specifications and construction drawings, and as directed by the Engineer. Rock filter dams are temporary berms constructed of stone to intercept and slow storm water runoff to retain sediment on the construction site. Depending upon the type of rock filter dam specified in the construction plans as Type 1, 2, 3, 4, or 5, the aggregate fill may be unwrapped, wrapped in twisted hexagonal wire mesh, or confined in a gabion wire basket.

Applications of RockFilter Dams:

A. Type 1 dams may be used at toe of slopes, around inlets, in small ditches, and at dike or swale outlets. Type 1 dams are recommended for erosion and sediment control from a drainage area of 5 acres or less.

B. Type 2 dams may be used in ditches and at dike or swale outlets.

C. Type 3 dams may be used in stream flow.

D. Type 4 sack gabions may be used in ditches and smaller channels to form an erosion and sediment control dam.

E. Type 5: As shown in plans.

750.2 Materials. Geotextile fabric shall consist of a woven monofilament or spunbond nonwoven fibers consisting of long chain synthetic polymers composed of at least 95 percent by weight of polyolefins. Geotextile fabric shall equal or exceed the following average roll values or as directed by the Engineer:

A. Minimum average roll value.
   1. Elongation ≥ 50%.
   2. Grab Strength – 200 pounds.
   3. Puncture Strength – 75 pounds.
4. UV Stability (retained strength) – 50% after 500 hours of exposure.

B. Maximum average roll value.

Apparent Opening Size (AOS) – 0.6 mm/#30 US sieve.

Geotextile fabric shall be resistant to commonly encountered soil chemicals, mildew, rot, insects, and deterioration resulting from exposure to sunlight or heat. Geotextile fabric shall provide an expected useable life comparable to the anticipated construction period.

Aggregate for the rock filter dams shall consist of crushed stone. Aggregate particles shall be composed of clean, hard, durable materials free from adherent coatings, salt, alkali, dirt, clay, loam, shale, soft or flaky materials or organic and injurious matter. Aggregate shall be cubic or rounded form, not elongated, flat, shapes. Spalls, fragments, and chips shall not exceed 5 percent by weight. Crushed concrete shall not be substituted for the crushed stone unless as approved by the Engineer.

Aggregate size shall depend upon the type of rock filter dam specified in the construction plans. Aggregate size based on type of rock filter dam is as follows:

A. Type 1: 3 inches to 5 inches, open graded.
B. Type 2: 3 inches to 5 inches, open graded.
C. Type 3: 4 inches to 8 inches, open graded.
D. Type 4: 3 inches to 5 inches, open graded.
E. Type 5: As shown on the plans.

Mesh is required for reinforced type rock filter dams. Mesh shall be 20 gauge galvanized double twisted hexagonal wire mesh with 1 inch diameter hexagonal openings. Mesh wire shall be zinc coated prior to being double twisted. Reinforcing spiral binders, lacing wire, and stiffeners shall be made of wire having the same coating material and same wire size as the wire mesh. Gabion wire baskets shall equal or exceed the requirements of the wire mesh.

Construction Methods. No clearing and grubbing or rough cutting, other than as specifically directed by the Engineer to allow for soil testing, surveying and installation of erosion protection and sediment control measures, shall be permitted until sediment control and erosion protection systems are in place.
Rock filter dams shall be installed at the locations shown on the construction plans and in accordance with the Standard Civil Drawing or as directed by the Engineer. Rock filter dams shall be the types specified in the construction plans. Rock filter dams shall be constructed in accordance with an approved schedule that clearly describes the timing during the construction process that the various erosion control measures will be implemented. Rock filter dams shall be installed so as to prevent downstream deposition of sediment and debris from the construction site.

The separation geotextile fabric and wire mesh shall be sized and placed in accordance with the rock filter dam detail and as specified by the type of rock filter dam shown in the construction plans. The separation geotextile fabric may be omitted only as approved by the Engineer. The separation geotextile fabric and wire mesh shall be securely staked with wooden or metal stakes to the bottom and side slopes of the ditch or channel prior to aggregate placement. Sack gabions for Type 4 rock filter dams shall be securely staked with wooden or metal stakes to the bottom and side slopes of the ditch or channel, as well.

Aggregate fill shall be placed to the width, length, height and slopes in accordance with this Item and the rock filter dam detail and as specified by the type of rock filter dam shown in the construction plans. The height of the dam shall be measured vertically from the existing ground to the top of the filter dam. The length of the dam shall be measured across the top centerline of the dam from embankment to embankment and includes the additional length embedded into the embankment. Width of the dam shall be measured along the top face of the dam.

Wire mesh shall be folded upstream side over the aggregate fill and tightly secured to itself on the downstream side using wire tires. Rings may be substituted for wire ties.

Additional aggregate fill or gravel bags shall be placed and secured at the embedded section to prevent low flows from short circuiting the dam at the adjacent dirt embankment area. Gravel bags shall meet the specifications of Item 741 “Inlet Protection Barrier (for Stage II Inlets, Gravel Bags)”.

The Contractor shall be responsible for periodic reshaping, repairing, and maintaining of rock filter dams as directed by the Engineer.

The Contractor shall inspect the rock filter dam at least once every week or as directed by the Engineer. Damage caused to rock filter dams shall be repaired immediately. Rock filter dams shall be maintained by the Contractor until construction staging requires removal or upon final stabilization of the construction site. Upon removal of the rock filter dam, the area shall be stabilized with vegetation, or other. (Note: Maintenance for Item 750 is paid for under Item 751 “SWPPP Inspection and Maintenance”)
The Contractor is responsible for removal and proper disposal of sediment and debris from the rock filter dam. Removed sediment and debris shall not be allowed to flush into the storm sewer system, waterways, jurisdictional wetlands, or onto adjacent properties. Sediment deposits shall be removed before they reach 1/3 of the height of the dam.

Uncontaminated sediment can be placed at the project spoil site or, if properly handled, spread out to supplement fill requirements. The Engineer will designate how the sediment deposits are to be handled. Uncontaminated sediment shall not be placed in waterways or jurisdictional wetlands, unless as approved by the Engineer. If sediment has been contaminated, then it shall be disposed of in compliance with current local, State and Federal Regulations. Offsite disposal shall be the responsibility of the Contractor.

After final stabilization and at the direction of the Engineer, the Contractor, when required, shall be responsible for removing all erosion protection and sediment control systems that are not permanent, from the project.

Pursuant to Section 404 of the Clean Water Act, a permit may be required for placement of fill, rock filter dams, into Waters of the United States, Waters of the State, and their associated jurisdictional wetlands. The Contractor shall not proceed with the construction of the rock filter dams in Waters of the United States, Waters of the State, and their associated jurisdictional wetlands until the permits are obtained.

750.4 Quality Assurance. The Contractor is responsible for the control of the quality of materials incorporated into the construction and quality of completed construction. The County will engage materials engineering services to provide quality assurance testing and inspection to assist the Engineer in determining the acceptability of materials and completed construction. Quality assurance services provided by the County do not relieve the Contractor of his responsibility for quality control. The Materials Engineer shall not have control of the means, methods, techniques, sequences or procedures of construction selected by the Contractor.

750.5 Measurement. When paid for separately as a pay item, measurement for rock filter dams, Types 1,2,3,4, or 5 shall be by the linear foot, as shown on the plans, complete in place. Measurement shall be along the centerline of the top of the dam from embankment to embankment and includes the additional length which is embedded into the embankment.

750.6 Payment. Payment for rock filter dams shall include and be full compensation for all labor, equipment, materials, supervision and for all incidental expenses for the construction of these items, complete in place, where 60 percent of the total unit cost shall be for furnishing and
installation with embankment and excavation. Thus, 40 percent of the total unit cost shall be for the removal of erosion protection and sediment control systems: rock filter dams, after final stabilization, at the end of the project. Geotextile fabric, reinforcement, aggregate fill, and gravel bags shall be considered incidental expenses to this Item. Disposal of sediment and debris are considered incidental expenses to this Item.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires drawing details that shall be incorporated into the contract documents.

NOTE: This Item requires other Standard Specifications.

Item 741 “Inlet Protection Barrier (for Stage II Inlets, Gravel Bags)”
Item 751 “SWPPP Inspection and Maintenance”

END OF ITEM 750
ITEM 751

SWPPP INSPECTION AND MAINTENANCE

751.1 Description. This Item shall govern for inspecting, maintaining, cleaning, and replacing as necessary, all SWPPP items, in conformance with the drawings and/or as directed by the Engineer. Included in the maintenance of the SWPPP will be once per week inspections and reports, or as directed by the Engineer. The day of the week established for the inspections, shall be mutually agreed to, by Harris County and the Contractor, prior to the Contract start date.

A Storm Water Pollution Prevention Plan (SWPPP) has been established for this project in accordance with the EPA and TCEQ regulations, and as defined by the TPDES General Permit.

751.2 Construction Methods. All SWPPP items shall conform to details shown on the drawings and the Storm Water Pollution Prevention Plan in the Project Manual.

Prior to beginning work, the Contractor shall designate in writing an authorized representative who will be responsible and available on the project site or in the immediate area to insure compliance with the SWPPP.

The Contractor is solely responsible for inspecting and maintaining all the SWPPP items. The Contractor’s responsibility in this regard extends for the entire duration of the project, from the start of construction until acceptance by the County.

All SWPPP items such as Sodding, Hydro-Mulch Seeding, Reinforced Filter Fabric Barrier, Inlet Protection Barrier (Stage I and/or Stage II), Stabilized Construction Access, Concrete Truck Washout, Rock Filter Dam, etc. shall be maintained at all times by cleaning, replacing or a combination thereof such that after rain or other inclement weather the SWPPP items shall be equal to or exceed their like new installed condition.

The Contractor shall receive compensation for inspecting and maintaining the necessary SWPPP items, and any incidentals necessary to achieve turf establishment and an approved final inspection and acceptance by the County.

The above does not preclude the requirements of the “Harris County General Conditions”.

751.3 Submittal. The Contractor shall be required to submit and fill out the SWPPP Inspection Report at least once per week, or as directed by the Engineer. The inspection and the Report shall be completed in conformance with the Storm Water Pollution Prevention Plan, and maintained at the project site. The Contractor shall maintain a corrective action log, and the SWPPP amendment log.

751.4 Measurement & Payment. Inspecting, maintaining, cleaning, and replacing any or all SWPPP items, shall be paid for by the month, provided the SWPPP is properly maintained, as approved by the Engineer. Included in the maintenance of the SWPPP will be the issues described in Item 725 “General Source Controls (SWPPP)” and required weekly inspections and Reports. All items noted in each weekly SWPPP Inspection Report shall be corrected within 72 hours, or prior to the next rain event, whichever come first, and/or as approved by the Engineer.

The SWPPP Monthly Maintenance Fee will be designated by a minimum bid amount.

If in the opinion of the Engineer, the Contractor does not comply with the above requirements of the work, a prorated portion of the SWPPP Monthly Maintenance Fee will be withheld from any money due or to become due to the Contractor.

There are line code(s), description(s) and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications as designated in the Project Manual.

NOTE: This Item requires other Standard Specifications

Item 162 “Sodding For Erosion Control and Stabilization”
Item 165 “Hydro-Mulch Seeding (For Erosion Control and Stabilization)”
Item 713 “Reinforced Filter Fabric Barrier”
Item 719 “Inlet Protection Barriers”
Item 724 “Stabilized Construction Access”
Item 725 “General Source Controls (SWPPP)”
Item 730 “Concrete Truck Washout Structures”
Item 741 “Inlet Protection Barrier (For Stage II Inlets, Gravel Bags)”

END OF ITEM 751
1000 ITEMS

- 1000 – Traffic Signal Installation and Modification
- 1210 – Intelligent Transportation System (ITS) Controller Cabinet Assembly
ITEM 1000

TRAFFIC SIGNAL INSTALLATION AND MODIFICATION

1000.1 Description. This Item shall govern for furnishing all labor, materials, tools, equipment, tests, adjustments and all other incidentals necessary to install and/or modify a traffic signal system.

All materials and equipment furnished for installation under this contract shall be new and unused, unless otherwise specified.

All bidders shall visit the job site prior to bidding in order to acquaint themselves with all job site conditions and problems, if any, and all other factors that may affect the bid. Any discrepancy between drawings and specifications shall be resolved prior to bidding.

The Contractor shall clean the job site of all debris, loose excess excavated materials, etc. accumulated as a result of work performed under this contract. The Contractor shall exercise care in working around the area not to infringe on or mutilate property; the Contractor shall be responsible for any such infringement or mutilation. It is the Contractor's responsibility to restore the construction area to its original condition prior to final acceptance of the contract.

All trades are to work in cooperation with one another, and all trades, when necessary and/or as standard procedure, shall construct preliminary grounds for work to be performed by succeeding trades. It is the General Contractor's responsibility to see that all work is properly coordinated and executed.

Any Contractor having any questions concerning this project should contact the Harris County Engineering Department, Construction Programs Division at (713) 274-1539.

1000.2 Permits, Codes, Etc. The Contractor shall be responsible for obtaining permits and inspections by regulatory bodies and shall work with Harris County in obtaining power to the system from the CenterPoint Energy and notify Harris County 48 hours prior to connecting the system to the CenterPoint Energy lines.

The meter service assembly shall be installed by the Contractor as required by CenterPoint Energy at the Contractor's expense (unless otherwise specified and/or shown).
All wiring throughout this system shall be in strict accordance with the National Electrical Code, all local applicable codes and shall also comply with all requirements of the CenterPoint Energy, in order that service may be obtained from them. All costs for code compliance are to be included in the bid for this contract.

All traffic signal system equipment shall be furnished and installed in accordance with drawings and specifications.

All construction will be in accordance with the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways", (TMUTCD), and in accordance with the specifications and drawings.

The Contractor shall contact the Lone Star Notification Center at (713)-223-4567 in Houston and 1-800-669-8344 outside of Houston and Texas One Call at 1-800-245-4545 72 hours before commencing any work to locate any utility lines in construction area. It is the Contractor's responsibility to physically locate any sewer, water or gas lines and to adjust the location of any foundations(s).

1000.3 Wiring Diagrams, Guarantees, Etc. This contract will not be considered complete until Harris County has been furnished with two complete sets of wiring diagrams (as built) for the controller and the system. A diagram of the phasing of the system shall be pasted inside the door of the controller cabinet to facilitate repairs and adjustments to the controller. One complete set along with brochures, warranties, etc. shall be forwarded to the Harris County Engineering Department, including one reproducible copy of wiring diagrams.

All items installed under this Item, having a manufacturer's guarantee shall be installed by or under the direction of the manufacturer or his certified agent, when required to conform with the manufacturer's guarantee, and all such manufacturer's guarantees, warranties and bonds shall be forwarded to the Engineer.

1000.4 Barricades and Warning Signs. Prior to closing any section of roadway to traffic, the Contractor shall furnish and install barricades and warning signs in accordance with the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways" (TMUTCD) and in accordance with Item 670 “Barricades” and Item 671 “Traffic Control”.

All of the above does not preclude the requirements of Item 4.04 “Barricades, Warning Lights, and Signs on Projects Involving Public Roads" of the "Harris County General Conditions for Roads, Bridges and Related Work".
1000.5 Construction Signs. Contractor shall furnish and install construction signs on all approaches to the intersection as shown on the drawings, and as required by TMUTCD and Harris County Specification Items 670 and 671.

Construction signs shall be installed at the start of the project and maintained during the entire construction, until final acceptance by Harris County.

Closing of lanes for construction shall be done in strict accordance with the TMUTCD and as shown on the drawings.

1000.6 Responsibility for Damage or Claims. (Also see Paragraphs 3.01 “Indemnification” and 4.01 “Laws to be observed” of “Harris County General Conditions for Roads, Bridges and Related Work”.)

The Contractor shall hold harmless the County and its representatives from all suits, actions, or claims of any character filed as a result of injuries or damages sustained by any person or property due to neglect in safeguarding the work, the use of unacceptable materials in the execution of the contract, or any act of omission by the Contractor or his Sub-Contractors. The Contractor shall not be released from responsibility until the contract has been completed and all work accepted. Money due the Contractor under and by virtue of his contract may be retained by the County or his surety may be held until such claims have been settled and suitable evidence to that effect furnished to the County.

Unless otherwise set forth in these Standard Specifications, the Contractor shall receive no direct compensation for furnishing, erecting, and maintaining the necessary barricades, lights, flares, flagmen, signs, or for any other incidentals necessary for the good and proper safety, convenience, and direction of traffic during the period prior to final inspection and acceptance by the County.

1000.7 Field Test. All traffic signal equipment furnished and installed by the Contractor shall be field-tested. The contract shall not be considered complete until all the signal equipment has been field-tested for 10 consecutive days without failure and/or malfunction and to Harris County's satisfaction. Should a failure and/or malfunction occur within the 10-day test period, the test period shall be extended until the signal equipment has operated successfully for 10 consecutive days.

1000.8 Guarantee. The Contractor, by accepting this contract, guarantees all workmanship, materials and equipment performed or furnished and installed under this Item for a period of one year from date of substantial completion and shall, at his entire expense and within said term of guarantee, repair, replace or adjust all faulty, broken, or maladjusted
materials and/or equipment furnished and installed under this Item. The Contractor shall initiate emergency repair service operations on the job site a maximum of 4 hours after notification by Harris County of system failure or malfunction, and the Contractor shall pursue repair operations with all haste in order that signal down time will be kept to absolute minimum. In the event the Contractor fails to respond within 4 hours, Harris County will pursue the repair operations and the Contractor shall reimburse the County from available retainage and project receivables. Vandal damage and/or acts of nature shall not be included under Contractor's guarantee. Contractor shall sign the inspection sheet on all warranty calls.

1000.9 Substitute Materials. Set forth in these Standard Specifications are definite models, materials, etc. of particular manufacturer; however, items of equal appearance, durability, performance and design will be accepted upon approval of Harris County. The successful bidder is required to submit to the Harris County Engineering Department, Traffic Signal Maintenance Section, engineering brochures and information on all materials he desires to furnish and install which are of different manufacturer or model number than specified herein. The submittal is for approval or disapproval by the Engineer. In the event approval is not obtained, the submitted items shall not be furnished and installed. The submittals shall be furnished no later than the initial pre-construction meeting.

1000.10 Equipment Location. Harris County or an authorized representative shall stake the location of all traffic signal supports, pull boxes, and controller. It is the Contractor's responsibility to verify these locations prior to commencing work.

1000.11 Special Equipment and Materials.

A. Lightning Arrestor. Shall be 2 pole, 3 wire, 175v per pole for 120/240 service. Lightning arrestor shall be installed on the main disconnect box (Joslyn J9200-10, General Electric 9L15ECB001, or approved equal).

B. Main Breaker. Shall be a minimum 30 amp breaker for sign lights and luminaires and a 40 amp breaker for the signal lights.

C. -OMITTED-

D. Photoelectric Cell. Shall be locking thermal type cell with maximum incandescent capacity of 120V at 60Hz, 1000W to 2000W, 8.3 Amps, Max ballasted capacity 8.3 Amps, ON at 1-5 foot candles, OFF at 3-15 foot candles, rated for temperatures of –0 F to 158 F.
Unit shall be Grainger Part # 54793 or equal. Photoelectric cell shall be installed as indicated on drawings. The Contractor shall permanently mark, scribe or etch installation date on bottom of photoelectric cell. Photoelectric cell shall have a warranty of 2 years.

E. Hardware. All hardware used in this construction shall be galvanized; all conduits shall be galvanized rigid steel conduits or Schedule 40 PVC as per Item 677 “Electrical Conduits for Traffic Signal Installation”.

All junction boxes and/or condulets shall have a cover and gasket and shall be located approximately 24 inches above natural ground for accessibility as shown on the drawings.

F. Pull Boxes. Pull boxes shall be installed at changes in direction of the conduit and/or as shown on the drawings.

All pull box lids shall be marked "Traffic Signal - HCED".

All pull boxes shall be installed over an 18 inch compacted gravel fill as shown on the drawings. All conduits coming to a pull box shall be sealed and grounded.

G. Signal Cables. All traffic signal cable shall be copper insulated jacketed cable in accordance with Item 679 “Insulated Jacketed Traffic Signal Cable”.

The number and size of conductors shall be as directed by the manufacturer to service the required signals and according to the National Electric Code or as shown on the drawings.

All wires for luminaires shall be a minimum 2 conductor #14 AWG (IMSA 2-1) stranded wire.

H. Messenger Wire (For Catenary System Only). The catenary system shall be tied to the poles at an elevation as required to obtain a 19 foot clearance from the bottom of signal lights to the pavement.

The galvanized steel catenary signal suspension system shall be 5/16 inch (Siemens Martin), 7 wire strand, one per signal, and two 1/4 inch horizontal span, all in accordance with Item 678 “Zinc Coated Steel Wire Strand”.
All signal cables shall be attached to the catenary system with stainless steel or aluminum "Lashed Cable Supports" two every 18 inches (Panduit Catalog No. MLT 4H-LP or approved equal).

I. Vehicle Detector. Shall be loop sensors in saw-cut slots in the pavement as per the detail drawings.

The loops shall be pairs, twisted wires for proper tuning. The loop lead-in wires shall be continuous to the controller or pull boxes (condulet or junction box), if any, and the connection shall be waterproof (3M Scotchcast or approved equal).

The wires to the poles shall be laid in minimum 1 inch conduit buried a minimum of 30 inches or as directed by the engineer in the field.

Where the wire leaves the pavement and enters the conduit, the junction shall be sealed with hot asphalt seal. The complete loop system shall be waterproof. In case of leakage and subsequent damage to or in operation of the loop system, the Contractor shall return to the job site and repair or replace the damaged or inoperative parts to Harris County's satisfaction.

The approximate location of the detectors is shown on the intersection drawings; however, Harris County will accurately locate them at the time of installation.

Trenching for conduit installation shall be back filled to surrounding undisturbed soil density, and any excess excavated material removed from the job site by the Contractor.

All saw cuts shall be cleaned with an air compressor to remove all debris and moisture prior to installation of loop detector wires. All loops shall be tested with a meter at the time of installation.

Wires shall not be placed in slots until the County Inspector has examined the depth, width, and condition of saw cut slot. Any loop installed prior to inspection shall be removed by the Contractor for slot inspection at the Contractor's expense.

Wires used for loop detectors and from loops to the first pull box, condulet or pole, shall be #14 X.H.H.W.

Wires used from pull box, condulet or pole to the controller shall be Belden 8720 Shielded Cable or approved equal.
J. Supports

1. Steel Strain Poles. Shall be 34 foot long hot dip galvanized steel traffic signal supports as shown on drawings.

The support shall be set on reinforced concrete foundation as shown on the drawings. The pole shall have an elevation as required to obtain the 19 foot clearance from the bottom of the signal lights to the crown of the pavement.

The traffic signal support shall be designed according to Item 680 “Steel Mast Arm and Steel Strain Pole Assemblies”.

2. Mast Arms. Shall be installed as shown on the drawings so as to obtain 19’ clearance from the bottom of the signal lights to the crown of the pavement. The mast arms shall be in accordance with Item 680.

3. Wood Poles. Shall be 35 foot, Class II treated timber poles in accordance with Item 681 “Treated Timber Poles”, unless otherwise specified in the drawings.

The poles shall be set at least 7 feet in the ground and shall be properly guyed with 3/8 inch galvanized guy wire, turnbuckle and cover shield. The anchor shall be 10 inch helix type, screw anchor with 1-1/4 inch rod 8 feet long (minimum 2 guys and anchors per pole). Sidewalk guy wire to be used where necessary due to right-of-way restriction or as directed by Harris County.

If the Contractor furnishes the poles, the Harris County Engineering Department, Traffic Signal Maintenance Section shall be supplied 2 certified copies of documentation verifying the treatment of the poles, at no additional cost to Harris County. The Contract shall not be considered complete until such copies are received by Harris County.

4. Pedestal Pole. Shall be a 4-1/2 inch O.D. steel or aluminum pedestal pole of the length specified in the drawings. Pedestal poles shall be in accordance with Item 683 “Traffic Signal Supports – Pedestal Poles”.

K. Meter Poles. Meter address shall be installed on the meter pole by permanent type numbers and shall be clearly visible.
1. Pedestal Poles. Shall be a 4-1/2 inch square steel pedestal pole of the length specified in the drawings with meter loop and disconnect, including any conduits, as shown on the drawings and as required by CenterPoint Energy.

2. Wood Poles. One of the proposed signal poles shall be used as a meter pole with new meter loop and disconnect, as required by the CenterPoint Energy and shown on the drawings.

3. Steel Strain Pole. One of the proposed signal poles shall be used as a meter pole with new meter loop and disconnect as shown on the drawings and as required by the CenterPoint Energy.

L. Controller Unit

The controller shall be designed in accordance with Item 2070 “Advanced Transportation Controller”.

M. Cabinet

1. Pole Mounted

Cabinet shall be made of sheet aluminum or cast aluminum, all in accordance with Item 1210 “Intelligent Transportation System (ITS) Controller Cabinet Assembly”.

2. Ground Mounted

Cabinet shall be made of sheet aluminum or cast aluminum, all in accordance with Item 1210.

The cabinet shall be ground mounted on a reinforced concrete foundation, as shown in the drawings.

N. Detector Amplifier

Detector amplifiers shall be in accordance with Harris County Specification Item 1210.

O. Signal Heads

"Polycarbonate" signal heads shall be adjustable face for span-wire, band-on arms, or pole mounting as indicated on drawings,
and shall be designed in accordance with Item 690 “Traffic Signal Heads”.

"Programmable" signal heads shall be adjustable face for spanwire, band-on arms, or pole mounting as indicated on the drawings, and in accordance with Item 691 “Twelve Inch Signal Head with Programmable Visibility of Signal Faces”.

All "T" connectors shall be made of aluminum and shall have a minimum of 2 screws to be tied to the horizontal signal assembly. All fluorescent type down lights shall be designed according to Item 694 “Down Lights for Traffic Signals”.

All incandescent type down lights shall be designed in accordance to Item 694.

P. Pedestrian Signals. Shall be 12 inch pedestrian signals in accordance with Item 692 “Symbolic Pedestrian Signal Head (Incandescent Type)” and installed as shown on the drawings.

Q. Signs. All required construction signs and regulatory signs shall be in accordance with the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways" as shown on the drawings.

Construction Signs. All required construction signs shall be installed prior to beginning of the project and shall be kept and maintained during the entire length of construction, until final acceptance by Harris County.

R. Pavement Markings. All pavement markings shall be installed in accordance with Item 660 “Reflectorized Pavement Markings” and Item 663 “Traffic Buttons and Pavement Markings”. All pavement markings shall be installed in accordance with the "Texas Manual on Uniform Traffic Control Devices for Streets and Highways", and Harris County Standards.

S. Materials Furnished by Harris County. It is the responsibility of the Contractor to obtain any equipment furnished by Harris County at designated location or locations at a date to be determined by Harris County.

T. Materials Furnished by Contractor. Contractor is required to furnish all equipment, materials, and labor necessary for the complete installation.
1000.12 Construction Phases. The Contractor will be required to construct this project in phase(s). The phases and the specific items that the Contractor will be required to complete in each are as shown by the special provision to this Item.

1000.13 Special Notes

A. Harris County reserves the right to add to or deduct from contract any loop detectors. Unit price bid shown on the bid sheet will be used; however, Contractor shall furnish and install all loop leads from poles to pull boxes and/or poles nearest to the proposed loops.

B. The location of all traffic signal poles shown is approximate and may be relocated as necessary. It is the Contractor's responsibility to verify exact location of the traffic poles with the Harris County Engineering Department, Construction Program Division (713-274-1539) prior to installation.

C. Location of CenterPoint Energy service outlet is subject to relocation to any corner at no additional cost to Harris County.

D. OMITTED -

E. All work in this contract shall be performed between the hours of 8:30 a.m. and 4:30 p.m., Monday through Friday unless prior authorization has been obtained from the Engineer.

F. It is the Contractor's responsibility to visit the location prior to bidding in order to fully understand the work to be performed in accordance with these Standard Specifications. Any discrepancies shall be resolved prior to bidding.

G. Contractor shall notify the Harris County Engineering Department, Construction Program Division (713-274-1539) 48 hours prior to commencement of work so that an inspector may be assigned.

H. The "Service Outlet Location and Data Statement" for these intersections will be supplied to the Contractor upon receipt from CenterPoint Energy.

I. The existing signal system, if included in this contract, shall remain operational during the modifications.

Down time, if any, shall be kept to absolute minimum. The switch over from the old system to the new system shall be accomplished
within 6 hours between 9 a.m. and 3 p.m. Contractor shall furnish and install all temporary traffic control (stop signs, flagmen, etc.) during any down time, in addition to all required construction signs. Contractor shall inform the Harris County Engineering Department, Construction Programs Division (713) 274-1539 at least 48 hours prior to turning on the new system, which shall be done during off-peak hours.

The Contractor shall be responsible for the maintenance and operation of the existing traffic control systems for 24-hours a day from commencement date of Purchase Order until final acceptance of contract by Harris County. During the construction of the proposed contract, the Contractor shall maintain the existing traffic control systems in accordance with the Texas Manual on Uniform Traffic Control Devices.

If during construction of the proposed contract, any major traffic signal equipment, such as traffic signal head, traffic signal controller assembly, and signal pole, that requires replacement due to normal wear, deterioration, or any circumstance over which the Contractor has no control (as determined by Harris County) will be furnished by Harris County at no cost to the Contractor and shall be picked up and installed by the Contractor. No extra compensation will be allowed to the Contractor for this work.

Any and all equipment/material furnished by Harris County to the Contractor which is not used in this contract is the property of Harris County and shall be returned to Harris County by the Contractor, at no cost to Harris County.

The Contractor shall furnish Harris County with a 24 hour telephone number for the purpose of forwarding malfunction calls. In the event that the Contractor cannot be reached at the above mentioned number, Harris County will take the necessary action to restore the traffic signal system to normal operation and all expenses incurred will be deducted from the final payment of the contract.

Contractor will be required to respond immediately and to initiate emergency maintenance operations on the job site a maximum of 6 hours after call is received from Harris County. In the event that operation is not returned to normal within 6 hours, the Contractor shall contact a representative from Harris County, Traffic Signal Maintenance Section at 713-881-3210 for further assistance and/or direction.
In the event the Contractor fails to respond within 6 hours, Harris County will pursue the repair operations. If the County pursues the repair operations due to failure of the Contractor to respond within this time frame, the County will subtract all associated costs from the Contractor’s retainage for the project at the time the final estimate for the project is processed. If sufficient retainage does not exist to make restitution, then the County will forward the bills to the Contractor for reimbursement and inform the appropriate bonding company.”

J. Contractor shall remove all existing traffic poles, signal heads, controller assembly, wire, conduit, etc. that are no longer used with the new traffic signal system. The Contractor shall disassemble and return salvageable equipment as per Harris County’s direction.

K. After installation and prior to connecting ends, each continuous run of insulated conductor shall have a minimum D.C. insulation resistance of 50 mega-ohms when tested at 500 volts D.C.

All or part of conductor system may be tested at Harris County's option. Conductors exhibiting an insulation resistance of less than 50 mega-ohms shall be replaced by the Contractor at his expense.

L. The controller housing, signal common, service common, conduit, and metal signal supports shall be bonded with No. 8 AWG copper wire or equal to form a continuous system and effectively grounded to 5/8 inch x 10 foot copper weld ground rods.

M. All signal heads shall be wrapped with burlap or an approved equal cover so that signal faces cannot be seen from the time of installation until placed in operation.

N. Each loop detector cable shall be tagged inside the cabinet with loop numbers as called for on the drawings.

O. The Contractor shall inform Harris County Engineering Department, Construction Programs Division (713) 274-1539 at least 48 hours prior to turn-on. Turn-on shall be scheduled for Monday through Thursday, only during off-peak hours. The following conditions shall be met prior to turn-on:

1. All pavement markings and signage complete;

2. All poles, controllers assemblies and electrical service correctly bonded to earth;
3. All appropriate signal faces clearly visible to approaching traffic for a minimum of 300 feet in advance of stop bar;

4. All vehicle and pedestrian detectors complete and in place;

5. All cables from signal heads connected to correct phase output terminals per plan layout and Harris County standards;

6. All loop lead-in cables connected to correct detector input terminals per plan layout and Harris County standards;

7. All pedestrian push button cables connected to correct pedestrian detector input terminals per plan layout and Harris County standards;

8. All electrical cables and conductors clearly labeled per function;

9. All screw terminals securely tightened.

The signal turn-on date shall not be set if the items listed above are incomplete or deficient in any manner without the approval of the HCED, Traffic Signal Maintenance Section Manager.

1000.14 Measurement and Payment. The measurement and payment shall be by the lump sum bid or unit price bid as they appear on the bid sheets for the completed contract, which bids shall be for full compensation for all costs of labor, materials, tools, equipment, test, adjustments, and all other incidentals necessary to construct the complete traffic signal system, excluding all other items shown in the bid sheets in accordance with the specifications and drawings and to the satisfaction of the Engineer.

There are line code(s), description(s), and unit(s) for this Item.

NOTE: This Item requires other Standard Specifications

Item 660 "Reflectorized Pavement Markings"
Item 663 “Traffic Buttons and Pavement Markers”
Item 670 “Barricades”
Item 671 “Traffic Control”
Item 677 “Electrical Conduits for Traffic Signal Installation”
Item 678 “Zinc Coated Steel Wire Strand”
Item 679 “Insulated Jacketed Traffic Signal Cable”
Item 680 “Steel Mast Arm & Steel Strain Pole Assemblies”
Item 681 “Treated Timber Poles”
Item 683 “Traffic Signal Supports – Pedestal Poles”
Item 690 “Traffic Signal Heads”
Item 691 “Twelve Inch Signal Head with Programmable Visibility of Signal Faces”
Item 692 “Pedestrian Signal Head”
Item 694 “LED Sign Lights for Traffic Signals”
Item 1210 “Intelligent Transportation System (ITS) Controller Cabinet Assembly”
Item 2070 “Advanced Transportation Controller”

END OF ITEM 1000
ITEM 1210
INTELLIGENT TRANSPORTATION SYSTEM (ITS) CONTROLLER CABINET ASSEMBLY

1210.2 Description.
Intelligent Transportation System (ITS) Cabinet for use with Type 2070 Advanced Transportation Controller (ATC). This specification does contain references from the “ITS Cabinet Standard v01.02.17b”.

1210.2.1 - OMITTED -

1210.2.2 Cabinet Overview.
The cabinet utilizes concepts from both the NEMA and Model 170 traffic signal equipment. From the Model 170 it takes the concept of rack-mounted subassemblies. From NEMA, it borrows the basic serial connections between the controller and subassemblies.

The cabinet provides the communications paths between the various subsystems, as well as a system to monitor their operation. The cabinet provides power supplies suitable for the various electronic subassemblies mounted throughout the cabinet. The ITS cabinet is an extension of the original cabinet used for the Model 170 controller in that it is based upon the EIA/TIA standard 19 in. equipment rack. In this rack, the subsystems that comprise the field controller assembly are mounted in a manner so as to facilitate user access. The controller and other subassemblies are also similar in concept to the Model 170 system in that they are essentially interchangeable circuit cards or device cages. This does not preclude other cabinet constructs that may be proposed for inclusion in this standard at some later date. An example might be that retrofitting to existing NEMA TS1 and TS2 type cabinets or other more specialized cabinets might one day be accommodated, so long as the architecture of the serial buses are maintained.

Each of the subassemblies is connected to the controller using a serial bus, similar to that used in the NEMA TS2 Type 1 specification. Using a serial interconnection between subassemblies allows for easy system expansion. The system supports up to twenty-eight switch packs (also known as solid state load switches) in six and fourteen switch pack increments and ninety-six detector channels in twenty-four channel increments. This serial bus may also be extended using inexpensive fiber optic transceivers, as an example, insomuch as multiple remote switching/data collection cabinets can be supported from a single controller.

The ITS Cabinet is essentially a platform within which modular components may be added to serve a variety of ITS applications.
1210.2.2.1 Cabinet Subsystems.

The major subsystems that may be installed in a cabinet housing are:

- Controller.
- Input Assembly(s).
- Output Assembly(s).
- Power Distribution Assembly(s).
- Fiber Optic Splice Tray (Optional, not specified herein).
- Service Panel Assembly.
- DC Power/Communications Assembly & Extension.
- RAW/CLEAN AC Power Assembly & Extension.
- Cabinet Monitoring System.

The cabinet is constructed in a modular manner with power distribution and serial connectors conveniently located throughout the cabinet to facilitate a wide variety of configurations and future expansion. Each of these subassemblies is discussed below.

A separate standard describes the controller.

1210.2.2.1.1 Input Assembly.

The input assembly provides services for the typical inductive loop detectors currently in use, as well as other more advanced systems that might provide the controller with serial data instead of the typical contact closure. Each assembly accommodates one Serial Interface Unit (SIU) to communicate with the controller. The rack has space for twelve two-channel detector units or six four-channel detector units. The system can address (i.e. the Serial Bus addressing structure supports) up to four of these assemblies.

The detectors in the assembly can communicate to the controller in the form of either a contact closure or use of serial data strings. The back plane of this assembly includes a serial bus to transmit data to and from detectors. This serial data is then transmitted to the controller by Serial Bus 1, which is described below. This allows for the use of “smart” detectors that can pass additional information such as vehicle classification, Automatic Vehicle Identification/Location information, speed information directly to the controller unit. Each slot provides general purpose power and input/output signals and a serial interface.

The input “slots” can also accommodate the standard collection of Model 170 or NEMA TS2 type cards, including preemption devices, and isolation modules, using the contact closure interface.

1210.2.2.1.2 Output Assembly 6 and 14 Pack.

The output assembly handles the switching of 120 VAC power to the signal heads. There are two versions of this assembly, one to accommodate six switch packs and one for fourteen switch packs. It also has an SIU and an Auxiliary Monitor Unit (AMU). The AMU is described in more detail in a following section. The output assembly includes provisions for managing cabinet flash with Flash Transfer Relays and flash configuration jumpers.
To support the AMU function of current monitoring, the output assembly includes current monitoring transformers for each switch pack. These current monitor transformers enable the detection of a “no-load” condition on a signal without having to wait for the signal to cycle.

The system can address (i.e. the Serial Bus addressing structure supports) ten combinations of six switch and fourteen switch assemblies. For a maximum configuration the system can address two fourteen switch pack modules for a total of twenty-eight switch packs or physical channels, plus four virtual channels for a total of thirty-two logical channels.

The field wires can also be connected to the back of this unit using plug-in type connectors. The field wires are terminated in these connectors, which are then be plugged into the back of the Assembly. This facilitates the change out of the assembly or the whole controller and housing assembly.

1210.2.2.1.3 Power Distribution Assembly (PDA 5 IP or EP).

The Power Distribution Assembly (PDA) provides protected power distribution to the various devices and subassemblies within the cabinet. This assembly also houses Emergency Flasher Units, control relays, signal power contactor, and the Cabinet Monitor Unit (CMU).

The internal power version (PDA IP) houses two low voltage DC power supplies. One provides power to 24 VDC devices, the other to 12 VDC devices. Each of these power supplies is packaged as a slide-out subassembly.

The external power version (PDA EP) provides distribution to the various devices and subassemblies within the cabinet. This assembly also houses Emergency Flasher Units, control relays, signal power contactor, and the Cabinet Monitor Unit (CMU).

The PDA EP requires an external rack mounted low voltage DC power supply for power to 24 VDC devices such as detectors and switchpacks. Dual Rack Cabinets may require an additional 12 VDC Supply if more than 3 Input Assemblies are required. Each of these power supplies is packaged as a rack mount assembly.

Figure 1
PDA 5 IP and EP
Modular Buses.

The modular buses are assemblies that are mounted on the rack rails in the back of the cabinet and provide a pluggable interconnection of the Assembly units to the controller unit and power. These assemblies control and protect the wiring between these key subsystems, provides additional shielding from electromagnetic interference. Their biggest benefit is to simplify cabinet assembly.

The cabinet may have any combination of these bus units depending upon the particular application. For example, a cabinet designed as a communications hub may only have a Modular Power Assembly unit. A small pole mounted cabinet (proposed but not included in this standard) may not have any of them and those installed in Cabinet Housing 2 would not use the extensions.

1210.2.2.1.3.1 Raw/Clean AC Power Assemblies.

The Raw/Clean AC Power Assembly attaches to the right rear rack rail. This assembly is internally wired to provide 120 VAC “clean power” to the controller, output assemblies and auxiliary devices needed within the Cabinet, as well as Signal and flasher power from the PDA is distributed by P1 and S1 to S4 to the Output Assemblies. The Raw/Clean Bus Assemblies are available in two configurations, a four socket and a two socket version. With the advent of the 14 Pack Output Assembly the two socket version provides adequate power distribution for most applications and with the additional clean power sockets it will eliminate the need for the extension. Extension Bus Assemblies are provided for additional clean power service when needed and room permits.

An AC Clean Modular Assembly is used to power the left hand rack in Housing 3. This assembly is primarily meant for those cabinets without output assemblies or for use in the dual rack system.

1210.2.2.1.3.2 DC Power /Communications Assembly and Extension.

This modular bus assembly provides 12 VDC and 24 VDC power to cabinet assemblies. It also houses the wiring for the serial buses 1 and 2 communications between the SIUs, CMUs, AMUs and the ATC Controller Unit. The Extension provides additional DC Power when needed.

1210.2.2.1.4 Cabinet Monitoring System.

The cabinet monitoring system provides a fail-safe mechanism for the entire collection of subassemblies. The system for the ATC is a departure from its predecessors in that it has been split into sub components, the Cabinet Monitor Unit (CMU) and the Auxiliary Monitor Unit (AMU). The adjacent diagram illustrates the architecture.

The real power of this architecture is that it allows the user a much greater degree of flexibility in cabinet configurations than previously possible. This diagram shows the control system for a single intersection. The use of serial communications to the CMU is a very powerful concept. Serial communications to multiple CMUs allow for the response to a conflict at a single intersection and not impact other intersections/ramps/etc. operated by the same controller. Therefore, one intersection
could go to flash independently of the others, provided that each cabinet (or each independent output assembly) has a PDA within which a CMU is installed.

1210.2.2.1.4.1 Cabinet Monitor Unit (CMU).

The CMU is housed in the PDA. There should only be one of these installed in each cabinet, or each grouping of output assemblies. It is the main processor unit of the cabinet monitoring system. It monitors main cabinet functions, such as the condition of cabinet power, door status, and status of the flasher. It communicates with the AMUs located in the output assemblies and compares requested actions (from the controller) with the actual cabinet operation (switch pack outputs) to detect errors, conflicts, and other anomalies. It can then direct the cabinet to a flashing or fail-safe condition.

The exception here is the Cabinet Housing 3, which could contain two separate groupings of input, output and power distribution assemblies for two separate intersections all controlled by a single controller.

The configuration and operational characteristics of the CMU is determined by software. This programming may be customized to user needs and desires. There is also a specific reporting format, in order to address the minimum mandatory functionality of this unit. The minimum functionality is at least that provided by the NEMA TS2 Malfunction Monitoring Unit.

To allow full programmability of the CMU, without a massive number of physical jumpers, the Model 210 and NEMA diode based conflict programming board is replaced by a serial memory key. This serial memory key contains all information to configure the monitoring system as well as other cabinet configuration information.

The CMU might carry an address so that multiple CMUs could be used to provide multiple intersection control assemblies controlled by a single controller. The CMU addressing is accomplished through address jumper programming on the rear of the PDA. A maximum of four CMUs are allowed.

1210.2.2.1.4.2 Auxiliary Monitor Unit (AMU).

The AMU is housed in each output assembly. This unit does the basic monitoring of the output of the switch packs and reports their status to the CMU. It is essentially a device that monitors the output voltage and current of each circuit of each switch pack. This module communicates to the CMU via Serial Bus 3. Having this unit as a separate module from the CMU allows greater modularity of the cabinet. The cabinet can contain any grouping of between one and four output assemblies. However, the grouping of output assemblies and associated CMU connected via a single Serial Bus 3 would remain as an associated grouping and not be split to different cabinets.

1210.2.2.1.4.3 Serial Memory Key.

This key is essentially a non-volatile computer memory device. There are two of these devices in the system, one in the controller and one in the CMU. It contains all the specific information to define unit operations and malfunctions. In general, the key in the CMU replaces the Model 210 and NEMA Conflict Monitor Programming Card, plus any information previously programmed into those units. The CMU serial memory key
does not contain the controller operating and application software. Start-up processes within the cabinet allow the CMU, and the controller, to verify a compatible configuration before starting normal operation.

1210.2.2.1.5 Cabinet Communications Systems.

The controller communicates with the various cabinet subassemblies via a serial bus arrangement. There are three separate serial buses employed. These buses are similar to those used in the NEMA TS2 specification and communicate using a Synchronous Data Link Control (SDLC) protocol. The Cabinet Block Diagram illustrates how this system is configured. The electrical characteristics of this communications circuit are defined by EIA/TIA 485 specifications.

1210.2.2.1.5.1 Serial Interface Unit (SIU).

The SIU functions as the cabinet communications and control unit. The SIU communicates with the ATC Controller Unit through Serial Bus 1 and Serial Bus 2 via the Modular Bus Assembly. In the case where the input and/or output assembly is mounted remotely, communications would be over a data grade interconnect cable. This cable might be a fiber optic cable because of its high noise immunity and reliability.

A SIU is needed for each input assembly and each output assembly connected to the ATC Controller Unit.

1210.2.2.1.5.2 Serial Bus 1.

This bus communicates real time information required to operate the system. It handles the highest priority, time sensitive data exchange between the SIUs in the input and output assemblies, controller unit and the CMU. An example would be the commands to the switch packs to change signal color or data from detection inputs. Serial Bus 1 is designed for a communications rate of 614,400 bits per second.

1210.2.2.1.5.3 Serial Bus 2.

This bus communicates less time critical information between the SIUs in the input and output assemblies, and the controller unit. An example would be servicing requests for general program information as might be requested from a central computer system. Serial Bus 2 is designed for an allowable communications rate of 614,400 bits per second.

1210.2.2.1.5.4 Serial Bus 3.

This bus is dedicated to communications between the AMUs and the CMU. It is used to allow the CMU to monitor the various voltages, operating conditions, and currents in the output assemblies to determine actual switch pack conditions. Serial Bus 3 has an operating communications rate of 153,600 bits per second.

1210.2.2.2 Standard Cabinet Assemblies.

There are three different cabinet assemblies, which consist of a specific collection of the subassemblies described above. Each of these assemblies is installed in a cabinet that is designed for a particular group of applications and is sized to hold the equipment...
required. The cabinets have doors both on the front and the back. The equipment is mounted on a standard EIA 19 in. rack that is fitted inside each cabinet.

Each cabinet includes at least the following common features:

- Enclosure
- Gasketing
- Doors
- Police Panel
- Latches/Locks
- Ventilation and Air Filtration
- Hinges and Door Catches
- Assembly Supports and Mounting

1210.2.2.2.1 Cabinet Housing 1.

This Cabinet Housing is very similar to the Type 332 series of cabinet used for the Model 170 Controller system. It is a single rack cabinet with sufficient capacity to operate a full eight-phase traffic signal. Dimensions are width 24.25 in., depth 30.25 in., and height 66.78 in.

1210.2.2.2.2 Cabinet Housing 2.

This shorter version of Cabinet Housing 1 is very similar to the Type 336S series of cabinet used for the Model 170 Controller system and is meant for applications that require less space for inputs and outputs. This cabinet might be found at small two through eight-phase traffic signals, ramp meters, data stations and similar less space demanding applications. Dimensions are width 24.25 in., depth 20.25 in., and height 46.25 in.

1210.2.2.2.3 Cabinet Housing 3.

This is a large two rack, four door cabinet with bottom details and a bolt pattern similar in size to the NEMA P cabinet. It is meant for installations requiring a lot of equipment. An example application may be a traffic signal controller with a communications hub or a ramp meter, or perhaps additional input/output assemblies. Dimensions are width 44.50 in., depth 26.00 in., height 66.38 in.

1210.3 General ITS Cabinet Requirements.

1210.3.1 General.

All furnished equipment must be new and unused. Vacuum or gaseous tubes and electro-mechanical devices (unless specifically called out) will not be used.

1210.3.1.1 References.

Reference is made to the following documents:

- ATC 2070 v01.05, Advanced Transportation Controller (ATC) Standard for the Type 2070 Controller, dated March 29, 2001

1210.3.1.2 Interchangeability.
Assemblies and their associated devices must be electrically and mechanically interchangeable at both the assembly and device levels:

<table>
<thead>
<tr>
<th>ASSEMBLIES</th>
<th>ASSOCIATED DEVICES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Assembly</td>
<td>- Model 222, 232 &amp; 224 Sensor Unit</td>
</tr>
<tr>
<td></td>
<td>- Model 242 and 252 Isolator Unit</td>
</tr>
<tr>
<td></td>
<td>- Type 218 Serial Interface Unit (SIU)</td>
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<tr>
<td>Output Assembly</td>
<td>- Model 200 Switch Pack Unit</td>
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<tr>
<td></td>
<td>- Model 205 Transfer Relay Unit</td>
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<tr>
<td></td>
<td>- Model 214 Auxiliary Monitor Unit</td>
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<tr>
<td></td>
<td>- Type 218 SIU Unit</td>
</tr>
<tr>
<td>PDA ITS</td>
<td>- Model 204 Flasher Units</td>
</tr>
<tr>
<td></td>
<td>- Model 212 Cabinet Monitor Unit</td>
</tr>
<tr>
<td></td>
<td>- Model 216-12 &amp; 216-24 Power Supply Units</td>
</tr>
</tbody>
</table>

1210.3.1.3 Documentation.

1210.3.1.3.1 Manuals.

Two copies of Manual Documentation must be supplied for each item purchased up to 200 manuals per order. The manual must be bound in durable covers made of either 65 pound stock paper or clear plastic. The manual must be printed on paper measuring 8-1/2 in. by 11 in., with the exception that schematics, layouts, parts lists and plan details may be on sheets measuring 11 in. by 17 in., with each sheet neatly folded to a size of 8-1/2 in. by 11 in. A minimum of Times New Roman or Arial 10 point font must be used for all manual text, excluding drawings and schematics. Drawing text may use a smaller font size.

1210.3.1.3.1.1 Cabinet Wiring Diagrams.

Two copies of Cabinet Wiring Diagrams must be included in each cabinet. Cabinet Wiring Diagrams must be on non-fading, minimum 22 in. x 34 in., sheets.

1210.3.1.3.2 Manual Contents.

Each manual must utilize the following outline, to the extent possible:

(1) Table of Contents
(2) Glossary
(3) Manufacturer Contact Information
   (a) Address
   (b) Telephone Number
(c) Fax Number
(d) General Email Address

(4) General Description
(5) General Characteristics
(6) Installation
(7) Adjustments
(8) Theory of Operation
   (a) Systems Description (include block diagram).
   (b) Detailed Description of Circuit Operation.

(9) Maintenance
   (a) Preventive Maintenance.
   (b) Trouble Analysis.
   (c) Trouble Shooting Sequence Chart.
   (d) Wave Forms.
   (e) Voltage Measurements.
   (f) Alignment Procedures.

(10) Parts List (include circuit and board designation, part type and class, power rating, component manufacturer, mechanical part manufacturer, data specification sheets for special design components and original manufacturer's part number).

(11) Electrical Interconnection Details & Drawings.

(12) Schematic and Logic Diagram

(13) Assembly Drawings and a pictorial diagram showing physical locations and identification of each component or part.

(14) The date, serial numbers, model numbers and revision numbers of equipment covered by the manuals must be printed on the front cover of the manuals.

1210.3.1.3.3 Manual Pouches.

Manuals for the cabinet must be furnished in a weatherproof plastic pouch placed in the cabinet.

1210.3.1.3.4 Draft Manual.
A preliminary draft of the manual must be submitted, when required, to the AGENCY for approval prior to final printing.

1210.3.1.4 Packaging.
Each item delivered must be individually packed in its own shipping container. When loose Styrofoam is used for packing the item, the item must be sealed in a plastic bag to prevent direct contact with the Styrofoam.

1210.3.1.5 Delivery.
Each item delivered for testing must be complete, including manuals, and ready for testing.

1210.3.1.6 Metals.
All sharp edges and corners must be rounded and free of any burrs.

1210.3.1.6.1 Aluminum.
Aluminum sheets must be Type 3003-H14 or Type 5052-H32 ASTM B209 “Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate” aluminum alloy. Rod, Bar and Extruded must be Type 6061-T6, or equal.

1210.3.1.6.2 Stainless Steel.
Stainless Steel sheets must be annealed or one-quarter-hard complying with the ASTM A666 “Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar” for Type 304, Grades A or B, stainless steel sheet.

1210.3.1.6.3 Cold Rolled Steel.
Cold Rolled Steel sheet, rod, bar and extruded must be Type 1018/1020.

1210.3.1.6.3.1 Plating.
All cold roll steel must be plated. All plating must be either cadmium plating meeting the requirements of Federal Specification QQ-P-416C, Type 2 Class I or zinc plating meeting the requirements of ASTM B633 “Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel” Type II SC4.

1210.3.1.7 Mechanical Hardware.
All bolts, nuts, washers, screws, hinges and hinge pins must be stainless steel unless otherwise specified.

1210.3.1.8 Electrical Isolation.
Within the circuit of any device, module, or Printed Circuit Board (PCB), electrical isolation must be provided between DC logic ground, equipment ground and the AC-conductor. They must be electrically isolated from each other by 500 Megohms, minimum, when tested at the input terminals with 500 VDC.
1210.3.1.9 Daughter Boards.

Keyboards and LCD/LED Displays are considered daughter boards. Daughter boards must be mechanically secured with a minimum of four spacers/metal screws. Connectors must be either Flat Cable or PCB Headers. Components are allowed to be mounted under the daughter board.

1210.3.2 Components.

1210.3.2.1 General.

All components must be second sourced and be of such design, fabrication, nomenclature or other identification as to be purchased from a wholesale distributor or from the component manufacturer, except as follows:

1210.3.2.1.1

When a component is of such special design that it precludes the purchase of identical components from any wholesale distributor or component manufacturer, one spare duplicate component must be furnished with each 20, or fraction thereof, components used.

1210.3.2.1.2

The electronic circuit design must be such that all components of the same generic type, regardless of manufacturer, function equally in accordance with the specifications.

1210.3.2.2 Electronic Components.

1210.3.2.2.1

No device to be socket mounted unless specifically called out.

1210.3.2.2.2

No component to be operated above 80% of its maximum rated voltage, current or power ratings. Digital components must not be operated above 3% over their nominal voltage, current or power ratings.

1210.3.2.2.3

Components must have been kept in the original packaging and stored in a proper environment, according to the manufacturer’s instructions. The design life of all components, operating for twenty-four hours a day and operating in their circuit application, must be ten years or longer.

1210.3.2.2.4

Components must be arranged so they are easily accessible, replaceable and identifiable for testing and maintenance. Where damage by shock or vibration exists,
the component must be supported mechanically by a clamp, fastener, retainer, or hold-
down bracket.

1210.3.2.2.5

The Manufacturer must submit detailed engineering technical data on all components at
the request of the AGENCY. The Manufacturer must certify that the component
application meets the requirements of this standard.

1210.3.2.3 Capacitors.

The DC and AC voltage ratings, as well as the dissipation factor, of a capacitor must
exceed the worst-case design parameters of the circuitry by 150%. Capacitor
encasements must be resistant to cracking, peeling and discoloration. All capacitors
must be insulated and be marked with their capacitance values and working voltages.
Electrolytic capacitors must not be used for capacitance values of less than 1.0
microfarad and be marked with polarity.

1210.3.2.4 Potentiometers.

Potentiometers with ratings from 1 to 2 watts must meet Military Type RV4
requirements. Under 1 Watt potentiometers must be used only for trimmer type
function. The potentiometer power rating must be at least 100% greater than the
maximum power requirements of the circuit.

1210.3.2.5 Resistors.

Fixed carbon film, deposited carbon, or composition-insulated resistors must conform to
the performance requirements of Military Specifications MIL-R-11F or MIL-R-22684. All
resistors must be insulated and be marked with their resistance values. Resistance
values must be indicated by the EIA color codes, or stamped value. The value of the
resistors must not vary by more than 5% between -37 degrees C and 74 degrees C.

1210.3.2.5.1

Special ventilation or heat sinking must be provided for all 2- watt or greater resistors.
They must be insulated from the PCB.

1210.3.2.6 Semiconductor Devices.

1210.3.2.6.1

All transistors, integrated circuits, and diodes must be a standard type listed by EIA and
clearly identifiable.

1210.3.2.6.2

All metal oxide semiconductor components located in a sub-assembly must contain
circuitry to protect their inputs and outputs against damage due to high static voltages or
electrical fields.

1210.3.2.6.3
Device pin "1" locations must be properly marked on the PCB adjacent to the pin.

1210.3.2.7 Transformers and Inductors.

All power transformers and inductors must have the manufacturer's name or logo and part number clearly and legibly printed on the case or lamination. All transformers and inductors must have their windings insulated, be protected to exclude moisture, and their leads color coded with an approved EIA color code or identified in a manner to facilitate proper installation.

1210.3.2.8 Triacs.

Each triac with a designed circuit load of greater than 0.5 Amperes at 120 VAC must be mounted to a heat sink with thermal conductive compound or material, in addition to being mechanically secured.

1210.3.2.9 Circuit Breakers.

Circuit breakers must be listed by UL or ETL. The trip and frame sizes must be plainly marked (marked on the breaker by the manufacturer), and the ampere rating must be visible from the front of the breaker. Contacts must be silver alloy and enclosed in an arc quenching chamber. Overload tripping must not be influenced by an ambient air temperature range of from -18 degrees C to 50 degrees C. The minimum Interrupting Capacity must be 5,000 Amperes, RMS when the breaker is secondary to a UL approved fuse or primary circuit breaker and both breakers in concert provide the rated capacity. For circuit breakers 80 Amperes and above, the minimum interrupting capacity must be 10,000 Amperes, RMS. Circuit breakers must be the trip-free type with medium trip delay characteristic (Carlingswitch Time Delay Curve #24 or equal).

1210.3.2.9.1 Load Circuit Breaker Auxiliary Internal Switches.

The Load Circuit Breakers located on the PDA that are used to control Output Assembly Model 200 Switch Packs must have auxiliary switches. The auxiliary switches must "open" when the load breaker has tripped and the system will transfer the power from the Main Contactor to the Flash or Blank condition.

1210.3.2.10 Fuses.

All Fuses that are resident in a bayonet style fuse holder must have the fuse size rating labeled on the holder or on the panel adjacent to the holder. Fuses must be easily accessible and removable without use of tools.

1210.3.2.11 Switches.

1210.3.2.11.1 Dip.

Dual-inline-package, quick snap switches must be rated for a minimum of 30,000 operations per position at 50 milliamperes, 30 VDC. The switch contact resistance must be 100 milliohms maximum at 2 milliamperes, 30 VDC. The contacts must be gold over brass.

1210.3.2.11.2 Logic.
The switch contacts must be rated for a minimum of 1 Ampere resistive load at 120 VAC and be silver over brass (or equal). The switch must be rated for a minimum of 40,000 operations.

1210.3.2.11.3 Control.

The switch contacts must be rated for a minimum of 5 Amperes resistive load at 120 VAC or 28 VDC and be silver over brass (or equal). The switch must be rated for a minimum of 40,000 operations.

1210.3.2.11.4 Power.

Ratings must be the same as CONTROL, except the contact rating must be a minimum of ten Amperes at 125 VAC.

1210.3.2.12 Terminal Blocks.

The terminal blocks must be barrier type, rated at 20 Amperes and 600 VAC RMS minimum. The terminal screws must be 0.3125 in. minimum length nickel plated brass binder head type with screw inserts of the same material. Screw size is called out under the associated file, panel or assembly.

1210.3.2.13 Screw Lug and Cam Driven Connectors.

Provided the connectors mate, screw lug cam driven devices or crimp pin connectors must be allowable if the interface is part of a harness. For field termination, screw lug and cam driven assemblies are interchangeable for field wiring termination, provided they both accommodate 22 gauge wire on the inputs and 22 gauge wire on the outputs.

1210.3.2.14 Wiring, Cabling and Harnesses.

1210.3.2.14.1

Harnesses must be neat, firm and properly bundled with external protection. They must be tie-wrapped and routed to minimize crosstalk and electrical interference. Each harness must be of adequate length to allow any conductor to be connected properly to its associated connector or termination point. Conductors within an encased harness have no color requirements. Printed circuit motherboards are to be used where possible to eliminate or reduce cabinet wiring.

1210.3.2.14.2

Wiring containing AC must be bundled separately or shielded separately from all DC logic voltage control circuits.

1210.3.2.14.3

Wiring must be routed to prevent conductors from being in contact with metal edges. Wiring must be arranged so that any removable assembly may be removed without disturbing conductors not associated with that assembly.
1210.3.2.14.4

All conductors, except those that can be readily traced, must be labeled. Labels attached to each end of the conductor must identify the destination of the other end of the conductor.

1210.3.2.14.5

All conductors must conform to MIL-W-16878E/1 or better and have a minimum of 19 strands of copper. The insulation must be polyvinyl chloride with a minimum thickness of 10 mils or greater. Where insulation thickness is 15 mils or less, the conductor must conform to MIL-W-16878/17.

1210.3.2.14.6

Conductor color identification must be as follows:

AC- circuits - white  
Equip. Ground - solid green or continuous green color with 1 or more yellow stripes.  
DC logic ground - continuous white with a red stripe.  
AC+ circuits - continuous black or black with colored stripe  
DC logic ungrounded or signal - any color not specified

1210.3.2.15  Indicators and Character Displays.

All indicators and character displays must be readily visible at a radius of up to 1.2 m (4 feet) within the cone of visibility when the indicator is subjected to 97,000 lux (9,000 foot-candles) of white light with the light source at 45 degrees (+/-2 degrees) to the front panel.

1210.3.2.15.1  Indicators.

All indicators and character displays must have a minimum 90 degrees cone of visibility with its axis perpendicular to the panel on which the indicator is mounted. All indicators must be self-luminous. All indicators must have a rated life of 100,000 hours minimum. Each LED indicator must be white or clear when off. Indicators supplied on equipment requiring handles must be mounted such that a horizontal clearance is provided.

1210.3.2.15.2  Character Displays.

Liquid Crystal Displays (LCD) must be readable at temperatures of -20 degrees C to +70 degrees C.

1210.3.2.16  Connectors.

1210.3.2.16.1  General.

Connectors must be keyed to prevent improper insertion of the wrong connector where equipment damage or operator injury may result. The mating connectors must be designated as the connector number and male/female relationship, such as C1P (plug or PCB edge connector) and C1S (socket).

1210.3.2.16.2  Type T.
Type T connector must be a single row, 10 position, feed through terminal block. The terminal block must be a barrier type with 6-32, 0.25 in. or longer, nickel plated brass binder head screws. Each terminal must be permanently identified as to its function.

1210.3.2.16.3 Plastic Circular and Type M.

Pin and socket contacts for connectors must be beryllium copper construction subplated with 1.27 microns nickel and plated with 0.76 microns gold. Pin diameter must be 0.0618 in. All pin and socket connectors must use the AMP #601105-1 or #91002-1 contact insertion tool and the AMP #305183 contact extraction tool.

1210.3.2.16.4 Card Edge and Two-Piece PCB.

1210.3.2.16.4.1 Edge connectors must have bifurcated gold-plated contacts. The PCB receptacle connector must meet or exceed the following:

- Operating Voltage: 600 VAC (RMS)
- Current Rating: 5.0 Amperes
- Insulation Material: Diallyl Phthalate or Thermoplastic
- Insulation Resistance: 5,000 Megohms
- Contact Material: Copper alloy plated with 0.00005 in. of nickel and 0.00010 in. of gold
- Contact Resistance: 0.006 Ohm maximum

1210.3.2.16.4.2 The two-piece PCB connector must meet or exceed DIN 41612.

1210.3.2.16.4.3 The PCB 22/44 Connector must have 22 independent contacts per side; dual sided with 0.156 in. contact centers.

1210.3.2.16.5 Wire Terminal.

Each wire terminal must be solderless with PVC insulation and a heavy duty short-locking spade type connector. All terminal connectors must be crimped using a Controlled-Cycle type crimping tool.

1210.3.2.16.6 Flat Cable.

Each flat cable connector must be designed for use with 26 AWG cable; have dual cantilevered phosphor bronze contacts plated with 0.00015 of gold over 0.00005 in. of nickel; and have a current rating of 1 Ampere minimum and an insulation resistance of 5 Megohms minimum.

1210.3.2.16.7 PCB Header Post.
Each PCB header post must be 0.025 in. square by 0.3425 in. high from the plane of the PCB to the end of the pin; be mounted on 0.10 in. centers; and be tempered hard brass plated with 0.00015 in. of gold over 0.00005 in. of nickel.

1210.3.2.16.8 PCB Header Socket.

Each PCB header socket block must be nylon or diallyl phthalate. Each PCB header socket contact must be removable, but crimp-connected to its conductor. The Manufacturer must list the part number of the extraction tool recommended by its manufacturer. Each PCB header socket contact must be brass or phosphor bronze plated with 0.00010 in. of gold over 0.00005 in. of nickel.

1210.3.2.17 Surge Protection Device.

The surge suppression device must comply with ANSI/IEEE C62.41 (100 Kilohertz Ring Wave, the 1.2/50 microseconds – 8/20 Combination Wave and the EFT Burst) at voltages and currents specified at “Location Category B2” and at “Test Severity” level III (i.e. up to 4.0 Kilovolts, open-circuit).

1210.3.3 Mechanical Requirements.

1210.3.3.1 Assemblies.

All assemblies must be modular, easily replaceable and incorporate plug-in capability for their associated devices or PCBs. Assemblies must be provided with two guides for each plug-in PCB or associated device (except relays). The guides must extend to within 0.75 in. from the face of either the socket or connector and front edge of the assembly. If Nylon guides are used, the guides must be securely attached to the file or assembly chassis.

1210.3.3.2 Locking Devices.

All screw type fasteners must utilize locking devices or locking compounds except for finger screws, which must be captive.

1210.3.3.3 PCB Design and Connectors.

No components, traces, brackets or obstructions must be within 0.125 in. of the board edge (guide edges). The manufacturer's name or logo, model number, serial number, and circuit issue or revision number must appear and be readily visible on all PCBs.

1210.3.3.4 Model and Serial Numbers.

1210.3.3.4.1 The manufacturer's model number and circuit issue or revision number must appear on the rear panel of all equipment supplied (where such panel exists). In addition to any assignment of model numbers by the manufacturer, the TYPE number must be displayed on the front panel in bold type, at least 0.25 in. high.

1210.3.3.5 Workmanship.
Workmanship must conform to the requirements of this Item and be in accordance with the highest industry standards.

1210.3.3.6 Tolerances.

The following mechanical tolerances must apply, except as specifically shown on the plans or in these specifications:

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DIMENSIONAL TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet Metal</td>
<td>+/-0.0525 in.</td>
</tr>
<tr>
<td>PCB</td>
<td>+0 in., - 0.010 in.</td>
</tr>
<tr>
<td>Edge Guides</td>
<td>+/-0.015 in.</td>
</tr>
</tbody>
</table>

*Note: These dimensional tolerances do not apply to material gauge or thickness.

1210.3.4 Engineering.

1210.3.4.1 Human Engineering.

1210.3.4.1.1

The equipment must be engineered for simplicity, ease of operation and maintenance.

1210.3.4.1.2

Knobs must be a minimum of 0.5 in. in diameter and a minimum separation of 0.5 in. edge to edge.

1210.3.4.1.3

PCBs must slide smoothly in their guides while being inserted into or removed from the frame and fit snugly into the plug-in PCB connectors. PCBs must require a force no less than 5 pounds-force or greater than 50 pounds-force for insertion or removal.

1210.3.4.2 Design Engineering.

The design must be inherently temperature compensated to prevent abnormal operation. The circuit design must include such compensation as is necessary to overcome adverse effects due to temperature in the specified environmental range. The design must take into consideration the protection of personnel from all dangerous voltages.

1210.3.4.3 Generated Noise.

No item, component or subassembly must emit an audible noise level exceeding the peak level of 55 dBA when measured at a distance of one meter away from its surface, except as otherwise noted. No item, component or subassembly must emit a noise level sufficient to interfere with processing and communication functions of the controller circuits.

1210.3.5 Printed Circuit Boards.
1210.3.5.1 Design, Fabrication and Mounting.

1210.3.5.1.1

All contacts on PCBs must be plated with a minimum thickness of 0.00003 in. gold over a minimum thickness of 0.000075 in. nickel.

1210.3.5.1.2

PCB design must be such that when a component is removed and replaced, no damage is done to the board, other components, conductive traces or tracks.

1210.3.5.1.3

Fabrication of PCBs must be in compliance with Military Specification MIL-P-13949, except as follows:

1210.3.5.1.3.1

NEMA FR-4 glass cloth base epoxy resin copper clad laminates 0.0625 in. minimum thickness must be used. Inter-component wiring must be by laminated copper clad track having a minimum weight of 0.2 ounces per square foot with adequate cross-section for current to be carried. All copper tracks must be plated or soldered to provide complete coverage of all exposed copper tracks. Jumper wires to external PCB components must be from plated-through padded holes and as short as possible.

1210.3.5.1.3.2

All PCBs must conform to Section 3.3 of Military Specification MIL-P-13949G Grade of Pits and Dents, and be of Grade B quality (3.5.1.3) or better. The class of permissible bow or twist must be Class C (Table V) or better. The class of permissible warp or twist must be Class A (Table II) or better.

1210.3.5.1.3.3

Sections 4.2 through 6.6 of Military Specification MIL-P-13949G (inclusive) must be omitted except as referenced in previous sections of this Item.

1210.3.5.1.4

The mounting of parts and assemblies on the PCB must conform to Military Specification MIL-STD-275E, except as follows:

1210.3.5.1.4.1

Semiconductor devices that dissipate more than 250 milliwatts or cause a temperature rise of 10 degrees C, or more, be mounted with spacers, transipads or heat sinks to prevent contact with the PCB.

1210.3.5.1.4.2

When completed, all residual flux must be removed from the PCB.
1210.3.5.1.4.3

The resistance between any two isolated, independent conductor paths must be at least 100 Megohms when a 500 VDC potential is applied.

1210.3.5.1.4.4

All PCBs must be coated with a moisture resistant coating.

1210.3.5.1.4.5

Where less than 0.25 in. lateral separation is provided between the PCB (or the components of a PCB) and any metal surface, a 0.0625 in. (+/-0.0005 in.) Thick Mylar (polyester) plastic cover must be provided on the metal to protect the PCB.

1210.3.5.1.5

Each PCB connector edge must be chamfered at 30 degrees from board side planes. The key slots must also be chamfered so that the connector keys are not extracted upon removal of board or jammed upon insertion. The key slots must be 0.045 in. (+/-0.005 in.) for 0.1 in. spacing and 0.055 in. (+/-0.005 in.) for 0.156 in. spacing.

1210.3.5.2 Soldering.

1210.3.5.2.1


1210.3.5.2.2

Automatic flow soldering must be a constant speed conveyor system with the conveyor speed set at optimum to minimize solder peaks or points. The temperature must be controlled to within +/-8 degrees C of the optimum temperature. The soldering process must result in the complete coverage of all copper runs, joints and terminals with solder except that which is covered by an electroplating process. Wherever clinching is not used, a method of holding the components in the proper position for the flow process will be provided.

1210.3.5.2.3

If exposure to the temperature bath is of such a time-temperature duration as to come within 80% of any component’s maximum specified time-temperature exposure, that component must be hand soldered to the PCB after the flow process has been completed.

1210.3.5.3 Definitions.

Definitions for the purpose of this section on PCBs must be taken from MIL-P-55110D Section 3.3 and any current addendum.

1210.3.5.4 Jumpers.
Jumpers are not allowed unless called out in the specifications or approved by the AGENCY.

1210.3.6 Quality Control.

1210.3.6.1 Components.

All components must be lot sampled to assure a consistent high conformance standard to the design specification of the equipment.

1210.3.6.2 Subassembly, Unit or Module.

Complete electrical and environmental compliance testing must be performed on each module, unit, printed circuit or subassembly. Housing, chassis, and connection terminals must be inspected for mechanical sturdiness, and harnessing to sockets must be electrically tested for proper wiring sequence. The equipment must be visually and physically inspected to assure proper placement, mounting, and compatibility of subassemblies.

1210.3.6.3 Pre-delivery Repair.

1210.3.6.3.1 Any defects or deficiencies found by the inspection system involving mechanical structure or wiring must be returned through the manufacturing process or special repair process for correction.

1210.3.6.3.2 PCB flow soldering is allowed a second time if copper runs and joints are not satisfactorily coated on the first run. Under no circumstances will a PCB be flow soldered more than twice.

1210.3.6.3.3 Hand soldering is allowed for printed circuit repair.

1210.3.7 Electrical, Environmental and Testing Requirements.

The framework of this section, along with the specific test requirements contained herein, is excerpted with modifications from NEMA TS2-2003 - Section 2 by permission of NEMA. Excerpt © 2002 AASHTO / ITE / NEMA.

1210.3.7.1 General.

This section establishes the limits of the environmental and operational conditions in which the Cabinet Assembly will perform. This section defines the minimum test procedures that may be used to demonstrate conformance of a device type with the provisions of the standard. These test procedures do not verify equipment performance under every possible combination of environmental requirements covered by this standard. Nothing in this testing profile must be construed as to relieve the requirement
that the equipment provided must fully comply with these standards/specifications under all environmental conditions stated herein.

The Department may wish to extend the testing profile or introduce additional tests to verify compliance. (Authorized Engineering Information).

1210.3.7.2 Inspection.

A visual and physical inspection must include mechanical, dimensional and assembly conformance to all parts of this standard.

1210.3.7.3 Testing Requirements.

1210.3.7.3.1 A complete quality control / final test report must be supplied with each item. Quality control procedures must be submitted to the Department prior to production. The test report must indicate the name of the tester and be signed by a responsible manager.

1210.3.7.3.2 The quality control procedure and test report format must be supplied to the Department for approval upon request. The quality control procedure must include the following, in the order shown:

- Design Acceptance testing of all supplied components.
- Physical and functional testing of all modules and items.
- Environmental testing reports for all equipment.
- Physical and functional testing of all items.

1210.3.7.3.3 Separate certifications must be provided for Design and Production. Design Acceptance testing must be performed with a fully loaded and functional Cabinet Assembly. Production testing must be performed as part of the Department's procurement delivery procedures and that testing should be performed at the Major Unit level. (Authorized Engineering Information).

1210.3.7.3.4 Certain portions of the test procedures contained in this standard may cause damage to the unit (e.g. protection devices may be aged) and are not recommended for routine Production testing. (Authorized Engineering Information)

1210.3.7.4 Definitions of Major Units of the Cabinet Assembly.

For the purpose of this section, "Major units of the Cabinet Assembly" must include the Controller Unit, Application Software for implementing the desired functionality, Cabinet Monitor Unit (CMU), Auxiliary Monitor Unit (AMU), Serial Interface Units (SIUs), Power Distribution Unit (PDA), Switch Packs, Flasher(s), and Detector(s).
1210.3.7.5 Environmental and Operating Requirements.

The requirements (voltage, temperature, etc.) of this section must apply in any combination.

1210.3.7.5.1 Voltage and Frequency.

1210.3.7.5.1.1 Operating Voltage.

The nominal voltage must be 120 VAC, unless otherwise noted.

1210.3.7.5.1.2 Operating Frequency.

The operating frequency range must be 60 hertz (+/-3.0 hertz), unless otherwise noted.

1210.3.7.5.2 Transients, Power Service.

The Test Unit must maintain all defined functions when the independent test pulse levels specified below occur on the alternating-current power service.

1210.3.7.5.2.1 High-Repetition Noise Transients

The test pulse shall not exceed the following conditions:

(1) Amplitude: 300 Volts, both positive and negative polarity.
(2) Peak Power: 2500 watts.
(3) Repetition: 1 pulse approximately every other cycle moving uniformly over the full wave in order to sweep across 360 degrees of line cycle once every 3 second.
(4) Pulse Rise Time: 1 microsecond.
(5) Pulse Width: 10 microseconds.
(6) This test is performed without protection in place or operational.

This test is considered to be minimum test for the Test Unit complying with ANSI/IEEE C62.41. Regional conditions may warrant additional testing as described in ANSI/IEEE C62.41. (Authorized Engineering Information)

1210.3.7.5.2.2 Low-Repetition High-Energy Transients

The test pulse shall not exceed the following conditions:

(1) Amplitude: 600 Volts (+/-5 percent), both positive and negative polarity.
(2) Energy Source: Capacitor, oil filled, 10 microfarads (+/-10 percent), internal surge impedance less than 1 ohm.
(3) Repetition: 1 discharge every 10 seconds.
(4) Pulse Position: Random across 360 degrees of the line cycle.
(5) This test is performed with protection in place or operational.
This test is considered to be minimum test for the Test Unit complying with ANSI/IEEE C62.41. Regional conditions may warrant additional testing as described in ANSI/IEEE C62.41. (Authorized Engineering Information)

1210.3.7.5.3 Nondestructive Transient Immunity Requirements.

The Test Unit (with protection in place and operational) must be capable of withstanding a high energy transient having the following characteristics repeatedly applied to the alternating current input terminals (AC power applied) without failure of the test specimen:

(1) Amplitude: 2000 Volts (+/-5 percent), both positive and negative polarity.

(2) Energy Source: Capacitor, oil filled, 15 microfarads (+/-10 percent), internal surge impedance less than 1 ohm.

(3) Repetition: Applied to the Test Unit once every 2 seconds for a maximum of three applications for each polarity.

(4) After the foregoing, the Test Unit must perform all defined functions upon the application of nominal alternating current power.

This test is considered to be a minimum test requirement for the Test Unit complying with ANSI/IEEE C62.41 (100 Kiloertz Ring Wave, the 1.2/50 microseconds – 8/20 Combination Wave and the EFT Burst) at voltages and currents specified at “Location Category B2” and at “Test Severity” level III (i.e. up to 4.0 Kilovolts, open-circuit). Regional conditions may warrant additional testing as described in ANSI/IEEE C62.41. (Authorized Engineering Information)

1210.3.7.5.4 Transients, Input-Output Terminals.

The Test Unit (without protection in place or operational) must maintain all defined functions, when the test pulse occurs on selected input-output terminals.

(1) Amplitude: 300 Volts, both positive and negative polarity.

(2) Pulse Source: 1000 ohms nominal impedance.

(3) Repetition: 1 pulse per second, for a minimum of 5 pulses per selected terminal.

(4) Pulse rise time: 1 microsecond.

(5) Pulse width: 10 microseconds.

This test is considered to be a minimum test requirement for the Test Unit complying with ANSI/IEEE C62.41. Regional conditions may warrant additional testing as described in ANSI/IEEE C62.41. (Authorized Engineering Information)

1210.3.7.5.5 Temperature and Humidity.

The Test Unit must maintain all programmed functions when the temperature and humidity ambients are within the specified limits defined herein.
1210.3.7.5.5.1 Ambient Temperature.

The operating ambient temperature range must be from -37 degrees C to +74 degrees C. The storage temperature range must be from -45 degrees C to +85 degrees C.

The rate of change in ambient temperature must not exceed 18 degrees C per hour, during which the relative humidity must not exceed 95 percent.

1210.3.7.5.5.2 Humidity.

The relative humidity must not exceed 95 percent non-condensing over the temperature range of -37 degrees C to +74 degrees C.

Above +46 degrees C, constant absolute humidity must be maintained. This will result in the relative humidity shown in Exhibit 3-1 for dynamic testing.

<table>
<thead>
<tr>
<th>Ambient Temperature/ Dry Bulb (in degrees C)</th>
<th>Relative Humidity (in percent)</th>
<th>Ambient Temperature/ Wet Bulb (in degrees C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-37.0 to 1.1</td>
<td>10</td>
<td>-17.2 to 42.7</td>
</tr>
<tr>
<td>1.1 to 46.0</td>
<td>95</td>
<td>42.7</td>
</tr>
<tr>
<td>48.8</td>
<td>70</td>
<td>42.7</td>
</tr>
<tr>
<td>54.4</td>
<td>50</td>
<td>42.7</td>
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<td>60.0</td>
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<tr>
<td>71.2</td>
<td>21</td>
<td>42.7</td>
</tr>
<tr>
<td>74.0</td>
<td>18</td>
<td>42.7</td>
</tr>
</tbody>
</table>

1210.3.7.6 Test Facilities.

All instrumentation required in the test procedures, such as voltmeters, ammeters, thermocouples, pulse timers, etc. must be selected in accordance with good engineering practice. In all cases where time limit tests are required, the allowance for any instrumentation errors must be included in the limit test.

(1) Variable Voltage Source: A variable source capable of supplying 20 amperes from 100 VAC to 135 VAC.

(2) Environmental Chamber: An environmental chamber capable of attaining temperatures of -37 degrees C to +74 degrees C and relative humidity given in Table 1.
(3) Transient Generators: Transient generators capable of supplying the transients outlined above.

1210.3.7.7 Test Procedure: Transients, Temperature, Voltage, and Humidity.

1210.3.7.7.1 Test A: Placement in Environmental Chamber and Check-Out of Hook-Up.

(1) Place the test unit in the environmental chamber. Connect the test unit AC input circuit to a variable voltage power transformer, voltmeter, and transient generator. The transient generator must be connected to the AC input circuit at a point at least 25 feet from the AC power source and not over 10 feet from the input to the test unit.

(2) Connect test switches to the appropriate terminals to simulate the various features incorporated into the test unit. Place these switches in the proper position for desired operation.

(3) Verify the test hook-up. Adjust the variable-voltage power transformer to 120 VAC and apply power to the test unit. Verify that the test unit goes through its prescribed startup sequence and cycles properly in accordance with the positioning of test switches in item b.

Upon the satisfactory completion and verification of the test hook-up, proceed with Test B.

1210.3.7.7.2 Test B: Nondestructive Transient Immunity.

(1) Turn off the AC power input to the test unit from the variable-voltage power source.

(2) Apply the following high-energy transient to the AC voltage input terminals of the test unit (no other power connected to terminals):
   (a) Amplitude: 1000 V, both positive and negative polarity.
   (b) Peak Power Discharge: Capacitor, oil-filled, 15 microfarads.
   (c) Maximum Repetition Rate: Applied to the Cabinet Assembly once every 2 seconds for a maximum of three applications for each polarity.

(3) Upon completion of the foregoing, apply 120 VAC to the test unit and verify that the test unit goes through its prescribed startup sequence and cycles properly in accordance with the programmed functions. The first operation of the over-current protective device during this test is not considered a failure of the test unit.
NOTE—Test C through G follow the profile indicated in Figure 2 to demonstrate the ability of the test unit to function reliably under stated conditions of temperature, voltage, and humidity.

NOTES:

- The rate of change in temperature must not exceed 18 degrees C per hour
- Humidity controls must be set in conformance with the humidity given in Table 1 during the temperature change between Test D and Test E.
- If a change in both voltage and temperature are required for the next test, the voltage must be selected prior to the temperature change.

1210.3.7.7.3 Test C - Low-Temperature Low-Voltage Tests.

(1) Definition of Test Conditions.
   (a) Environmental Chamber Door: Closed.
   (b) Temperature: -37 degrees C.
   (c) Low Voltage: 100 VAC.
   (d) Humidity Control: Off.
(2) Test Procedure: While at room temperature, adjust the input voltage to 100 VAC and verify that the test unit is still operable.

(a) With the test unit cycling through normal operations, lower the test chamber to -37 degrees C at a rate not exceeding 18 degrees C per hour. Allow the test unit to cycle for a minimum of 5 hours at -37 degrees C with the humidity controls in the off position. Then operate the test switches as necessary to determine that all functions are operable.

(b) Remove power from the test unit for a minimum period of 5 hours. Upon restoration of power, the test unit must go through its prescribed startup sequence and then resume cycling.

(c) With the test unit at -37 degrees C and the input voltage at 100 VAC, evaluate the following items against the respective standards:

- Power Interruption Tests.

On satisfactory completion of this test, proceed with Test D.

1210.3.7.7.4 Test D - Low-Temperature High-Voltage Tests.

(1) Definition of Test Conditions.

(a) Environmental Chamber Door: closed.

(b) Low Temperature: -37 degrees C.

(c) High Voltage: 135 VAC.

(d) Humidity Controls: Off.

(2) Test Procedure: While at -37 degrees C and with humidity controls off, adjust the input voltage to 135 VAC and allow the test unit to cycle for 1 hour. Then operate the test switches as necessary to determine that all functions are operable.

(3) With the test unit at -37 degrees C and the input voltage at 135 VAC (humidity controls off), evaluate the following items against the respective standards:

- Power Interruption Tests.

On satisfactory completion of this test, proceed to Test E.

1210.3.7.7.5 Test E - High-Temperature High-Voltage Tests.

(1) Definition of Test Conditions

(a) Environmental Chamber Door: Closed.

(b) High Temperature: +74 degrees C.

(c) High Voltage: 135 VAC.

(d) Humidity Controls: In accordance with the humidity given in Table 1.

(2) Test Procedure—With the test unit cycling, raise the test chamber to +74 degrees C at a rate not to exceed 18 degrees C per hour. Verify the input voltage is 135 VAC.
(3) Set the humidity controls to not exceed 95 percent relative humidity over the temperature range of +1.1 degrees C to +46 degrees C. When the temperature reaches +46 degrees C, readjust the humidity control to maintain constant absolute humidity; +42.7 degrees C wet bulb that results in the relative humidity shown in Table 1. Verify that the test unit continues to cycle satisfactory during the period of temperature increase and at established levels of relative humidity.

(a) Allow the test unit to cycle for a minimum of 15 hours at +74 degrees C and 18 percent relative humidity. Then operate the test switches as necessary to determine that all functions are operable.

(b) With the test unit at +74 degrees C and 18 percent relative humidity and the input voltage at 135 VAC, evaluate the following items against the respective standards:

- Power Interruption Tests

On satisfactory completion of this test, proceed to Test F.

1210.3.7.7.6 Test F - High-Temperature Low-Voltage Tests.

(1) Definition of Test Conditions

(a) Environmental Chamber Door: Closed.

(b) High Temperature: +74 degrees C.

(c) Low Voltage: 100 VAC.

(d) Humidity Controls: 18 percent relative humidity and +42.7 degrees C wet bulb.

(2) Test Procedure: Adjust the input voltage to 100 VAC and proceed to operate the test switches to determine that all functions are operable. With the test unit at +74 degrees C and 18 percent relative humidity, +42.7 degrees C wet bulb, and the input voltage at 100 VAC, evaluate the following items against the respective standards:

- Power Interruption Tests

On satisfactory completion of this test, proceed to Test G.

1210.3.7.7.7 Test G - Test Termination.

(1) Program the test unit to cycle.

(2) Adjust the input voltage to 120 VAC.

(3) Set the controls on the environmental chamber to return to room temperature, +20 degrees C (+/-5 degrees C), with the humidity controls in the off position. The rate of temperature change must not exceed 18 degrees C per hour.

(4) Verify the test unit continues to cycle through normal operations properly.

(5) Allow the test unit to stabilize at room temperature for 1 hour. Proceed to operate the test switches to determine that all functions are operable.

1210.3.7.7.8 Test H - Appraisal of Equipment under Test.
(1) A failure is defined as any occurrence that results in other than normal operation of the equipment. (See item 2 for details.) If a failure occurs, the test unit must be repaired or components replaced, and the test during which failure occurred must be restarted from its beginning.

(2) The test unit is considered to have failed if any of the following occur:

(a) If the test unit skips normal program intervals/steps or portions thereof when in normal operation, places false inputs, presents false outputs, exhibits disruption of normal sequence of operations, or produces changes in parameters beyond specified tolerances, or

(b) If the test unit fails to satisfy the requirements of Tests A to G, inclusive.

(3) An analysis of the failure must be performed and corrective action taken before the test unit is retested in accordance with this standard. The analysis must outline what action was taken to preclude additional failures during the tests.

(4) When the number of failures exceeds two, it must be considered that the test unit fails to meet these standards. The test unit may be completely retested after analysis of the failure and necessary repairs have been made in accordance with item c.

(5) Upon completion of the tests, visually inspect the test unit. If material changes are observed which will adversely affect the life of the test unit, the cause and conditions must be corrected before making further tests.

1210.3.7.8 Power Interruption Test Procedures.

Conduct the following power interruption tests at low input voltage (100 VAC) and high input voltage (135 VAC) at -37 degrees C, and +74 degrees C.

1210.3.7.8.1 Short Power Interruption.

While the Test Unit is cycling through normal operations, remove the input voltage for a period not to exceed 475 milliseconds. Upon restoration of the input voltage, check to insure that the Test Unit continues normal operation as though no power interruption has occurred. Repeat this test three times.

1210.3.7.8.2 Voltage Variation.

All circuits of the Test Unit must be subjected to slowly varying line voltage during which the Test Unit must be subjected to line voltage that is slowly lowered from a nominal 120 VAC line voltage to 0 VAC at a rate of not greater than 2 Volts per second. The line voltage must then be slowly raised to 100 VAC at which point the Test Unit must resume normal operation without operator intervention. Perform this test at both -37 degrees C and +74 degrees C, at a nominal 120 VAC line voltage. Repeat this test three times.

1210.3.7.8.3 Rapid Power Interruption.
Subject the Test Unit to rapid power interruption testing of the form that the power is off for 350 milliseconds and on for 650 milliseconds for a period of 2 minutes. Perform power interruption through electromechanical contacts of an appropriate size for the load. During this testing, the controller must function normally and continue normal sequencing (operation) at the conclusion of the test. This test must be performed at both -37 degrees C and +74 degrees C, at a nominal 120 VAC line voltage. Repeat this test three times.

1210.3.7.9 Cabinet Subassembly Tests.

1210.3.7.9.1 Cabinet Monitor Unit Tests.

The CMU shall perform its specified functions under the conditions set forth in section 3.7.5 when installed in a fully functional cabinet assembly.

1210.3.7.9.2 Auxiliary Monitor Unit Tests.

The AMU shall perform its specified functions under the conditions set forth in section 3.7.5 when installed in a fully functional cabinet assembly.

1210.3.7.9.3 Power Supply Assembly Test.

The +24V and +12V Power Supplies shall perform its specified functions under the conditions set forth in section 3.7.5 when installed in a fully functional cabinet assembly.

1210.3.7.9.4 Switch Pack Test.

The switch pack shall perform its specified function under the conditions set forth in section 3.7.5 when installed in a fully functional cabinet assembly.

1210.3.7.9.5 Flasher Tests.

The flasher shall perform its specified functions under the conditions set forth in section 3.7.5 when installed in a fully functional cabinet assembly.

1210.3.7.9.6 Flasher Transfer Relay Tests.

The flasher transfer relay shall perform its specified functions under the conditions set forth in section 3.7.5 when installed in a fully functional cabinet assembly.

1210.3.7.9.7 Loop Detector Unit Tests.

The loop detector unit shall perform its specified functions under the conditions set forth in section 3.7.5 when installed in a fully functional cabinet assembly.

1210.3.7.9.8 Serial interface Unit Test.

The SIU shall perform its specified functions under the conditions set forth in section 3.7.5 when installed in a fully functional cabinet assembly.

1210.4 Auxiliary Cabinet Units.
1210.4.1 General Requirements.

1210.4.1.1 Models 200 and 204 General.

1210.4.1.1.1 The unit chassis must be made of metal suitable to meet rigid support and environmental requirements. Where electrical isolation is the only requirement, plastic insulation material may be used in lieu of metal.

1210.4.1.1.2 The unit control circuitry and switches must be readily accessible by the use of a screwdriver or wrench. Only one type of screw head end (Slotted or Phillips) to be used.

1210.4.1.1.3 The unit must be constructed so that no live voltage is exposed. A handle must be attached to the front panel for insertion or removal from the unit mating connector.

1210.4.1.1.4 The unit must be so constructed that its lower surface must be no more than 2.06 in. below the centerline of the connector and no part extend more than 0.9 in. to the left or 1.1 in. to the right of the connector centerline.

1210.4.1.1.5 Continuous edge guides must be provided on the unit.

1210.4.1.1.6 Each switch must be capable of switching any current from 0.050 Amperes to 10.0 Amperes (AC) load with power factor of 0.85 or higher.

1210.4.1.1.7 Unit indicators must be vertically centered on the front panel with indicators positioned no more than 1 in. from said center.

1210.4.1.2 Model Plug Connectors.

Model plug connectors must be:

- Model 200 BEAU P 5412 - LAB or approved equal.
- Model 204 BEAU P 5406 - LAB or approved equal.
1210.4.2 Model 200 Switch Pack Unit.

1210.4.2.1 General.

1210.4.2.1.1

The Model 200 Switch Pack Unit must be a modular plug-in device containing three solid-state switches. Each switch must open or close a connection between applied power and external load.

1210.4.2.1.2

A Ground True Controller Unit Input (0 VDC to 6 VDC) must cause the switch to conduct (ON) and a Ground False (16 VDC or more) must cause it to not conduct (OFF). State transition must occur between 6 VDC and 16 VDC. The input must not sink more than 20 milliamperes or be subjected to more than 30 VDC. The input must have reverse polarity protection.

1210.4.2.1.3

With all switches ON, the unit must not draw more than 60 milliamperes at +16 VDC or more from the +24 VDC cabinet power supply.

1210.4.2.1.4

Each switch must have an OFF state dv/dt rating of 100 Volts per microsecond or better. Each switch must provide isolation between inputs and outputs of at least 2000 Vdc and at least 100 megaohms resistive.

1210.4.2.1.5

The unit front panel must have an indicator on the input to each switch. The indicator must be labeled or color-coded “Red”-top switch, “Yellow”-middle switch, and “Green”-bottom switch. The middle switch indicator must be vertically centered on the unit front panel with the other indicators positioned 1 in. above and below.

1210.4.2.1.6

The resistance between the AC+ input terminal and the AC+ output terminal of each switch must be a minimum of 15K Ohms when the switch is in open (OFF) state. When the switch is in the OFF state, the output current through the load must not exceed 10 milliamperes peak.

1210.4.3 Model 204 Flasher Unit and Model 205 Flash Transfer Relay Unit.

1210.4.3.1 Model 204 Flasher Unit.

1210.4.3.1.1

The FLASHER UNIT must be a modular plug-in device containing a flasher control circuit and two solid-state switches. The unit’s function is to alternatively open and close connections between applied power and external load.
1210.4.3.1.2
The unit must generate its own internal DC power from the AC Line.

1210.4.3.1.3
The unit must commence flashing operation when AC power is applied providing 50 to 60 flashes per minute per switch with a 50 % duty cycle.

1210.4.3.1.4
Each switch must have an OFF state dv/dt rating of 200 V/microsecond or better. The resistance between the AC+ input terminal and the AC+ output terminal of each switch must be a minimum of 15K Ohms when the switch is in open (OFF) state. When the switch is in OFF state the output current must not exceed 10 milliamperes peak.

1210.4.3.1.5
An indicator showing each switch output state must be provided. The two indicators must be centered with 1 in. minimum spacing.

1210.4.3.1.6
Each circuit must be designed to operate in an open-circuit condition without load for 10 years minimum.

1210.4.3.1.7
A surge arrestor must be provided between AC (pin 11) and Flasher Output (pins 7 & 8). The arrestor must meet the following requirements:

- Recurrent Peak Voltage 212 Volts
- Maximum Energy Rating 50 Joules
- Average Power Dissipation 0.85 Watts
- Peak I for pulses less than 6 microseconds 2000 Amperes
- Standby I less than 1 Ma

1210.4.3.2 Model 205 Flash Transfer Relay Unit.

Each switch must be designed for a minimum of 100,000 (reference is a 10-year lifespan) operations while switching a tungsten load of 1000 Watts at 70 degrees C. Switch isolation between DC input and AC output circuit must be at least 10,000 Megohms at 2000 VDC.

1210.4.3.2.1
The Flash Transfer Relay Unit must be of electromechanical type, designed for continuous duty.
1210.4.3.2.2

Each unit must be enclosed in a removable, clear plastic cover. The manufacturer’s name, electrical rating, and part number must be placed on the cover. They must be durable, permanent and readily visible.

1210.4.3.2.3

Each unit must be provided with DPDT contacts. The contact points must be of fine silver, silver alloy or a superior alternate material. Contact points and arms must be capable of switching 20 Amperes or 1 Kilowatt Tungsten Load at 120 VAC per contact at least 100,000 operations without contact welding or excessive burning, pitting or cavitation. The points and arms must be able to withstand 10 Gs, 10 –55 Hertz without contact chatter.

1210.4.3.2.4

The relay coil must have a power consumption of 10 Volt - Ampere maximum.

1210.4.3.2.5

Each relay must withstand a potential of 1500 VAC at 60 Hertz between insulated parts and between current carrying or non-carrying parts. Each relay must have a one cycle surge rating of 175 Amperes RMS and pickup and drop out within 20 milliseconds.

1210.4.4 Model 212 ITS Cabinet Monitor Unit (CMU).

1210.4.4.1 General.

The CMU is the principle part of the ITS Cabinet Monitoring System. It is resident in the Power Distribution Assembly. The role of the CMU is to query various cabinet conditions and, if the application requires action, the CMU will transfer control from the ATC Controller Unit to a safe control mode, examples include Signalized Intersection, Ramp Metering or other applications. Some applications may not require any action, only data gathering and report back to the ATC Controller Unit.

The CMU is composed of a microprocessor, memory devices including non-volatile memory, communications circuitry to interface with Serial Buses #1 and #3, front panel indicators, front panel communication connector and a serial memory key device. The Operating Program must be resident in the Non-volatile memory. The serial memory key Memory must possess the conditions and function selections of the Unit.

1210.4.4.2 Traffic Control Application.

The Model 212 is intended for traffic control applications.

1210.4.4.3 Failed State Action (FSA).

Only Unit Reset must reset the CMU from a LATCHED FAILED STATE ACTION (LFSA). Only a Unit Reset or a CMU Power Fail must reset a LATCHED RESETTABLE FAILED STATE ACTION (LFSA-R).
A NONLATCHED FAILED STATE ACTION (NFSA) must be reset if the fault conditions causing the NFSA have been removed. An NFSA must last for the programmed Minimum Flash time at a minimum.

Only one LFSA, LFSA-R or NFSA fault state must be set at any time.

1210.4.4.4 Unit Reset.

The CMU must be reset from a FSA as a result of the front panel reset button or the EXTERNAL TEST RESET input. This reset command must be a one-time event, such that a continuous reset command does not prevent the CMU from operating. The EXTERNAL TEST RESET input must be isolated from the AC+ Raw circuitry.

The EXTERNAL TEST RESET input must be True when the voltage is less than 8 VDC. The EXTERNAL TEST RESET input must be False when the voltage is greater than 16 VDC. A minimum True pulse width on the EXTERNAL TEST RESET input of 100 milliseconds is required for a Unit Reset.

1210.4.4.5 Exit From Failed State Action.

Prior to the CMU transferring the Output Relay contacts from the Fault state to the No Fault state, a transition period of 500 milliseconds must occur. During the transition period the Output Relay contacts must be in the Fault state and the CMU must set the Start-Up Flash Call bit in the Type 189 Frame to 1. At all other times the Start-Up Flash Call bit of the Type 189 Frame must be set to 0.

1210.4.4.6 Monitor Functions.

1210.4.4.6.1 Cabinet Power Supply.

The CMU must sense the Cabinet +24 VDC and +12 VDC power supply sources to +/-5% accuracy. The CMU must also sense the Cabinet +24 VDC state in each Output Assembly as reported by each AMU. Voltages equal to or greater than +22 VDC and +11 VDC respectively must NOT cause a LFSA. Voltages at or less than +18 VDC and +9 VDC for 500 milliseconds or longer must cause a LFSA. If the sensed voltage is less than +22 VDC or +11 VDC for 200 milliseconds or less, the CMU must NOT cause a LFSA. All other timing or voltage conditions may or may not cause LFSA. A +24 VDC failure or +12 VDC failure during the programmed Minimum Flash time or during a CMU Power Failure must not cause a LFSA. The CMU must report the value of the +24 VDC and +12 VDC power supply sources in the Type 189 response frame.

There must be programming in the serial memory key to disable +12 VDC power supply monitoring.

1210.4.4.6.2 Conflicting Channels.

For purpose of conflict determination, an active signal on either of the Green/Walk or Yellow inputs associated with any of the thirty-two channels must be considered as that channel being active. The serial memory key must contain the permissive channel pair programming. When any conflicting channels are detected as concurrently active for less than 200 milliseconds the CMU must not cause a LFSA. When any conflicting channels are detected as concurrently active for 500 milliseconds or more, the CMU
must cause a LFSA. When any conflicting channels are detected as concurrently active for more than 200 milliseconds but less than 500 milliseconds, the CMU may or may not cause a LFSA. The time interval between the beginning of the concurrently conflicting channels and the transfer to the LFSA must not exceed 500 milliseconds.

1210.4.4.6.3 Serial Bus Error.

The CMU communicates with both Serial Bus (SB) #1 and #3. In SB #1 the CMU is a Secondary, polled by the ATC Controller Unit Primary. On SB #1, the CMU must respond to the Serial Bus #1 Address defined by the ADDRESS 0 and ADDRESS 1 pins. In SB #3 the CMU is the Primary, polling each AMU Secondary.

1210.4.4.6.3.1 Serial Bus #1 Error.

The CMU must cause a FSA when a Type 61 or Type 67 Frame has not been received from the ATC Controller Unit for greater than 1000 milliseconds. The first and second failures in a 24-hour period must be a NFSA. The third failure in a 24-hour period must be a LFSA-R. If a CMU Power Fail resets the LFSA-R, the SB #1 timeout count must be reset to 2 such that the next SB #1 timeout results in a LFSA-R.

A SB #1 timeout failure during the programmed Minimum Flash time or during a CMU Power Failure must not cause a FSA. The SB #1 Timeout function must be disabled if the SB #1 DISABLE input is at a True (Low) state.

The SB #1 DISABLE input must be True when the voltage is less than 8 VDC. The SB #1 DISABLE input must be False when the voltage is greater than 16 VDC. The SB #1 DISABLE input must be isolated from the AC+ Raw circuitry.

1210.4.4.6.3.2 Serial Bus #3 Error.

The CMU must cause a FSA when a Type 129 or Type 130 Frame has not been received from each AMU for greater than 300 milliseconds. The first and second failures in a 24-hour period must be a NFSA. The third failure in a 24-hour period must be a LFSA-R. If a CMU Power Fail resets the LFSA-R, the SB #3 timeout count must be reset to 2 such that the next SB #3 timeout results in a LFSA-R. A SB #3 timeout failure during the programmed Minimum Flash time or during a CMU Power Failure must not cause a FSA.

1210.4.4.6.4 Type 62 – Send to Local Flash Command Message.

If the “N” bit is set in a Type 62 – Send to Local Flash Command message, the CMU must react by causing a NFSA. The NFSA must remain until the receipt of a Type 62 – Send to Local Flash Command message with the “N” bit cleared or until the CMU is reset by a Unit Reset or CMU Power Fail. The NFSA must last for the programmed Minimum Flash time at a minimum. If the “L” bit is set in a Type 62 – Send to Local Flash Command message, the CMU must react by causing a LFSA.
1210.4.4.6.5 Diagnostics.

1210.4.4.6.5.1 Diagnostics Error.

The CMU must be provided with a resident series of self-check diagnostic capabilities. The CMU must contain provisions to verify all memory elements on power-up. When a fault is detected, the LFSA-R must be set and the DIAGNOSTIC indicator illuminated.

1210.4.4.6.5.2 RAM Diagnostic.

This test must verify that all RAM elements are operating correctly at power-up or following a Unit Reset. Patterns must be written to RAM. Each write must be followed by a read to verify that it contains the written pattern.

1210.4.4.6.5.3 Nonvolatile Diagnostic.

This test must verify that the nonvolatile ROM(s) contain the proper program. The routine must perform a check on each ROM and make a comparison with a preprogrammed check value. This test must be performed at power-up and at a minimum rate of 1024 bits per second during operation.

1210.4.4.6.5.4 Serial Memory Key Memory Diagnostic.

This test must verify whether the non-volatile serial memory key contains valid data and that the data has not changed since the last write. The routine must perform a check on each nonvolatile memory element at power-up and whenever read and make a comparison with a preprogrammed check value. The serial memory key not present must cause a LFSA if the DOOR SWITCH FRONT input is sensed as not active (door closed).

1210.4.4.6.5.5 Internal MPU Monitor.

The CMU must monitor the operation of its microprocessor with an independent circuit. At a minimum, the monitoring circuit must receive logic state transitions at least once every 50 milliseconds from the microprocessor. When the logic state transition is not received for 500 milliseconds the monitor circuit must force a LFSA-R and illuminate the DIAGNOSTIC indicator.

1210.4.4.6.6 Multiple Input.

The CMU must be capable of monitoring for the presence of an active signal on two or more inputs of a channel. When the presence of an active signal on two or more inputs of a channel is detected for less than 200 milliseconds, the CMU must not cause a LFSA. When the presence of an active signal on two or more inputs to a channel is detected for 450 milliseconds or more, the CMU must cause a LFSA. When the presence of an active signal on two or more inputs to a channel is detected for more than 200 milliseconds but less than 450 milliseconds, the CMU may or may not cause a LFSA. Multiple Input monitoring must be disabled when the MAIN CONTACTOR COIL STATUS input is not active. There must be programming in the serial memory key to disable Multiple Indication monitoring on a color combination basis (G+Y, Y+R, G+R).
1210.4.4.6.7 Lack of Signal Inputs.

The unit must detect the absence of any required signal voltage OR signal current (CSU) on the inputs of a channel. For voltage purposes a required signal on the Green or Yellow or Red inputs associated with a channel must be considered as that channel being active. When an absence of an active channel is detected for less than 700 milliseconds, the CMU must not cause a LFSA. When an absence of an active channel is detected for 1000 milliseconds or more, the CMU must cause a LFSA. When an absence of an active channel is detected for more than 700 milliseconds but less than 1000 milliseconds, the CMU may or may not cause a LFSA. Lack of Signal Input monitoring must be disabled for all channels when the MAIN CONTACTOR COIL STATUS input is not active. There must be programming in the serial memory key to disable Lack of Signal Input monitoring on a per channel basis.

Lack of Signal Input monitoring must also be disabled for any channel which has the DARK CHANNEL MAP bit set to "1" in the serial memory key programming for the DARK CHANNEL MAP addressed by the DARK CHANNEL MAP SELECT bits in a Type 61 message. The CSU monitor function is hardwired to twenty-eight physical channels, thus Virtual Channels do not have CSU monitoring capability. The CSU monitor function must be disabled for any physical channel that has an input remapped to a Virtual Channel.

1210.4.4.6.8 Yellow Clearance.

The CMU must verify that the Yellow Change interval is at least 2.7 seconds (+/-0.1 seconds). When the minimum Yellow Change interval is not satisfied, the CMU must cause a LFSA. The CMU must report a Skipped Yellow Clearance when the Yellow Change interval is less than 100 milliseconds. The CMU must report a Short Yellow Clearance when the Yellow Change interval is less than 2.7 seconds (+/-0.1 seconds) and greater than 100 milliseconds.

Minimum Yellow Change interval monitoring must be disabled when the MAIN CONTACTOR COIL STATUS input is not active. There must be programming in the serial memory key to disable Minimum Yellow Change interval monitoring on a per channel basis.

1210.4.4.6.9 Yellow Plus Red Clearance.

The CMU must verify that the Yellow Change plus Red Clearance interval between the end of an active GREEN signal and the beginning of the next conflicting GREEN signal is at least 2.7 (+/-0.1 seconds). When the minimum Yellow Change plus Red Clearance interval is not satisfied, the CMU must cause a LFSA. Minimum Yellow Change plus Red Clearance monitoring must be disabled when the MAIN CONTACTOR COIL STATUS input is not active. There must be programming in the serial memory key to disable Minimum Yellow Change plus Red Clearance interval monitoring on a per channel basis.
1210.4.4.6.10 Local Flash Status.

The CMU must monitor the LF STATUS input. When this signal is sensed as not active for greater than 500 milliseconds, the CMU must cause a NFSA. When this signal is sensed as not active for less than 200 milliseconds, the CMU must not cause a NFSA.

1210.4.4.6.10.1 Local Flash Status Recovery.

Recovery from Local Flash Status NFSA must occur when this signal is sensed as active for greater than 500 milliseconds. When this signal is sensed as active for less than 200 milliseconds, the CMU must not cause recovery from Local Flash Status NFSA.

1210.4.4.6.11 Circuit Breaker Trip Status.

The CMU must monitor the CB TRIP STATUS input. When this signal is sensed as not active for greater than 500 milliseconds, the CMU must cause a LFSA. When this signal is sensed as not active for less than 200 milliseconds, the CMU must not cause a LFSA.

1210.4.4.6.12 Flasher Unit Output Failed.

The CMU must monitor the FLASHER 1-1, FLASHER 1-2, FLASHER 2-1, and FLASHER 2-2 voltage states reported by each AMU. These inputs must be considered active when the input voltage exceeds 89 Volts RMS. These inputs must not be considered active when the input voltage is less than 70 Volts RMS. Signals between 89 Volts RMS and 70 Volts RMS may or may not be considered active. When a transition from the inactive state to the active state or a transition from the active state to the inactive state is absent for greater than 2500 milliseconds, the CMU must set a status bit in the Type 189 frame. This alarm condition must not cause a FSA. It should cause the appropriate response in the ATC Controller Unit. This status is non-latching, such that once a status bit has been set, the sensing of five valid transitions of the input must clear the status bit.

1210.4.4.6.13 CMU Power Failure.

The CMU must monitor the AC+ Raw input and the NRESET and POWERDOWN cabinet control inputs to determine a CMU Power Failure response. The POWERDOWN signal in the low state indicates loss of AC+ Raw in the Controller Unit. A CMU Power Failure must be recognized when both the POWERDOWN and NRESET signals are active low for greater than 100 milliseconds or the AC+ Raw voltage is less than 82 Volts RMS (+/-2 Volts RMS).

1210.4.4.6.14 AC+ Raw Level Sense.

The CMU must monitor the AC+ Raw input and AC+ Raw inputs reported by each AMU. When any AC+ Raw voltage is less than 82 Volts RMS (+/-2 Volts RMS) for greater than 650 milliseconds (+/-100 milliseconds) the CMU must cause a NFSA. Once NFSA has been set, the POWERDOWN and NRESET signals must not be monitored until all AC+ Raw voltages have exceeded 87 Volts RMS (+/-2 Volts RMS).
1210.4.4.6.15 Power Interrupt.

The CMU must disable monitoring of the +12VDC and +24VDC power supply inputs when either the POWERDOWN or NRESET input is low. When the POWERDOWN and NRESET signals are both low the CMU must cause a NFSA.

1210.4.4.6.16 Power Recovery.

When the POWERDOWN input is high and the NRESET signal goes from low to high the CMU must begin timing the programmed Minimum Flash Interval. During the Minimum Flash Interval the CMU must be in NFSA.

1210.4.4.6.17 Power Up.

Following initial application of AC+ Raw voltage the CMU must maintain a NFSA until the POWERDOWN input is high and the NRESET signal goes from low to high. The CMU must then begin timing the programmed Minimum Flash Interval. During the Minimum Flash Interval the CMU must be in NFSA.

1210.4.4.6.18 Minimum Flash Interval.

The CMU must be in NFSA during the Minimum Flash Interval. The Minimum Flash Interval must be programmed in the serial memory key between the limits of 6 seconds to 16 seconds with an incremental adjustment of 1 second. The CMU must not set a FSA during the Minimum Flash Interval.

1210.4.4.7 Field Output Check.

1210.4.4.7.1 Field Check Mode.

The CMU must compare the active states of the field signals with the states reported by the ATC Controller Unit in the Type 61 frame. When a mismatch is detected for less than 700 milliseconds the CMU must not cause a LFSA. When a mismatch is detected for 1000 milliseconds or more, the CMU must cause a LFSA. When a mismatch is detected for more than 700 milliseconds but less than 1000 milliseconds, the CMU may or may not cause a LFSA. Field Output Check monitoring must be disabled when the MAIN CONTACTOR COIL STATUS input is not active. There must be a programming in the serial memory key to disable Field Output Check monitoring on a field input basis.

1210.4.4.7.2 Field Check Status.

The CMU must compare the active states of the field signals with the states reported by the ATC Controller Unit in the Type 61 frame. When a mismatch is detected while a Conflict, Lack of Signal, or Multiple fault is timing, Field Check Status must be reported with the fault to indicate the faulty channel(s) and color(s). Field Output Check monitoring must be disabled when the MAIN CONTACTOR COIL STATUS input is not active. There must be a programming in the serial memory key to disable Field Output Check monitoring on a field input basis.
1210.4.4.8 CMU Temperature.

The CMU must measure the temperature at the CMU and report this value in the Type 182 frame. Temperature accuracy must be +/-6 degrees C over the operating temperature range of the CMU.

1210.4.4.9 Input Signals.

1210.4.4.9.1 Field Signal Inputs.

A Green or Yellow signal input must be sensed active when it exceeds 25 Volts RMS and must not be sensed active when it is less than 15 Volts RMS. A Green or Yellow signal between 15 Volts RMS and 25 Volts RMS may or may not be sensed active. There must be a programming in the serial memory key to disable the Yellow input for each physical channel. A Red signal input must be sensed active when it exceeds 70 Volts RMS and must not be sensed active when it is less than 50 Volts RMS. A Red signal between 50 Volts RMS and 70 Volts RMS may or may not be sensed active.

1210.4.4.9.2 Switch Pack Current.

A channel must be sensed active when the load current exceeds 105% of the Channel Current Sense Threshold programmed for that channel in the serial memory key. A channel must not be sensed active when the load current is less than 95% of the Channel Current Sense Threshold programmed for that channel in the serial memory key. A load current value between 95% and 105% of the Channel Current Sense Threshold may or may not be sensed active.

1210.4.4.9.3 PDA Control Signal Inputs.

1210.4.4.9.3.1 Local Flash Status.

This input must be internally connected to the CMU Output Relay COM pin. This input must be considered active when the input voltage exceeds 89 Volts RMS. This input must not be considered active when the input voltage is less than 70 Volts RMS. Signals between 89 Volts RMS and 70 Volts RMS may or may not be considered active. Operation of the cabinet in AUTO mode must place AC+ on this input. Operation of the cabinet in FLASH mode must be open circuit on this input. The CMU must report the state of this input in the Type 189 frame.

1210.4.4.9.3.2 Main Contactor Coil Status.

The MAIN CONTACTOR COIL STATUS input must be connected to the AC+ Raw side of the main contactor signal bus relay coil. An active signal on this input indicates the Signal Bus should be powering the Switch Packs. This input must be considered active when the input voltage exceeds 89 Volts RMS. This input must not be considered active when the input voltage is less than 70 Volts RMS. Signals between 89 Volts RMS and 70 Volts RMS may or may not be considered active. The CMU must report the state of this input in the Type 189 frame.
1210.4.4.9.3.3 Main Contactor Secondary Status.

The MAIN CONTACTOR SECONDARY STATUS input must be connected to the output side of the main contactor signal bus relay. This input must be considered active when the input voltage exceeds 89 Volts RMS. This input must not be considered active when the input voltage is less than 70 Volts RMS. Signals between 89 Volts RMS and 70 Volts RMS may or may not be considered active. The CMU must report the state of this input in the Type 189 frame.

1210.4.4.9.3.4 FTR Coil Drive Status.

The FTR COIL DRIVE STATUS input must be connected to the FTR COIL DRIVE signal in the AC SIGNAL POWER BUS. This input must be considered active when the input voltage exceeds 89 Volts RMS. This input must not be considered active when the input voltage is less than 70 Volts RMS. Signals between 89 Volts RMS and 70 Volts RMS may or may not be considered active. The CMU must report the state of this input in the Type 189 frame.

1210.4.4.9.3.5 Circuit Breaker (CB) Trip Status.

The CB TRIP STATUS input must be connected to the Auxiliary Switch output of the circuit breaker unit. This input must be considered active when the input voltage exceeds 89 Volts RMS. This input must not be considered active when the input voltage is less than 70 Volts RMS. Signals between 89 Volts RMS and 70 Volts RMS may or may not be considered active. The CMU must report the state of this input in the Type 189 frame.

1210.4.4.9.3.6 Front/Rear Door Switch.

The CMU must monitor the DOOR SWITCH FRONT and DOOR SWITCH REAR inputs. These inputs must be considered active (door open) when the input voltage exceeds 89 Volts RMS. These inputs must not be considered active (door closed) when the input voltage is less than 70 Volts RMS. Signals between 89 Volts RMS and 70 Volts RMS may or may not be considered active. The CMU must report the state of these inputs in the Type 189 frame.

1210.4.4.9.3.7 Monitor Interlock.

The MONITOR INTERLOCK input must be connected to VDC GROUND within the CMU.

1210.4.4.9.3.8 CMU Address Inputs.

The Address Select input pins ADDRESS 0 and ADDRESS 1 define the Serial Bus #1 address of the CMU. The pins are left open for a logical False, and are connected to VDC GROUND for a logical True.
1210.4.4.10 Power and Circuit Requirements.

1210.4.4.10.1 AC+ Raw.

The CMU must be operational over the voltage range of 80 Volts RMS to 135 Volts RMS. It must be capable of insertion and removal while AC power is applied to the cabinet. Surge current on AC+ Raw must be less than 2 Amperes peak.

1210.4.4.10.1.1 +24VDC Power Supply.

The CMU must not use the Cabinet +24VDC Power Supply to run any of its internal circuitry. The +24 VDC MONITOR and +12 VDC MONITOR input circuits must be optically isolated from the AC+ Raw circuitry. The maximum current into the +24 VDC or +12 VDC Monitor inputs over the voltage range of 0 VDC to 30 VDC must be less than 20 milliamperes.

1210.4.4.10.2 Failed State Output Circuit.

The Output relay of the CMU must have one set of isolated Form C contacts. These relay contacts must be rated for a minimum of 3 Amperes at 120 Volts RMS and 100,000 operations. Contact opening/closing time must be 30 milliseconds or less. The relay coil must be energized in the No Fault state and de-energized in the FSA state.

1210.4.4.11 Front Panel Devices.

1210.4.4.11.1 Indicators.

All indicators must be clear LEDs. Clear LEDs must not depend on a reflector or diffusion as part of its design. Clear LEDs must only show the die and not appear to be ON when exposed to ambient light. The following indicators must be provided (Top to Bottom).

1210.4.4.11.2 Power.

A green POWER indicator must illuminate to indicate AC+ Raw voltage is proper. It must flash at a 2 Hertz rate when the NRESET or POWERDOWN input is True. It must remain off when the voltage is less than 80 Volts RMS (+/-2 Volts RMS).

<table>
<thead>
<tr>
<th>ADDRESS 1</th>
<th>ADDRESS 0</th>
<th>SB Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>False</td>
<td>False</td>
<td>0x0F</td>
</tr>
<tr>
<td>False</td>
<td>True</td>
<td>0x10</td>
</tr>
<tr>
<td>True</td>
<td>False</td>
<td>0x11</td>
</tr>
<tr>
<td>True</td>
<td>True</td>
<td>0x12</td>
</tr>
</tbody>
</table>
1210.4.4.11.3 24 VDC Fail.
A red 24VDC FAIL indicator must illuminate when the CMU is in FSA as a result of a 24VDC cabinet power supply fault.

1210.4.4.11.4 12 VDC Fail.
A red 12VDC FAIL indicator must illuminate when the CMU is in FSA as a result of a 12VDC cabinet power supply fault. The 12VDC FAIL indicator must flash at a 2 Hertz rate when the 12 VDC monitor function is disabled.

1210.4.4.11.5 Conflict.
A red CONFLICT indicator must illuminate when the CMU is in FSA as a result of a Conflicting Channels fault.

1210.4.4.11.6 Lack of Signal.
A red LACK OF SIGNAL indicator must illuminate when the CMU is in FSA as a result of a Lack of Signal Inputs fault.

1210.4.4.11.7 Multiple.
A red MULTIPLE indicator must illuminate when the CMU is in FSA as a result of a Multiple Inputs fault.

1210.4.4.11.8 ATC/Local Flash.
A red ATC/LOCAL FLASH indicator must illuminate when the CMU is in FSA as a result of a Type 62 – Send to Local Flash Command from the ATC Controller Unit, the LOCAL FLASH STATUS input sensed inactive, or CB TRIP STATUS active.

1210.4.4.11.9 Clearance.
A red CLEARANCE indicator must illuminate when the CMU is in FSA as a result of a Yellow Clearance or Yellow Plus Red Clearance fault.

1210.4.4.11.10 Field Check.
A red FIELD CHECK indicator must illuminate when the CMU is in FSA as a result of a Field Output Check fault. The indicator must flash at a 2 Hertz rate when the CMU is in FSA with Field Check Status as a result of Conflict, Lack of Signal, or Multiple fault.

1210.4.4.11.11 SB #1 Error.
A red SB #1 ERROR indicator must illuminate when the CMU is in FSA as a result of a Serial Bus #1 fault.

1210.4.4.11.12 SB #3 Error.
A red SB #3 ERROR indicator must illuminate when the CMU is in FSA as a result of a Serial Bus #3 fault.
1210.4.4.11.13 Diagnostic.

A red DIAGNOSTIC indicator must illuminate when the CMU is in FSA as a result of a Diagnostic fault. The DIAGNOSTIC indicator must flash at a 4 Hertz rate if the serial memory key is not present and a FSA state does not exist.

1210.4.4.11.14 SB #1 Rx.

A yellow indicator must illuminate for 40 milliseconds (+/-5 milliseconds) each time the CMU correctly receives a frame on Serial Bus #1.

1210.4.4.11.15 SB #3 Rx.

A yellow indicator must illuminate for 40 milliseconds (+/-5 milliseconds) each time the CMU correctly receives a frame on Serial Bus #3.

1210.4.4.12 Serial Bus #3 Terminations.

The Serial Bus #3 RxD+ input must be terminated on the CMU to the Serial Bus #3 EIA-485 supply voltage through a 560 Ohm resistor. The Serial Bus #3 RxD- input must be terminated on the CMU to AC Raw- through a 560 Ohm resistor. A 120 Ohm resistor must be connected on the CMU between RxD+ and RxD-. The CMU Serial Bus #3 TxD drivers must remain in the mark state with drivers enabled when the CMU is not transmitting a command frame. Note: A 120 Ohm resistor must be connected between TxD+ and TxD- on the Serial Bus #3 cable assembly in the last Output Assembly installed in the Serial Bus #3 daisy chain.

1210.4.4.13 Terminal Port.

An EIA-232-E Data Terminal Equipment (DTE) interface and connector must be provided for interconnecting to a personal computer. Where differences occur between the EIA-232 standard and this document, this document must govern.

1210.4.4.13.1 Physical.

The connector must be mounted on the front panel and must be a 9-position subminiature D-type connector with metal shell. The connector must utilize female contacts with 15 millionths of an inch gold plating in the mating areas.

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Function</th>
<th>I/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reserved</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>RxD</td>
<td>I</td>
</tr>
<tr>
<td>3</td>
<td>TxD</td>
<td>O</td>
</tr>
<tr>
<td>4</td>
<td>Reserved</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Signal Ground</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>Reserved</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>Reserved</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Reserved</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>Reserved</td>
<td>-</td>
</tr>
</tbody>
</table>
1210.4.4.13.2 Receive Data (RxD).
The RxD input must contain the serial data input to the CMU.

1210.4.4.13.3 Transmit Data (TxD).
The TxD output must contain the serial data output from the CMU.

1210.4.4.13.4 Signal Ground.
All signals must be referenced to Signal Ground and must be optically isolated from the CMU.

1210.4.4.13.5 Data Link Layer.
Transmission must be in asynchronous start/stop mode. The format must be 8 bit data, 1 stop bit, even parity, and 9600 bits per second (+/-2%) at a minimum. The CMU must be capable of full duplex operation. Flow control must use XON/XOFF procedures.

1210.4.4.14 Monitor Unit Serial Memory Key.
The CMU must have a Datakey™ model KC4210 Keycepticle™ socket or equivalent serial memory key receptacle, which will intermate with the Datakey™ model LCK4000-RED, mounted on the front panel. The CMU must be provided with a Datakey™ model LCK4000-RED serial memory key or equivalent. The serial memory key must be rated for –40 to +80 degrees C operation. Note: Datakey™ and Keycepticle™ are registered trademarks of Datakey, Inc.

1210.4.4.14.1 Monitor Unit Serial Memory Key Interface.
The CMU must not provide the capability to program the serial memory key. Writing to the serial memory key may be accomplished through the use of a serial memory key writer. The serial memory key must be used as a read only device. The 16 bit Frame Check Sequence (FCS) procedure defined in clause 4.6.2 of ISO/IEC 3309 must be used to verify the integrity of the read data. Failure to read the serial memory key correctly must result in LFSA. Interface circuitry to the device must utilize the LOFO switch on the serial memory key socket to ensure the device is removed and inserted with no power applied to the interface pins (i.e. dead socket).

1210.4.4.14.2 Serial Memory Key Data.
All bytes and bits marked as “reserved” must be set to “0”.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0x01</td>
<td>Serial Memory Key Version</td>
</tr>
<tr>
<td>2</td>
<td>Ch 1-9, …, 1-2</td>
<td>Permissive Programming for channels 1-32: A bit set to “1” programs a channel pair</td>
</tr>
<tr>
<td>3</td>
<td>Ch 1-17, …, 1-10</td>
<td></td>
</tr>
</tbody>
</table>

47-233
<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Ch 1-25, ..., 1-18</td>
<td>to the permissive state. In the event the CMU has fewer than 32 channels, the bit positions corresponding to the nonexistent channels must be 0. Default programming must be 0.</td>
</tr>
<tr>
<td>5</td>
<td>Ch 2-3, ..., 1-26</td>
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<tr>
<td>6</td>
<td>Ch 2-11, ..., 2-4</td>
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<td>7</td>
<td>Ch 2-19, ..., 2-12</td>
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<td>Ch 2-27, ..., 2-20</td>
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<td>9</td>
<td>Ch 3-6, ..., 2-28</td>
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<td>10</td>
<td>Ch 3-14, ..., 3-7</td>
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<td>11</td>
<td>Ch 3-22, ..., 3-15</td>
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<td>Ch 3-30, ..., 3-23</td>
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<td>Ch 4-10, ..., 3-31</td>
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<td>14</td>
<td>Ch 4-18, ..., 4-11</td>
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<td>15</td>
<td>Ch 4-26, ..., 4-19</td>
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<td>Ch 5-7, ..., 4-27</td>
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<td>Ch 5-15, ..., 5-8</td>
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<td>18</td>
<td>Ch 5-23, ..., 5-16</td>
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<td>19</td>
<td>Ch 5-31, ..., 5-24</td>
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<td>20</td>
<td>Ch 6-13, ..., 5-32</td>
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<td>21</td>
<td>Ch 6-21, ..., 6-14</td>
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<td>23</td>
<td>Ch 7-12, ..., 6-30</td>
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<td>24</td>
<td>Ch 7-20, ..., 7-13</td>
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<td>25</td>
<td>Ch 7-28, ..., 7-21</td>
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<td>Ch 8-12, ..., 7-29</td>
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<td>Ch 8-28, ..., 8-21</td>
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<td>29</td>
<td>Ch 9-13, ..., 8-29</td>
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<td>Ch 9-21, ..., 9-14</td>
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<td>32</td>
<td>Ch 10-15, ..., 9-30</td>
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<td>Ch 10-23, ..., 10-16</td>
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<td>Ch 11-18, ..., 10-32</td>
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<td>Ch 11-26, ..., 11-19</td>
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<td>37</td>
<td>Ch 12-14, ..., 11-19</td>
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<td>38</td>
<td>Ch 12-22, ..., 12-15</td>
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<td>41</td>
<td>Ch 13-27, ..., 13-20</td>
<td></td>
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<td>42</td>
<td>Ch 14-17, ..., 13-28</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Ch 14-25, ..., 14-18</td>
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<td>45</td>
<td>Ch 15-24, ..., 15-17</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>Ch 15-32, ..., 15-25</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>Ch 16-24, ..., 16-17</td>
<td></td>
</tr>
</tbody>
</table>

If b1 is set, then channel 1 is permissive with channel 27.
<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>Ch 16-32, ..., 16-25</td>
<td></td>
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<tr>
<td>49</td>
<td>Ch 17-25, ..., 17-18</td>
<td></td>
</tr>
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<td>50</td>
<td>Ch 18-19, ..., 17-26</td>
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<td>51</td>
<td>Ch 18-27, ..., 18-20</td>
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<td>52</td>
<td>Ch 19-22, ..., 18-28</td>
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<td>53</td>
<td>Ch 19-30, ..., 19-23</td>
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<td>54</td>
<td>Ch 20-26, ..., 19-31</td>
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<td>Ch 21-23, ..., 20-27</td>
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<td>Ch 21-31, ..., 21-24</td>
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<td>57</td>
<td>Ch 22-29, ..., 21-32</td>
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<td>58</td>
<td>Ch 23-28, ..., 22-30</td>
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<td>59</td>
<td>Ch 24-28, ..., 23-29</td>
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<td>60</td>
<td>Ch 25-29, ..., 24-29</td>
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<td>61</td>
<td>Ch 26-31, ..., 25-30</td>
<td></td>
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<td>62</td>
<td>Ch 28-30, ..., 26-32</td>
<td></td>
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<tr>
<td>63</td>
<td>Ch 31-32, ..., 28-31</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>Ch 8:1</td>
<td>Lack of Signal Input Enable:</td>
</tr>
<tr>
<td>65</td>
<td>Ch 16:9</td>
<td>A bit set to “1” enables the Lack of Signal Input monitoring function for that channel. This bit must be set to “0” for any channel that has an input mapped to a virtual channel. In the event the CMU has fewer than 32 channels, the bit positions corresponding to the nonexistent channels must be 0. Default programming must be 1.</td>
</tr>
<tr>
<td>66</td>
<td>Ch 24:17</td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>Ch 32:18</td>
<td></td>
</tr>
<tr>
<td>68</td>
<td>Ch 8:1</td>
<td>Dark Channel Map #1</td>
</tr>
<tr>
<td>69</td>
<td>Ch 16:9</td>
<td>A bit set to “1” disables the Lack of Signal Input monitoring function for that channel. For channels that are set to 0, Lack of Signal Input Enable programming must determine Lack of Signal Input operation. Default programming must be 0.</td>
</tr>
<tr>
<td>70</td>
<td>Ch 24:17</td>
<td></td>
</tr>
<tr>
<td>71</td>
<td>Ch 32:18</td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>Ch 8:1</td>
<td>Dark Channel Map #2</td>
</tr>
<tr>
<td>73</td>
<td>Ch 16:9</td>
<td>A bit set to “1” disables the Lack of Signal Input monitoring function for that channel. For channels that are set to 0, Lack of Signal Input Enable programming must determine Lack of Signal Input operation. Default programming must be 0.</td>
</tr>
<tr>
<td>74</td>
<td>Ch 24:17</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Ch 32:18</td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>Ch 8:1</td>
<td>Dark Channel Map #3</td>
</tr>
<tr>
<td>77</td>
<td>Ch 16:9</td>
<td>A bit set to “1” disables the Lack of Signal Input monitoring function for that channel. For channels that are set to 0, Lack of Signal Input Enable programming must determine Lack of Signal Input operation. Default programming must be 0.</td>
</tr>
<tr>
<td>78</td>
<td>Ch 24:17</td>
<td></td>
</tr>
<tr>
<td>Byte #</td>
<td>Contents</td>
<td>Description</td>
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<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>79</td>
<td>Ch 32:18</td>
<td>channel. For channels that are set to 0, Lack of Signal Input Enable programming must determine Lack of Signal Input operation. Default programming must be 0.</td>
</tr>
<tr>
<td>80</td>
<td>Ch 8:1</td>
<td>Dark Channel Map #4</td>
</tr>
<tr>
<td>81</td>
<td>Ch 16:9</td>
<td>A bit set to “1” disables the Lack of Signal Input monitoring function for that channel. For channels that are set to 0, Lack of Signal Input Enable programming must determine Lack of Signal Input operation. Default programming must be 0.</td>
</tr>
<tr>
<td>82</td>
<td>Ch 24:17</td>
<td></td>
</tr>
<tr>
<td>83</td>
<td>Ch 32:18</td>
<td></td>
</tr>
<tr>
<td>84</td>
<td>Ch 8:1</td>
<td>GY Multiple Channel Enable: A bit set to “1” enables the Green/Yellow Multiple Channel monitoring function for that channel. This bit must be set to “0” for any channel that has had a Green or Yellow input remapped to a virtual channel. In the event the CMU has fewer than 32 channels, the bit positions corresponding to the nonexistent channels must be 0. Default programming must be 1.</td>
</tr>
<tr>
<td>85</td>
<td>Ch 16:9</td>
<td></td>
</tr>
<tr>
<td>86</td>
<td>Ch 24:17</td>
<td></td>
</tr>
<tr>
<td>87</td>
<td>Ch 32:18</td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>Ch 8:1</td>
<td>YR Multiple Channel Enable: A bit set to “1” enables the Yellow/Red Multiple Channel monitoring function for that channel. This bit must be set to “0” for any channel that has had a Yellow or Red input remapped to a virtual channel. In the event the CMU has fewer than 32 channels, the bit positions corresponding to the nonexistent channels must be 0. Default programming must be 1.</td>
</tr>
<tr>
<td>89</td>
<td>Ch 16:9</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>Ch 24:17</td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>Ch 32:18</td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>Ch 8:1</td>
<td>GR Multiple Channel Enable: A bit set to “1” enables the Green/Red Multiple Channel monitoring function for that channel. This bit must be set to “0” for any channel that has had a Green or Red input remapped to a virtual channel. In the event the CMU has fewer than 32 channels, the bit positions corresponding to the nonexistent channels must be 0. Default programming must be 1.</td>
</tr>
<tr>
<td>93</td>
<td>Ch 16:9</td>
<td></td>
</tr>
<tr>
<td>94</td>
<td>Ch 24:17</td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>Ch 32:18</td>
<td></td>
</tr>
<tr>
<td>96</td>
<td>Ch 8:1</td>
<td>Minimum Yellow Change Enable: A bit set to “1” enables the Minimum</td>
</tr>
<tr>
<td>97</td>
<td>Ch 16:9</td>
<td></td>
</tr>
<tr>
<td>Byte #</td>
<td>Contents</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>----------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>98</td>
<td>Ch 24:17</td>
<td>Yellow Change monitoring function for that channel. In the event the CMU has</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fewer than 32 channels, the bit positions corresponding to the nonexistent</td>
</tr>
<tr>
<td>99</td>
<td>Ch 32:18</td>
<td>channels must be 0. Default programming must be 1.</td>
</tr>
<tr>
<td>100</td>
<td>Ch 8:1</td>
<td>Minimum Yellow Change Plus Red Clearance Enable:</td>
</tr>
<tr>
<td>101</td>
<td>Ch 16:9</td>
<td>A bit set to “1” enables the Minimum Yellow Change Plus Red monitoring</td>
</tr>
<tr>
<td>102</td>
<td>Ch 24:17</td>
<td>function for that channel. In the event the CMU has fewer than 32 channels,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the bit positions corresponding to the nonexistent channels must be 0. Default</td>
</tr>
<tr>
<td>103</td>
<td>Ch 32:18</td>
<td>programming must be 1.</td>
</tr>
<tr>
<td>104</td>
<td>Ch 8:1</td>
<td>Yellow Input Disable:</td>
</tr>
<tr>
<td>105</td>
<td>Ch 16:9</td>
<td>A bit set to “1” forces the Yellow input to the OFF state for that channel.</td>
</tr>
<tr>
<td>106</td>
<td>Ch 24:17</td>
<td>In the event the CMU has fewer than 28 physical channels, the bit positions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>corresponding to the nonexistent channels must be 0.</td>
</tr>
<tr>
<td>107</td>
<td>Ch 28:25</td>
<td>Minimum Yellow Change Plus Red Clearance Enable:</td>
</tr>
<tr>
<td>108</td>
<td>Ch 8:1</td>
<td>A bit set to “1” enables the Lack of Indication current monitoring function</td>
</tr>
<tr>
<td>109</td>
<td>Ch 16:9</td>
<td>for that channel. This bit must be set to “0” for any channel that has an</td>
</tr>
<tr>
<td>110</td>
<td>Ch 24:17</td>
<td>input mapped to a virtual channel. In the event the CMU has fewer than 28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>physical channels, the bit positions corresponding to the nonexistent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>channels must be 0. Default programming must be 1.</td>
</tr>
<tr>
<td>111</td>
<td>Ch 28:25</td>
<td>Current Sense Full Scale Parameter</td>
</tr>
<tr>
<td>112</td>
<td>Ch 4:1</td>
<td>These bits must define the Full Scale (FS) parameter for the Current Sense</td>
</tr>
<tr>
<td>113</td>
<td>Ch 8:5</td>
<td>circuit for each channel. Default programming must be 00.</td>
</tr>
<tr>
<td>114</td>
<td>Ch 12:9</td>
<td>b1,b0 = channel n</td>
</tr>
<tr>
<td>115</td>
<td>Ch 16:13</td>
<td></td>
</tr>
<tr>
<td>116</td>
<td>Ch 20:17</td>
<td></td>
</tr>
<tr>
<td>117</td>
<td>Ch 24:21</td>
<td></td>
</tr>
<tr>
<td>Byte #</td>
<td>Contents</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>118</td>
<td>Ch 28:25</td>
<td>$b_3, b_2 = \text{channel } n+1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$b_5, b_4 = \text{channel } n+2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$b_7, b_6 = \text{channel } n+3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>00 = 0.25 Amperes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01 = 0.33 Amperes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 = 0.50 Amperes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 = 1.0 Amperes</td>
</tr>
<tr>
<td>119</td>
<td>Channel 1</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>Channel 2</td>
<td></td>
</tr>
<tr>
<td>121</td>
<td>Channel 3</td>
<td></td>
</tr>
<tr>
<td>122</td>
<td>Channel 4</td>
<td></td>
</tr>
<tr>
<td>123</td>
<td>Channel 5</td>
<td></td>
</tr>
<tr>
<td>124</td>
<td>Channel 6</td>
<td></td>
</tr>
<tr>
<td>125</td>
<td>Channel 7</td>
<td></td>
</tr>
<tr>
<td>126</td>
<td>Channel 8</td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>Channel 9</td>
<td></td>
</tr>
<tr>
<td>128</td>
<td>Channel 10</td>
<td></td>
</tr>
<tr>
<td>129</td>
<td>Channel 11</td>
<td></td>
</tr>
<tr>
<td>130</td>
<td>Channel 12</td>
<td></td>
</tr>
<tr>
<td>131</td>
<td>Channel 13</td>
<td></td>
</tr>
<tr>
<td>132</td>
<td>Channel 14</td>
<td></td>
</tr>
<tr>
<td>133</td>
<td>Channel 15</td>
<td></td>
</tr>
<tr>
<td>134</td>
<td>Channel 16</td>
<td></td>
</tr>
<tr>
<td>135</td>
<td>Channel 17</td>
<td></td>
</tr>
<tr>
<td>136</td>
<td>Channel 18</td>
<td></td>
</tr>
<tr>
<td>137</td>
<td>Channel 19</td>
<td></td>
</tr>
<tr>
<td>138</td>
<td>Channel 20</td>
<td></td>
</tr>
<tr>
<td>139</td>
<td>Channel 21</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>Channel 22</td>
<td></td>
</tr>
<tr>
<td>141</td>
<td>Channel 23</td>
<td></td>
</tr>
<tr>
<td>142</td>
<td>Channel 24</td>
<td></td>
</tr>
<tr>
<td>143</td>
<td>Channel 25</td>
<td></td>
</tr>
<tr>
<td>144</td>
<td>Channel 26</td>
<td></td>
</tr>
<tr>
<td>145</td>
<td>Channel 27</td>
<td></td>
</tr>
<tr>
<td>146</td>
<td>Channel 28</td>
<td></td>
</tr>
<tr>
<td>147</td>
<td>Red Ch 8:1</td>
<td></td>
</tr>
<tr>
<td>148</td>
<td>Red Ch 16:9</td>
<td></td>
</tr>
<tr>
<td>149</td>
<td>Red Ch 24:17</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>Red Ch 32:25</td>
<td></td>
</tr>
<tr>
<td>151</td>
<td>Yellow Ch 8:1</td>
<td></td>
</tr>
<tr>
<td>152</td>
<td>Yellow Ch 16:9</td>
<td></td>
</tr>
<tr>
<td>153</td>
<td>Yellow Ch 24:17</td>
<td></td>
</tr>
<tr>
<td>154</td>
<td>Yellow Ch 32:25</td>
<td></td>
</tr>
<tr>
<td>155</td>
<td>Green Ch 8:1</td>
<td></td>
</tr>
<tr>
<td>156</td>
<td>Green Ch 16:9</td>
<td></td>
</tr>
</tbody>
</table>

**Channel Current Sense Threshold**

The threshold value for channel current sense must be programmed in percent (0 to 95) of full scale (FS). This value should be set in accordance with minimum accuracy tolerances defined in AMU section 3.8.5.1, AC RMS CURRENT SENSING. Default programming must be 25 (25% of 1.0 Amp full scale = 250 milliamperes).

**Field Output Check Enable:**

A bit set to “1” enables the Field Output Check monitoring function for that input. This bit must be set to “0” for any input that has been remapped to a virtual channel. In the event the CMU has fewer than 32 channels, the bit positions corresponding to the nonexistent inputs must be 0. Default programming must be 1.
<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>157</td>
<td>Green Ch 24:17</td>
<td>Minimum Flash Time</td>
</tr>
<tr>
<td>158</td>
<td>Green Ch 32:25</td>
<td>Minimum Flash Time</td>
</tr>
<tr>
<td></td>
<td>Minimum Flash Time</td>
<td>Values of 0 thru 5 must result in 6 seconds of minimum flash. Maximum value is 15. Default programming must be 6.</td>
</tr>
<tr>
<td>160</td>
<td>+12 VDC Enable</td>
<td>+12 VDC Power Supply Monitor Enable</td>
</tr>
<tr>
<td></td>
<td>+12 VDC Power Supply Monitor Enable</td>
<td>Bit 0 set to 1 must enable the +12 VDC Power Supply monitor. Default programming must be 0x01.</td>
</tr>
<tr>
<td>161</td>
<td>Ch 29 Red</td>
<td>Virtual Channel Assignment</td>
</tr>
<tr>
<td>162</td>
<td>Ch 29 Yellow</td>
<td>Virtual Channel Assignment</td>
</tr>
<tr>
<td>163</td>
<td>Ch 29 Green</td>
<td>Channels that have not been assigned must be set to 0. Default programming must be 0.</td>
</tr>
<tr>
<td>164</td>
<td>Ch 30 Red</td>
<td>Channels that have not been assigned must be set to 0. Default programming must be 0.</td>
</tr>
<tr>
<td>165</td>
<td>Ch 30 Yellow</td>
<td>Channels that have not been assigned must be set to 0. Default programming must be 0.</td>
</tr>
<tr>
<td>166</td>
<td>Ch 30 Green</td>
<td>Channels that have not been assigned must be set to 0. Default programming must be 0.</td>
</tr>
<tr>
<td>167</td>
<td>Ch 31 Red</td>
<td>Channels that have not been assigned must be set to 0. Default programming must be 0.</td>
</tr>
<tr>
<td>168</td>
<td>Ch 31 Yellow</td>
<td>Channels that have not been assigned must be set to 0. Default programming must be 0.</td>
</tr>
<tr>
<td>169</td>
<td>Ch 31 Green</td>
<td>Channels that have not been assigned must be set to 0. Default programming must be 0.</td>
</tr>
<tr>
<td>170</td>
<td>Ch 32 Red</td>
<td>Channels that have not been assigned must be set to 0. Default programming must be 0.</td>
</tr>
<tr>
<td>171</td>
<td>Ch 32 Yellow</td>
<td>Channels that have not been assigned must be set to 0. Default programming must be 0.</td>
</tr>
<tr>
<td>172</td>
<td>Ch 32 Green</td>
<td>Channels that have not been assigned must be set to 0. Default programming must be 0.</td>
</tr>
<tr>
<td>173</td>
<td>AMU Position 1</td>
<td>AMU Configuration</td>
</tr>
<tr>
<td>174</td>
<td>AMU Position 2</td>
<td>AMU Configuration</td>
</tr>
<tr>
<td>175</td>
<td>AMU Position 3</td>
<td>AMU Configuration</td>
</tr>
<tr>
<td>176</td>
<td>AMU Position 4</td>
<td>AMU Configuration</td>
</tr>
<tr>
<td></td>
<td>AMU Position 4</td>
<td>AMU Position 4 is valid only for position #1 (#1=14, #2=0) and #3 (#3=14, #4=0). All other values are reserved.</td>
</tr>
<tr>
<td>177:21</td>
<td>ASCII string</td>
<td>Monitor ID</td>
</tr>
<tr>
<td>178</td>
<td>ASCII string</td>
<td>Monitor ID</td>
</tr>
<tr>
<td></td>
<td>ASCII string</td>
<td>A packed 40 character ID must be stored in ASCII format. Allowable characters are 020h through 07Eh. If less than 40 characters are used, the unused locations must be set to 00h. Default programming must be 00h.</td>
</tr>
<tr>
<td>Byte #</td>
<td>Contents</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>217:25 6</td>
<td>ASCII string</td>
<td>User ID A packed 40 character ID must be stored in ASCII format. Allowable characters are 020h through 07Eh. If less than 40 characters are used, the unused locations must be set to 00h. Default programming must be 00h.</td>
</tr>
<tr>
<td>257:510 0</td>
<td>0x00</td>
<td>Reserved for future use.</td>
</tr>
<tr>
<td>511</td>
<td>FCS lsb</td>
<td>16 bit Check Value FCS Polynomial calculation of bytes #1 through #510.</td>
</tr>
<tr>
<td>512</td>
<td>FCS msb</td>
<td></td>
</tr>
</tbody>
</table>

1210.4.4.15 CMU Connector.

The CMU Connector must be a DIN 4161264 Header Type. The CMU Connector pin assignments must be as shown on drawing 4-11-5.

1210.4.4.16 Serial Bus #1 Frames.

1210.4.4.16.1 Type 60 Command – Module ID.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>Frame Type</td>
</tr>
</tbody>
</table>
1210.4.4.15.2 Type 188 Response – Module ID.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>188</td>
<td>Frame Type</td>
</tr>
<tr>
<td>2</td>
<td>CMU address</td>
<td>Serial Bus #1 Address</td>
</tr>
</tbody>
</table>

1210.4.4.16.3 Type 61 Command – Switch Pack Drivers.

The destination for this frame must be the CMU. The Channel numbers in the Description column below refer to the channel numbers of the CMU. The ATC Controller Unit must include a definition, via program entry, of the CMU Channel to ATC Controller Unit signal driver group utilization. The Dark Channel Map Select bits must select a preprogrammed mask in the CMU serial memory key that disables Lack of Signal Input monitoring for the selected channels.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>61</td>
<td>Frame Type</td>
</tr>
<tr>
<td>2</td>
<td>Channel 8:1 Red</td>
<td>Switch Pack Status</td>
</tr>
<tr>
<td>3</td>
<td>Channel 16:9 Red</td>
<td>A bit set to 1 indicates the Switch Pack output is set ON.</td>
</tr>
<tr>
<td>4</td>
<td>Channel 24:17 Red</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Channel 28:25 Red</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Channel 8:1 Yellow</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Channel 16:9 Yellow</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Channel 24:17 Yellow</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Channel 28:25 Yellow</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Channel 8:1 Green</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Channel 16:9 Green</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Channel 24:17 Green</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Channel 28:25 Green</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Map Select</td>
<td>Dark Channel Map Select</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bit 1 and bit 0 must select one of four Dark Channel Maps programmed in the serial memory key that disables Lack of Signal Input monitoring for a selected channel. Bits 2 thru 7 are reserved.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>00 = Mask #1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01 = Mask #2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 = Mask #3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 = Mask #4</td>
</tr>
</tbody>
</table>
1210.4.4.16.4  Type 61 Response – CMU Status.

If the CMU is in FSA (byte #2, Fault Type not equal to 0), then all bytes of the information field of this frame except Control Status 1, Control Status 2, and Output Assembly Flasher Status must contain an exact image of the signals that were applied to the CMU at the point in time of the detection of the failure. Control Status 1, Control Status 2, and Output Assembly Flasher Status must always reflect current status. If a channel block is not used (AMU not present) the Channel Fault Status bits, Channel Input Status bits, and Channel Input Voltage values bits for that block must be set to 0.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>189</td>
<td>Frame Type</td>
</tr>
<tr>
<td>2</td>
<td>Fault Type</td>
<td>Enumerated fault code</td>
</tr>
<tr>
<td></td>
<td></td>
<td>00 = No Fault</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01 = CMU/AMU +24 VDC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>02 = CMU +12 VDC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>03 = Conflict</td>
</tr>
<tr>
<td></td>
<td></td>
<td>04 = Serial Bus #1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>05 = Serial Bus #3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>06 = ATC LFSA Flash (Type 62)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>07 = ATC NFSA Flash (Type 62)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>08 = Diagnostic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>09 = Multiple</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 = Lack of Signal Input</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 = Short Yellow Clearance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 = Skipped Yellow Clearance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13 = Yellow + Red Clearance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14 = Field Output Check</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 = Serial Memory Key absent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16 = Serial Memory Key FCS error</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17 = Serial Memory Key Data error</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18 = Local Flash</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19 = CB Trip</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 = CMU/AMU AC+ Raw Fail</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21 = NRESET Active</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22:127 = Reserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>128:255 = Spare</td>
</tr>
<tr>
<td>3</td>
<td>Channel Fault Status 8:1</td>
<td>Channel Fault Status</td>
</tr>
<tr>
<td>4</td>
<td>Channel Fault Status 16:9</td>
<td>Channel Fault Status bits must be set to 1 for channels that were detected in fault for fault types 03, 09, 10, 11, 12, 13, and 14.</td>
</tr>
<tr>
<td>5</td>
<td>Channel Fault Status 24:17</td>
<td>Channel Fault Status</td>
</tr>
<tr>
<td>Byte #</td>
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<td>Description</td>
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</tr>
<tr>
<td>6</td>
<td>Channel Fault Status 32:25</td>
<td>For fault type 01, 05, and 20 a bit must be set in Channel Fault Status 8:1 for each enabled AMU that failed. Bit 0 must be set if the CMU detected a failure: b0 = CMU b1 = AMU #1 b2 = AMU #2 b3 = AMU #3 b4 = AMU #4 For all other fault types the Channel Fault Status bits must be set to 0.</td>
</tr>
<tr>
<td>7</td>
<td>Channel Red Status 8:1</td>
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<tr>
<td>8</td>
<td>Channel Red Status 16:9</td>
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<td>Channel Red Status 24:17</td>
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<td>Channel Red Status 32:25</td>
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<td>11</td>
<td>Channel Yellow Status 8:1</td>
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<td>12</td>
<td>Channel Yellow Status 16:9</td>
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<td>Channel Yellow Status 32:25</td>
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<td>Channel Green Status 8:1</td>
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<td>Channel Yellow Status 8:1</td>
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<td>24</td>
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<td>25</td>
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</tbody>
</table>

Channel Color Status

Channel Color Status bits must be set to 1 for channels that are sensed active. For channel inputs that have been remapped to a virtual channel (29-32), the Channel Fault Status bits must be set to 0. For virtual channel (29-32) inputs that have not been assigned to a physical output, the Channel Fault Status bits must be set to 0.

Field Check Status

Field Check Status bits must be set to 1 for channels that are sensed with field check status. For channel inputs that have been remapped to a virtual channel (29-32), the Field Check Status bits must be set to 0. For virtual channel (29-32) inputs that have not been assigned to a physical output, the Field Check Status bits must be set to 0.
<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
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<tbody>
<tr>
<td>26</td>
<td>Channel Yellow Status 32:25</td>
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<td>29</td>
<td>Channel Green Status 24:17</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Channel Green Status 32:25</td>
<td></td>
</tr>
</tbody>
</table>
| 31     | Control Status #1            | Control Status #1  
  b7 = Start-up Call (1=Exit from Flash)  
  b6 = Flasher Output Fail (1 = Fail)  
  b5 = Rear Door (1=Open)  
  b4 = Front Door (1=Open)  
  b3 = MAIN CONTACTOR Coil (1=Active)  
  b2 = MAIN CONTACTOR Secondary (1=Active)  
  b1 = FTR Coil Drive (1= Active)  
  b0 = Output Relay Transfer (1=Fault)  |
| 32     | Control Status #2            | Control Status #2  
  b7 = Reserved  
  b6 = Reserved  
  b5 = Reserved  
  b4 = Reserved  
  b3 = Reserved  
  b2 = Reserved  
  b1 = Reserved  
  b0 = Configuration Change  
  This bit set to 1 indicates the configuration programming has changed since the last poll of message 65. It must also be set to 1 when the CMU is exiting flash (Start-up Call bit changes from 0 to 1) and at CMU power-up.  |
<p>| 33     | AC+ Raw Voltage              | CMU AC+ Raw Voltage  |
| 34     | Assembly #1 AC+ Raw Voltage  | Assembly AC+ Raw Voltage  |
| 35     | Assembly #1 AC+ Raw Voltage  | Assembly AC+ Raw Voltage  |
| 36     | Assembly #1 AC+ Raw Voltage  | Assembly AC+ Raw Voltage  |
| 37     | Assembly #1 AC+ Raw Voltage  | Assembly AC+ Raw Voltage  |
| 38     | Channel 1 Red Voltage        | Channel Input Voltages  |
| 39     | Channel 2 Red Voltage        | The Channel input voltages must be the most |</p>
<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
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<tr>
<td>40</td>
<td>Channel 3 Red Voltage</td>
<td>recent values reported from the AMUs. For channel inputs that have been remapped to a virtual channel (29-32), the Channel Voltage value must be set to 0. For virtual channel (29-32) inputs that have not been assigned to a physical output, the Channel Voltage value must be set to 0.</td>
</tr>
<tr>
<td>41</td>
<td>Channel 4 Red Voltage</td>
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<td>134</td>
<td>Channel 1</td>
<td>Scaled Channel Load Current</td>
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<td>Channel 2</td>
<td>The value reported must be the measured current in Amperes</td>
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<td>136</td>
<td>Channel 3</td>
<td>times 256 divided by the Full Scale (FS) parameter.</td>
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<tr>
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<td>Channel 4</td>
<td>For 1 primary turn, FS=10 (range is 0 to 10 Arms)</td>
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<td>138</td>
<td>Channel 5</td>
<td>For 2 primary turns, FS=5 (range is 0 to 5 Arms)</td>
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<td>139</td>
<td>Channel 6</td>
<td>For 3 primary turns, FS= 3.3 (range is 0 to 3.3 Arms)</td>
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<td>Channel 7</td>
<td>For 4 primary turns, FS=2.5 (range is 0 to 2.5 Arms)</td>
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<td>Binary Seconds</td>
<td>CMU Time and Date</td>
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<td>Binary Minutes</td>
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<td>Binary Hours (0:23)</td>
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<td>168</td>
<td>Voltage * 4</td>
<td>24 VDC Supply Voltage</td>
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<td>169</td>
<td>Voltage * 8</td>
<td>12 VDC Supply Voltage</td>
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<td>170</td>
<td>degrees F + 40</td>
<td>CMU Temperature (Fahrenheit)</td>
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<td>171</td>
<td>Channel 8:1</td>
<td>Channel Current Sense Status</td>
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<td></td>
<td>Status bits must be set to 1 for channels that are sensed active. Status bits must be set to 0 for channels that have the Current Sense monitor function disabled.</td>
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<tr>
<td>172</td>
<td>Channel 16:9</td>
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<td>174</td>
<td>Channel 28:25</td>
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<td>175</td>
<td>Assembly 2:1</td>
<td>Output Assembly Flasher Status (1=Fail)</td>
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<td>176</td>
<td>Assembly 4:3</td>
<td>b0 = Assembly #1 (#3) FL1-1 b1 = Assembly #1 (#3) FL1-2 b2 = Assembly #1 (#3) FL2-1 b3 = Assembly #1 (#3) FL2-2 b4 = Assembly #2 (#4) FL1-1 b5 = Assembly #2 (#4) FL1-2 b6 = Assembly #2 (#4) FL2-1 b7 = Assembly #2 (#4) FL2-2</td>
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</tbody>
</table>

1210.4.4.16.5 Type 62 – Send to Local Flash Command – SET FSA.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62</td>
<td>Frame Type</td>
</tr>
<tr>
<td>2</td>
<td>FSA mode</td>
<td>Set Failed State Action</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b0 = Set LFSA (L)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b1 = Set NFSA (N)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b2:7 = reserved</td>
</tr>
</tbody>
</table>

1210.4.4.16.6 Type 190 Response – Send to Local Flash Response – Set FSA.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>190</td>
<td>Frame Type</td>
</tr>
</tbody>
</table>

1210.4.4.16.7 Type 65 Command – Get CMU Configuration.

The ATC Controller Unit must request the serial memory key programming using this message and validate that the CMU Permissive Program settings are equal or less permissive than the ATC Controller Unit programming, and that the AMU Configuration programming is consistent with Output Assembly SIU assignment. If the programming of the CMU is not proper, the ATC Controller Unit must issue a Type 62 frame with the L bit set causing a LFSA in the CMU. This check must be performed at initialization and when the Type 189 or Type 195 Control Status 2, Configuration Change bit is set to 1.
1210.4.4.16.8 Type 193 Response – CMU Configuration.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>65</td>
<td>Frame Type</td>
</tr>
</tbody>
</table>

2:513 Bytes #1 thru #512 Serial Memory Key Contents

1210.4.4.16.9 Type 66 Command – Time and Date Command.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>66</td>
<td>Frame Type</td>
</tr>
<tr>
<td>2</td>
<td>0x01:0x0C</td>
<td>Month</td>
</tr>
<tr>
<td>3</td>
<td>0x01:0x1F</td>
<td>Day</td>
</tr>
<tr>
<td>4</td>
<td>0x00:0x63</td>
<td>Year</td>
</tr>
<tr>
<td>5</td>
<td>0x00:0x17</td>
<td>Hour</td>
</tr>
<tr>
<td>6</td>
<td>0x00:0x3B</td>
<td>Minutes</td>
</tr>
<tr>
<td>7</td>
<td>0x00:0x3B</td>
<td>Seconds</td>
</tr>
<tr>
<td>8</td>
<td>0x00:0x3B</td>
<td>Tenth Seconds</td>
</tr>
</tbody>
</table>

This frame must be transmitted from the ATC Controller Unit once every second. The destination address must be the All Station Address of 255 (0xFF). No response from secondary devices is allowed to the All Station Address. The transmission of this frame must begin within +/-100 milliseconds of the ATC Controller Unit real time contained within the frame.

1210.4.4.16.10 Type 67 Command – Switch Pack Drivers.

The format of this command frame must be identical to Message 61 but requests a short status response from the CMU. This frame may be used as an alternate to Message 61. The destination for this frame must be the CMU. The Channel numbers in the Description column below refer to the channel numbers of the CMU. The ATC Controller Unit must include a definition, via program entry, of the CMU Channel to ATC Controller Unit signal driver group utilization.

The Dark Channel Map Select bits must select a preprogrammed mask in the CMU serial memory key that disables Lack of Signal Input monitoring for the selected channels.
<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>67</td>
<td>Frame Type</td>
</tr>
<tr>
<td>2</td>
<td>Channel 8:1 Red</td>
<td>Switch Pack Status</td>
</tr>
<tr>
<td>3</td>
<td>Channel 16:9 Red</td>
<td>A bit set to 1 indicates the Switch Pack output is set ON.</td>
</tr>
<tr>
<td>4</td>
<td>Channel 24:17 Red</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Channel 28:25 Red</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Channel 8:1 Yellow</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Channel 16:9 Yellow</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Channel 24:17 Yellow</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Channel 28:25 Yellow</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Channel 8:1 Green</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Channel 16:9 Green</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Channel 24:17 Green</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Channel 28:25 Green</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Map Select</td>
<td>Dark Channel Map Select</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bit 1 and bit 0 must select one of four Dark Channel Maps programmed in the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>serial memory key that disables Lack of Signal Input monitoring for a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>selected channel. Bits 2 thru 7 are reserved.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>00 = Mask #1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01 = Mask #2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 = Mask #3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 = Mask #4</td>
</tr>
</tbody>
</table>

1210.4.4.16.11 Type 195 Response – CMU Short Status.

If the CMU is in FSA (byte #2, Fault Type not equal to 0), then the Channel Color Status bytes must contain an exact image of the signals that were applied to the CMU at the point in time of the detection of the failure. Control Status 1, Control Status 2, and Output Assembly Flasher Status must always reflect current status.

If a channel block is not used (AMU not present), the Channel Fault Status bits and Channel Color Status bits for that block must be set to 0.
<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>195</td>
<td>Frame Type</td>
</tr>
<tr>
<td>2</td>
<td>Fault Type</td>
<td>Enumerated fault code</td>
</tr>
<tr>
<td></td>
<td></td>
<td>00 = No Fault</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01 = CMU/AMU +24 VDC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>02 = CMU +12 VDC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>03 = Conflict</td>
</tr>
<tr>
<td></td>
<td></td>
<td>04 = Serial Bus #1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>05 = Serial Bus #3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>06 = ATC LFSA Flash (Type 62)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>07 = ATC NFSA Flash (Type 62)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>08 = Diagnostic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>09 = Multiple</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 = Lack of Signal Input</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 = Short Yellow Clearance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 = Skipped Yellow Clearance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13 = Yellow + Red Clearance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14 = Field Output Check</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 = Serial Memory Key absent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16 = Serial Memory Key FCS error</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17 = Serial Memory Key Data error</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18 = Local Flash</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19 = CB Trip</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 = CMU/AMU AC+ Raw Fail</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21 = NRESET Active</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22:127 = Reserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>128:255 = Spare</td>
</tr>
<tr>
<td>3</td>
<td>Channel Fault Status 8:1</td>
<td>Channel Fault Status</td>
</tr>
<tr>
<td>4</td>
<td>Channel Fault Status 16:9</td>
<td>Channel Fault Status bits must be set to 1 for channels that</td>
</tr>
<tr>
<td></td>
<td></td>
<td>were detected in fault for fault types 03, 09, 10, 11, 12,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13, and 14.</td>
</tr>
<tr>
<td>5</td>
<td>Channel Fault Status 24:17</td>
<td>For fault type 01, 05, and 20 a bit must be set in Channel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fault Status 8:1 for each enabled AMU that failed. Bit 0 must</td>
</tr>
<tr>
<td></td>
<td></td>
<td>be set if the CMU detected a failure:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b0 = CMU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b1 = AMU #1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b2 = AMU #2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b3 = AMU #3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b4 = AMU #4</td>
</tr>
<tr>
<td>6</td>
<td>Channel Fault Status 32:25</td>
<td>For all other fault types the Channel Fault Status bits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>must be set to 0.</td>
</tr>
<tr>
<td>7</td>
<td>Channel Red Status 8:1</td>
<td>Channel Color Status</td>
</tr>
<tr>
<td>8</td>
<td>Channel Red Status 16:9</td>
<td>Channel Color Status bits must be set to 1</td>
</tr>
</tbody>
</table>

66-233
<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Channel Red Status 24:17</td>
<td>for channels that are sensed active. For channel inputs that have been remapped to a virtual channel (29-32), the Channel Fault Status bits must be set to 0. For virtual channel (29-32) inputs that have not been assigned to a physical output, the Channel Fault Status bits must be set to 0.</td>
</tr>
<tr>
<td>10</td>
<td>Channel Red Status 32:25</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Channel Yellow Status 8:1</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Channel Yellow Status 16:9</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Channel Yellow Status 24:17</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Channel Yellow Status 32:25</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Channel Green Status 8:1</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Channel Green Status 16:9</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Channel Green Status 24:17</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Channel Green Status 32:25</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Control Status #1</td>
<td>Control Status #1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b7 = Start-up Call (1=Exit from Flash)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b6 = Flasher Output Fail (1 = Fail)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b5 = Rear Door (1=Open)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b4 = Front Door (1=Open)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b3 = MC Coil (1=Active)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b2 = MC Secondary (1=Active)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b1 = FTR Coil Drive (1 = Active)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b0 = Output Relay Transfer (1=Fault)</td>
</tr>
<tr>
<td>20</td>
<td>Control Status #2</td>
<td>Control Status #2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b7 = Reserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b6 = Reserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b5 = Reserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b4 = Reserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b3 = Reserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b2 = Reserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b1 = Reserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b0 = Configuration Change</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This bit set to 1 indicates the configuration programming has changed since the last poll of message 65. It must also be set to 1 when the CMU is exiting flash (Start-up Call bit changes from 0 to 1) and at CMU power-up.</td>
</tr>
<tr>
<td>21</td>
<td>Assembly 2:1</td>
<td>Output Assembly Flasher Status (1=Fail)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b0 = Assembly #1 (#3) FL1-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b1 = Assembly #1 (#3) FL1-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b2 = Assembly #1 (#3) FL2-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b3 = Assembly #1 (#3) FL2-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b4 = Assembly #2 (#4) FL1-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b5 = Assembly #2 (#4) FL1-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b6 = Assembly #2 (#4) FL2-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b7 = Assembly #2 (#4) FL2-2</td>
</tr>
<tr>
<td>22</td>
<td>Assembly 4:3</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td>Reserved</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>Reserved</td>
</tr>
</tbody>
</table>
1210.4.5    Model 214 ITS Auxiliary Monitor Unit (AMU).

1210.4.5.1    General.

The AMU must reside in each of the Output Assemblies. The AMU must interface to the CMU via Serial Bus #3. An AMU must operate in a fourteen-channel mode (14 Pack) or a six-channel mode (6 Pack) depending on the Address Select inputs.

1210.4.5.1.1    AMU Addressing.

The Address Select input pins ADDRESS 0, ADDRESS 1, and ADDRESS 2 must define the Serial Bus #3 address of the AMU and the number of channels reported. The pins must be left open for a logical False, and are connected to ADDRESS COMMON for a logical True.

<table>
<thead>
<tr>
<th>Mode / Position</th>
<th>ADDRESS 2</th>
<th>ADDRESS 1</th>
<th>ADDRESS 0</th>
<th>SB #3 ADDRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 Ch/1 and 2</td>
<td>False</td>
<td>False</td>
<td>True</td>
<td>0x01</td>
</tr>
<tr>
<td>14 Ch/3 and 4</td>
<td>False</td>
<td>True</td>
<td>True</td>
<td>0x03</td>
</tr>
<tr>
<td>6 Ch/1</td>
<td>True</td>
<td>False</td>
<td>True</td>
<td>0x05</td>
</tr>
<tr>
<td>6 Ch/2</td>
<td>True</td>
<td>True</td>
<td>False</td>
<td>0x06</td>
</tr>
<tr>
<td>6 Ch/3</td>
<td>True</td>
<td>True</td>
<td>True</td>
<td>0x07</td>
</tr>
<tr>
<td>6 Ch/4</td>
<td>True</td>
<td>False</td>
<td>False</td>
<td>0x04</td>
</tr>
</tbody>
</table>

A 14 Pack Output Assembly configured in position 1 and 2 must respond as AMU #1 with AMU #2 reserved. A 14 Pack Output Assembly configured in position 3 and 4 must respond as AMU #3 with AMU #4 reserved.

The 6 Pack Output Assembly must have ADDRESS 2 permanently connected to ADDRESS COMMON on the assembly.

1210.4.5.2    AC Voltage Sensing.

All AC RMS voltage measurements must be made over an RMS period of 33.3 milliseconds (two AC Line cycles). All AC signals must be sampled at a minimum of 1920 samples per second. A True RMS voltage measurement must be made regardless of phase or wave-shape, including both positive and negative half wave sinusoids, over the voltage range of 0 Volts RMS to 135 Volts RMS. AC voltage measurements must be accurate to +/-2 Volts RMS.

1210.4.5.3    Field Signal Sensing.

Three inputs must be provided for each of fourteen channels (36 total) to permit the monitoring of voltages at the Green, Yellow, and Red signal field terminals. The AMU must be designed so that unused Green, Yellow, or Red signal inputs are not sensed as active signals. The AMU must sense an input at less than 15 Volts RMS when connected to AC Line through 1500 picofarads. Each field input voltage must be reported in the Type 129 or 130 frame.
1210.4.5.4 AC Line Sensing.

The AMU must include the capability of monitoring the AC Line voltage applied to its AC+ Raw input. The AC Line voltage must be reported in the Type 129 or 130 frame.

1210.4.5.5 Flasher Input Sensing.

Four inputs must be provided for sensing of voltages at the FLASHER #1-1, FLASHER #1-2, FLASHER #2-1, and FLASHER #2-2 signal input terminals of the Output Assembly. Each FLASHER input voltage must be reported in the Type 129 or 130 frame.

1210.4.5.6 +24 VDC Sensing.

The AMU must sense the state of the +24 VDC MONITOR input. Voltages at, or greater than, +22 VDC must be considered proper for Assembly operation. Voltages at, or less than, +18 VDC must be considered not proper for Assembly operation. The +24 VDC MONITOR state must be reported in the Type 129 or 130 frames. The +24 VDC MONITOR voltage section must be electrically isolated from the AC- Raw referenced circuitry.

1210.4.5.7 Current Sensing.

1210.4.5.7.1 AC RMS Current Sensing.

All AC RMS current measurements must be made over a period of two AC Line cycles (33.3 milliseconds). A True RMS current measurement must be made regardless of phase or wave-shape, including both positive and negative half wave sinusoids. AC current measurements must be accurate to +/-35%.

1210.4.5.7.2 Switch Pack Current Sensing.

The AMU must sense the total output current of each Switch Pack. Each Switch Pack output current must be reported in the Type 129 or 130 frames.

The input impedance of the COIL+ input with respect to the COIL-input must be 1000 Ohms. Full-scale current is set by the number of primary turns through the transformer and must be a maximum of four turns. Unless specified otherwise, one turn must be provided.
1210.4.5.7.3 Current Transformer Parameters.

The Switch Pack current sensing transformers must meet the following requirements:

- **Linearity**: 25% from 10 milliamperes to 1 Ampere (single primary turn)
- **Accuracy**: +/-25% ( Rin = 1000 Ohms)
- **Primary Current**: 10 Amperes maximum
- **Minimum hole size**: 0.25 in. diameter
- **Insulation Resistance**: 100 Megohms at 500 VDC

The transformer must output a voltage of 1.0 Volts RMS (+/-5%) across 1K Ohms when driven by 1.0 Arms sinusoidal current through one primary turn. Sufficient secondary turns must be provided to compensate for differences in core material and losses to produce the 1.0 Volts RMS output.

1210.4.5.8 Diagnostic Error.

The AMU must be provided with a resident series of self-check diagnostic capabilities. At a minimum, the AMU must contain provisions to verify all memory elements on power-up and Reset. When an error is detected, the AMU must illuminate the DIAGNOSTIC indicator and disable the Serial Bus #3 port.

1210.4.5.8.1 RAM Diagnostic.

This test must verify that all RAM elements are operating correctly at power-up. Patterns must be written to RAM. Each Write must be followed by a Read to verify that it contains the written pattern.

1210.4.5.8.2 Nonvolatile Memory Diagnostic.

This test must verify that the nonvolatile ROM(s) contain the proper program. The routine must perform a check on each ROM and make a comparison with a preprogrammed check value. This test must be performed at power-up and at a minimum rate of 1024 bits per second during operation.

1210.4.5.8.3 Internal MPU Monitor.

The AMU must monitor the operation of its microprocessor. At a minimum, the monitoring circuit must be triggered at least every 100 milliseconds. The microprocessor must be reset and the DIAGNOSTIC indicator illuminated if the monitoring circuit has not been triggered for a maximum of 1000 milliseconds.

1210.4.5.9 Power Requirements.

The AMU must generate its own power supply voltage from the AC+ Raw input using no more than 5 Watts. It must be capable of insertion and removal while AC power is applied to the cabinet. Surge current on AC+ Raw input must be less than 2 Amperes peak.
1210.4.5.9.1 Operating Voltage Range.

The AMU must be operational over the voltage range of 80 Volts RMS to 135 Volts RMS. The AMU must be fully functional within 500 milliseconds following AC+ Raw voltage exceeding 80 Volts RMS or Reset.

1210.4.5.9.2 Power Supply Holdup.

During the loss of AC+ Raw voltage for 700 milliseconds or less the AMU must continue to operate.

1210.4.5.10 AMU User Interface.

All indicators must be clear LEDs. Clear LEDs must not depend on a reflector or diffusion as part of its design. Clear LEDs must only show the die and not appear to be ON when exposed to ambient light. The following indicators must be provided (Top to Bottom).

1210.4.5.10.1 AC Power Indicator.

A green POWER indicator must be provided. The indicator must be illuminated when the AC+ Raw input is 80 Volts RMS (+/-2 Volts RMS) or greater. This indicator must be labeled POWER.

1210.4.5.10.2 Serial Bus #3 Indicator.

A yellow Serial Bus #3 indicator must be provided. The indicator must pulse ON for 40 milliseconds each time the AMU correctly receives a frame with its address on the Bus #3 input. This indicator must be labeled SB #3 RX.

1210.4.5.10.3 Diagnostic Indicator.

A red DIAGNOSTIC indicator must be provided. The indicator must be ON when an internal diagnostic error is detected. This indicator must be labeled DIAGNOSTIC.

1210.4.5.10.4 Reset Button.

A recessed RESET switch must be provided which applies a direct reset to the microprocessor device on the AMU. All voltage and current data must be initialized to 0 following Reset. The access hole must be 0.25 in. in diameter.

1210.4.5.10.5 AMU Connector.

The AMU connector must be a DIN 4161296 Header Type. Pins A31 (Equipment Ground), B32 (AC-Raw), and C32 (AC-Raw) must pre-mate before all other pins. The AMU pin assignments must be as shown on specification drawing.
1210.4.5.11 Bus #3 Profile.

1210.4.5.11.1 Electrical.


All voltage potentials on the Bus #3 TxD+, TxD-, RxD+, and RxD- interface links must be referenced to AC- Raw.

1210.4.5.11.2 Data Link Layer.

The data link layer protocol is based on a subset of HDLC as defined by ISO/IEC 3309. Each frame must consist of the following fields:

1. Flag byte = 0x7E
2. Address byte = 0x01 through 0x07
3. Control byte = 0x13 (U Format)
4. Information field = defined below in section, Frame Types
5. Frame Check Sequence = 16 bit FCS procedure defined in clause 4.6.2 of ISO/IEC 3309.
6. Flag byte = 0x7E

Transmission must be in start/stop mode with basic transparency defined by clause 4.5.2.2 of ISO/IEC 3309 applied. The format must be 8 bit data, 1 stop bit, no parity, and 153,600 bits per second (+/-2%). Only asynchronous half duplex operation must be permitted.

1210.4.5.11.3 Procedures.

Frames transmitted by the CMU must be referred to as command frames and frames transmitted by the AMU must be referred to as response frames. Command frames must be transmitted only to those AMUs that are present, as determined by the programming entries made in the CMU. Response frames must only be transmitted as a result of correctly receiving a command frame. The first eight bits in each information field must contain the frame Type number. There must be a maximum of 64 different command frame types and 64 different response frame types. Additionally, there must be 64 different command frame types reserved for special application use and 64 different response frame types reserved for special application use, as outlined below.
<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>01</td>
<td>Frame Type</td>
</tr>
</tbody>
</table>
1210.4.5.12.2 Type 129 Response Frame.

This AMU-6 Status frame must be transmitted only if a Type 1 command frame has been correctly received from the CMU. The AMU-6 must report the data for the most recent RMS period calculated when the Type 1 command is received. The Type 1 command frame polling rate must not affect the accuracy or RMS period of the data.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>129</td>
<td>Frame Type</td>
</tr>
<tr>
<td>2</td>
<td>AMU Status</td>
<td>6 Pack AMU Status</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b0 = set to 1 if +24 VDC MONITOR input is Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b1:4 = reserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b5 = set if AMU has reset since last poll</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b6 = set if last RMS period data was not transmitted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b7 = diagnostic failure</td>
</tr>
<tr>
<td>3</td>
<td>0-135</td>
<td>AC+ Raw voltage</td>
</tr>
<tr>
<td>4</td>
<td>Channel 1 Red</td>
<td>Channel RMS Voltages</td>
</tr>
<tr>
<td>5</td>
<td>Channel 2 Red</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Channel 3 Red</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Channel 4 Red</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Channel 5 Red</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Channel 6 Red</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Channel 1 Yellow</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Channel 2 Yellow</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Channel 3 Yellow</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Channel 4 Yellow</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Channel 5 Yellow</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Channel 6 Yellow</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Channel 1 Green</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Channel 2 Green</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Channel 3 Green</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Channel 4 Green</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Channel 5 Green</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Channel 6 Green</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Flasher #1-1</td>
<td>Flasher RMS Voltages</td>
</tr>
<tr>
<td>23</td>
<td>Flasher #1-2</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Flasher #2-1</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Flasher #2-2</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Channel 1</td>
<td>Channel Load Current</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The current value reported must be the measured current in Amperes times 255</td>
</tr>
<tr>
<td></td>
<td></td>
<td>divided by the Full Scale (FS) parameter.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For 1 primary turn, FS = 1.0 (range is 0 to</td>
</tr>
<tr>
<td>27</td>
<td>Channel 2</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Channel 3</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Channel 4</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Channel 5</td>
<td></td>
</tr>
</tbody>
</table>
1210.4.5.12.3 Type 2 Command Frame

This frame must be transmitted from the CMU to each AMU-14 at least once every RMS period. Its purpose is to request the status from an AMU-14. Polling the AMU-14 more often than the RMS period may result in the same response frame being repeated.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
</table>
| 31     | Channel 6| 1.0 Arms)  
For 2 primary turns, FS =0.5 (range is 0 to 0.5 Arms)  
For 3 primary turns, FS = 0.33 (range is 0 to 0.33 Arms)  
For 4 primary turns, FS =0.25 (range is 0 to 0.25 Arms) |
| 32     | 0        | Reserved    |
| 33     | 0        | Reserved    |

1210.4.5.12.4 Type 130 Response Frame

This AMU-14 Status frame must be transmitted only if a Type 2 command frame has been correctly received from the CMU. The AMU-14 must report the data for the most recent RMS period calculated when the Type 2 command is received. The Type 2 command frame polling rate must not affect the accuracy or RMS period of the data.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>02</td>
<td>Frame Type</td>
</tr>
</tbody>
</table>
| 2      | AMU Status | 14 Pack AMU Status  
b0 = set to 1 if +24 VDC MONITOR input is Low  
b1:4 = reserved  
b5 = set if AMU has reset since last poll  
b6 = set if last RMS period data was not transmitted  
b7 = diagnostic failure |
<p>| 3      | 0-135    | AC+ Raw voltage |
| 4      | Channel 1 Red | Channel RMS Voltages |
| 5      | Channel 2 Red | |
| 6      | Channel 3 Red | |
| 7      | Channel 4 Red | |
| 8      | Channel 5 Red | |
| 9      | Channel 6 Red | |
| 10     | Channel 7 Red | |
| 11     | Channel 8 Red | |
| 12     | Channel 9 Red | |</p>
<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Channel 10 Red</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Channel 11 Red</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Channel 12 Red</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Channel 13 Red</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Channel 14 Red</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Channel 1 Yellow</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Channel 2 Yellow</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Channel 3 Yellow</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Channel 4 Yellow</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Channel 5 Yellow</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Channel 6 Yellow</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Channel 7 Yellow</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Channel 8 Yellow</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Channel 9 Yellow</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Channel 10 Yellow</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Channel 11 Yellow</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Channel 12 Yellow</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Channel 13 Yellow</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Channel 14 Yellow</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Channel 1 Green</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Channel 2 Green</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Channel 3 Green</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Channel 4 Green</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Channel 5 Green</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Channel 6 Green</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Channel 7 Green</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Channel 8 Green</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Channel 9 Green</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Channel 10 Green</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Channel 11 Green</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Channel 12 Green</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Channel 13 Green</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Channel 14 Green</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>Flasher #1-1</td>
<td>Flasher RMS Voltages</td>
</tr>
<tr>
<td>47</td>
<td>Flasher #1-2</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Flasher #2-1</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Flasher #2-2</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Channel 1</td>
<td>Channel Load Current</td>
</tr>
<tr>
<td>51</td>
<td>Channel 2</td>
<td>The current value reported must be the measured</td>
</tr>
<tr>
<td>52</td>
<td>Channel 3</td>
<td>current in Amperes times 255 divided by the</td>
</tr>
<tr>
<td>53</td>
<td>Channel 4</td>
<td>Full Scale (FS) parameter. For 1 primary turn,</td>
</tr>
<tr>
<td>54</td>
<td>Channel 5</td>
<td>FS =1.0 (range is 0 to 1.0 Arms)</td>
</tr>
<tr>
<td>55</td>
<td>Channel 6</td>
<td>For 2 primary turns, FS =0.5 (range is 0 to 0.5</td>
</tr>
<tr>
<td>56</td>
<td>Channel 7</td>
<td>Arms)</td>
</tr>
<tr>
<td>57</td>
<td>Channel 8</td>
<td></td>
</tr>
</tbody>
</table>
1210.4.5.12.5 Type 128 Response Frame.

This frame must be transmitted from the AMU to the CMU as a Negative Acknowledge response frame if the AMU correctly receives a command frame with an invalid parameter.

<table>
<thead>
<tr>
<th>Byte #</th>
<th>Contents</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>128</td>
<td>Frame Type (Negative Acknowledge)</td>
</tr>
</tbody>
</table>
| 2      | Status   | AMU SB #3 Error Type  
|        |          |   b0 = set to 1 if invalid frame type received  
|        |          |   b1:7 = reserved         |

1210.4.6 Model 216-12 & 216-24 ITS Power Supply Units.

1210.4.6.1 General Requirements.

1210.4.6.1.1

The unit chassis must be vented. The power supply cage and transformers must be securely braced to prevent damage in transit. When resident in the PDA ITS, the units must be held firmly in place by its stud screws and wing nut.

1210.4.6.1.2

Two units, 216-12 and 216-24 must provide +12 and +24 VDC, respectively, to the cabinet assemblies. They must be of ferro-resonant design. They must have no active components and conform to the requirements of this section.

1210.4.6.1.2.1

Line and load regulation must meet the two power supply ranges for +24 VDC (23.0 VDC to 26 VDC) and +12 VDC (11.65 VDC to 13.35 VDC). This includes ripple noise; from 90 VAC to 135 VAC at 60 Hertz, plus an additional 1.6% for each additional 1.0% frequency change; and current range from 1 Ampere to 5 Amperes with a maximum temperature rise of 30 degrees C above ambient.
1210.4.6.1.2.2
Design Center Voltage must be +24 VDC (+/-0.5 VDC) and +12 VDC (+/-0.5 VDC) at full load, at 30 degrees C, and with 115 VAC incoming after a 30-minute warm-up period.

1210.4.6.1.2.3
Full Load Current must be 5 AMPERES each for +24 VDC and +12 VDC, minimum.

1210.4.6.1.2.4
Ripple Noise must be 2 Volts peak-to-peak and 500 millivolts RMS at full load.

1210.4.6.1.2.5
Line Voltage must be 90 VAC to 135 VAC.

1210.4.6.1.2.6
Efficiency must be 70% minimum.

1210.4.6.1.2.7
Circuit capacitors must be rated for 40 Volts minimum.

1210.4.6.1.3
The front panel must include AC and DC fuses, power ON light and banana clip test points for monitoring the output voltages. The unit, including terminals, must be protected with a 1K Ohm, 0.5 watt, resistor to prevent accidental contact with energized parts.

1210.4.7.1 Type 218 – Serial Interface Unit (SIU).

1210.4.7.1 General.

The SIU must be capable of processing fifty-four Input/Output pins and four Optical Input pins. When installed in an ITS Input Assembly, it processes twenty-four detector outputs (pins F and W), twenty-four detector status outputs, and provides six detector rest signals (per two slots). In advanced detectors, the status outputs may be converted to per channel resets. When installed in an ITS 14 Pack Output Assembly, the SIU controls fourteen Switch Pack Units (forty-two Outputs) and four Optical Inputs through the CDC socket.

1210.4.7.2 Power Requirements.

The SIU requires a nominal supply voltage of 24 VDC (+/-2 VDC). A voltage of 16 VDC or less must be considered loss of power and a voltage of 18 VDC or greater must be considered adequate for operation. The SIU must not require more than 300 milliamperes over the voltage range of 16 VDC to 30 VDC and the power surge must be limited to a maximum of 1.25 Amperes from initial application of DC power. The SIU
must not be damaged by insertion to, or removal from, powered input or output assemblies. The SIU operates normally for 700 milliseconds after power loss.

1210.4.7.3 Microprocessor.

The SIU Controller Unit must include a microprocessor/controller unit together with all required clocking and support circuitry.

1210.4.7.4 Memory.

Operational software necessary to meet housekeeping and functional requirements must be provided resident in socketed firmware or internal Flash memory.

1210.4.7.5 Control Signals.

The SIU uses NRESET lines for SIU shut down/turn on operations matching the ATC Controller Unit CPU. The SIU must be fully initialized and providing specified operation upon NRESET Line going HIGH (Power Up). In the ATC Controller, the NRESET operation must cause the SIU program restart. No prior message operation data retention is required. The Request Module Status Response may report this restart as either a Power On or Watchdog. ATC Controller Unit LINESYNC is used as a system time reference. The microprocessor/controller unit is reset by any of the following:

- Pushbutton Reset
- NRESET Signal
- +5 VDC out of regulation
- Microprocessor/controller unit watchdog

1210.4.7.6 Time Reference.

The SIU includes a 1 Kilohertz Time Reference to provide system response time stamps. The 1 Kilohertz Time Reference must maintain a frequency accuracy of +/-0.01% (+/-0.1 counts per second).

1210.4.7.7 Watchdog.

A watchdog circuit must be provided. The SIU must power up with the watchdog enabled. Within the first watchdog time period, the watchdog value must be set to 200 milliseconds +/-100 milliseconds. The watchdog state must be reported in the SIU status byte as an indication that a watchdog has occurred, which will remain until cleared in the Request Module Status command. Failure of the SIU to reset the watchdog timer must result in hardware reset.

1210.4.7.8 Millisecond Counter.

A 32-bit Millisecond Counter must be provided for “time stamping.” Each 1 Kilohertz reference must increment the Millisecond Counter.

1210.4.7.9 Buffers.

A Transition Buffer must be provided capable of holding a minimum of 1024 recorded entries. The Transition Buffer must default to empty. There must be two entry types:
Transition and Rollover. The inputs must be monitored for state transition. At each transition (if the input has been configured to report transition, a transition entry must be added to the Transition Buffer. If multiple inputs change state during one input sample, these transitions must be entered into the Input Transition Buffer by increasing input number. The Millisecond Counter must be monitored for rollover. At each rollover transition ($xxxx FFFF - $xxxx 0000), a rollover entry must be added to the Transition Buffer. For rollover entries, all bits of byte 1 are set to indicate that this is a rollover entry. A new entry must be discarded when storage is not available for the new entry. Transition Buffer blocks are sent to the ATC Controller Unit upon command. Upon confirmation of their reception, the blocks must be removed from the Transition Buffer. The entry types are as follows:

**Input Transition Entry**

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>Isb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition Entry Identifier</td>
<td>S</td>
<td>Input Number (I0 – I59)</td>
<td>1</td>
</tr>
<tr>
<td>Timestamp NLSB</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Timestamp LSB</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

**Millisecond Counter Rollover Entry**

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>Isb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rollover Entry Identifier</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Timestamp MSB</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Timestamp NMSB</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

1210.4.7.10 Power Up Initialization.

At Power Up, the SIU loss of communications timer must indicate loss of communications until the user program sends the Request Module Status message to reset the “E” Bit and a subsequent set output command is processed.

1210.4.7.11 Interrupts.

All interrupts must be capable of asynchronous operation with respect to all processing and all other interrupts. The SIU includes three interrupt sources as follows:

1210.4.7.11.1 MILLISECOND Interrupt.

MILLISECOND Interrupt must be activated by the Time Reference. A timestamp rollover flag set by Millisecond Counter (MC) rollover must be cleared only on command.

1210.4.7.11.2 LINESYNC Interrupt.

The LINESYNC signal must be generated by the controller power supply. LINESYNC Interrupt must be generated by both the 0-1 and 1-0 transitions of the LINESYNC signal. The LINESYNC interrupt must monitor the Millisecond Counter interrupt and set the Millisecond Counter error flag if there has not been an interrupt from the 1 Kilohertz
source for 0.5 seconds (≥60 consecutive LINESYNC interrupts). The LINESYNC interrupt must synchronize the 1 KHz time reference with the 0-1 transition of the LINESYNC signal once a second. A LINESYNC error flag must be set if the LINESYNC interrupt has not successfully executed for 0.5 seconds or longer (≥500 consecutive millisecond interrupts).

1210.4.7.11.3 Line Frequency Reference.

The Line Frequency Reference input pin must receive a square wave signal from the cabinet power supply for the purposes of synchronizing SIU outputs with the AC line. Line Frequency Reference Interrupt must be generated by both the 0-1 and 1-0 transitions of the Line Frequency Reference signal. The Line Frequency Reference interrupt must monitor the Millisecond Counter interrupt and set the Millisecond Counter error flag if there has not been an interrupt from the 1 Kilohertz source for 0.5 seconds (≥60 consecutive Line Frequency Reference interrupts). The Line Frequency Reference interrupt must synchronize the Time Reference with the 0-1 transition of the Line Frequency Reference signal once a second. A Line Frequency Reference error flag must be set if the Line Frequency Reference interrupt has not successfully executed for 0.5 seconds or longer (≥500 consecutive millisecond interrupts). The electrical characteristics of the Line Frequency input are as follows:

1. A voltage between 0 and 8 volts must be considered the LOW state, and must occur when the AC line is in the positive half cycle.
2. A voltage between 16 and 26 volts must be considered the High state, and must occur when the AC line is in the negative half-cycle.
3. The Line Frequency Reference input must exhibit a nominal impedance of 10K (+/- 10%) to the +24 VDC input and must not have more than 1000 picofarads of load capacitance.
4. The rise and fall time of the signal connected to this input must not exceed 50 microseconds.

The SIU/BIU input must be used by the SIU to determine the AC timing source. If the SIU/BIU input is grounded, LINESYNC must be used as the interrupt source. If the SIU/BIU input is pulled up, Line Frequency Reference must be used as the interrupt source.

1210.4.7.11.4 Communication Service Routine.

A low-level communication service routine must be provided to handle reception, transmission, and EIA-485 communication faults. The communication server must automatically:
For Transmission:

- Generate the opening and closing flags
- Generate the CRC value
  
  Generate the abort sequence (minimum of 8 consecutive ‘1’ bits) when commanded by the Microprocessor Unit
- Provide zero bit insertion

For Reception:

- Detect the opening and closing flags
- Provide address comparison, generating an interrupt for messages addressed to the SIU, and ignoring messages not addressed to the SIU
- Strip out inserted zeros
- Calculate the CRC value, compare it to the received value, and generate an interrupt on an error
  
  Generate an interrupt if an abort sequence is received

1210.4.7.12 Communication Processing.

The task must be to process the command messages received from the ATC Controller Unit, prepare, and start response transmission. The response message transmission must begin within 4 milliseconds of the receipt of the received message. The SIU must complete the execution of each command within 70 milliseconds of the end of each response message transmission.

1210.4.7.13 Input Processing.

This task must process the raw input data scanned in by the 1 milliseconds interrupt routine, perform all filtering, and maintain the transition queue entries.

1210.4.7.14 Inputs and Outputs.

The SIU must have four Optically Coupled Inputs, fifty-four Parallel Input/Outputs and four Serial Ports.

1210.4.7.14.1 Optically-Coupled Inputs.

1210.4.7.14.1.1 Opto Common.

The Opto Common input must be the common reference pin for four Opto Inputs.

1210.4.7.14.1.2 Opto Inputs.

The Opto Inputs are intended to provide optical isolation for Pedestrian Detection, internal cabinet functions, Remote Interconnect or other auxiliary inputs. The Opto Inputs are intended to connect through external 27K Ohm, 1-Watt resistors for 120 VAC operations, and are intended for direct connection to 12 VAC for Pedestrian Detector applications. These inputs may also be used for low-true DC applications when the Opto Common pin is connected to -24 VDC. These inputs may function in the place of 242/252 isolator modules.

(1) The Opto Inputs must provide electrical isolation of 10 Megohms minimum resistance and 1000 VAC RMS minimum breakdown to all connector pins except
the Opto Common pin, at a maximum breakdown leakage current of 1 milliamperes RMS.

(2) These inputs must exhibit nominal impedance to the Opto Common pin of 5000 Ohms, +10% to the Opto Common input.

(3) The Opto Inputs must not recognize 3 Volts RMS (AC sinusoid or DC) or less relative to the Opto Common input.

(4) The Opto Inputs must recognize 8 Volts RMS (AC sinusoid or DC) or more relative to the Opto Common input.

(5) Any steady state voltage applied between an Opto Input and the Opto Common must not exceed 35 VAC RMS.

(6) Opto Inputs must not be acknowledged when active for 25 milliseconds or less, and must be acknowledged when active for 50 milliseconds or more.

(7) The opto inputs shall conform to transient immunity specification of section 3.7.5.4.

The first Output Assembly assignments must be dedicated as follows:

<table>
<thead>
<tr>
<th>PIN</th>
<th>1st OUTPUT ASSEMBLY</th>
<th>APPLICABLE HOUSING TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opto Input 1</td>
<td>Manual Control Enable</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opto Input 2</td>
<td>Interval Advance</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opto Input 3</td>
<td>Stop Time</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opto Input 4</td>
<td>Manual Flash</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opto Input Common</td>
<td>AC-</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1210.4.7.14.2 Parallel Inputs and Outputs.

SIU must control fifty-four input/output lines using ground-true logic.

1210.4.7.14.2.1 Input Section.

Each input must be read logic "1" (ON) when the input voltage at its field connector input is less than 8 VDC, and must be read logic "0" (OFF) when the input voltage exceeds 16 VDC. Each input must have an internal pull-up to +24 VDC of 11K Ohms maximum, and must not deliver greater than 10 milliamperes to a short circuit to ground.

1210.4.7.14.2.2 Output Section.

Each output written as a logic "1" (ON) must have a voltage at its field connector output of less than 4.0 VDC. Each output written as logic "0" (OFF) must provide an open circuit (1 Megohm or more) at its field connector output. Each output must consist of an open-collector capable of driving 40 VDC minimum and sinking 100 milliamperes.
minimum. Each output circuit must be capable of switching from logic "1" to logic "0"
within 100 microseconds when connected to a load of 100K Ohms minimum. Each
output circuit must be protected from transients of 10 microseconds (+/-2 microseconds)
duration, +/-300 VDC from a 1K Ohm source, with a maximum rate of 1 pulse per
second. Each output must latch the data written and remain stable until either new data
is written or the active-low reset signal. Upon an active-low reset signal, each output
must latch a logic "0" and retain that state until a new writing. The state of all output
circuits at the time of Power Up or in Power Down state must be OFF. It must be
possible to simultaneously assert all outputs within 100 microseconds of each other. An
output circuit state not changed during a new writing must not glitch when other output
circuits are updated.

1210.4.7.14.3 Input/Output Function.

Each parallel Input/Output function contains all of the functions listed below of both the
Input Function and Output Function.

1210.4.7.14.4 Input Section Function.

Input scanning must begin at I0 (bit 0) and proceed to the highest numbered input,
ascending from LSB to MSB. Each complete input scan must finish within 100
microseconds. Once sampled, the logic state of an input must be held until the next
input scan. Each input must be sampled 1,000 times per second. The time interval
between samples must be 1 millisecond (+/-100 microseconds). The Millisecond
Counter must be sampled within 10 microseconds of the completion of the input scan.

1210.4.7.14.5 Input Data Filtering.

If configured, the inputs must be filtered by the SIU to remove signal bounce. The
filtered input signals must then be monitored for changes as noted. The filtering
parameters for each input must consist of Ignore Input Flag and the ON and OFF filter
samples. If the Ignore Input flag is set, no input transition entries must be placed into
the Input Transition buffer. The ON and OFF filter samples must determine the number
of consecutive samples an input must be ON and OFF, respectively, before a change of
state is recognized. If the change of state is shorter than the specified value, the
change of state must be ignored. The ON and OFF filter values must be in the range of
0 to 255. A filter value of 0, for either or both values, must result in no filtering for this
input. The default values for input signals after reset must be as follows:

<table>
<thead>
<tr>
<th>Filtering:</th>
<th>Enabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>On and off filter values must be set to:</td>
<td>5</td>
</tr>
<tr>
<td>Transition monitoring:</td>
<td>Disabled (Timestamps are not logged)</td>
</tr>
</tbody>
</table>

1210.4.7.14.6 Output Function.

Simultaneous assertion of all outputs must occur within 100 microseconds. Each output
must be capable of being individually configured in state to ON, OFF, or a state
synchronized with either phase of LINESYNC. The condition of the outputs must only
be "ON" if the SIU continues to receive active communications from the ATC Controller
Unit. If there is no valid communications with the ATC Controller Unit for 2.0 seconds, all outputs must revert to the OFF condition, and the SIU status byte must be updated to reflect the loss of communication from the ATC Controller Unit. The data and control bits in the ATC Controller Unit-SIU frame protocol must control each output as follows:

**Output Bit Translation**

<table>
<thead>
<tr>
<th>Case</th>
<th>Output Data Bit</th>
<th>Output Control Bit</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
<td>Output in the OFF state</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>1</td>
<td>Output is a square wave, synchronized to the LINESYNC signal. When LINESYNC is ON (1), the output is OFF, and when LINESYNC is OFF (0), the output is ON.</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>1</td>
<td>Output is a square wave, synchronized to the LINESYNC signal. When LINESYNC is ON (1), the output is ON, and when LINESYNC is OFF (0), the output is OFF</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>0</td>
<td>Output is in the ON state.</td>
</tr>
</tbody>
</table>

In Case A above, the corresponding output must be turned OFF if previously ON and if previously OFF remain OFF until otherwise configured. For half-cycle switching (cases B and C), all outputs to be changed must be changed within 50 microseconds after the corresponding LINESYNC transition and must remain in the same state during the entire half cycle. In Case D above, the corresponding output must be turned ON if previously OFF and if previously ON remain ON until otherwise configured. All outputs must never change state unless configured to do so.

1210.4.7.14.7 Serial Ports.

The SIU must have a minimum of four serial ports, identified as SIU Ports 1-4. Serial Ports 1 and 3 are connected to the SIU microprocessor/controller unit, while Serial Ports 2 and 4 provide a buffered communications path from the ATC Controller Unit to the detectors, and are not connected to the microprocessor/controller unit. Communications circuitry must be capable of 614.4 Kilobits per second of data pass through.

1210.4.7.14.7.1 SIU Port 1 Operation.

Port 1 must interface the SIU to Serial Bus 1 of the ITS cabinet Modular Bus Assemblies. All communications circuitry and protocol must match Serial Bus 1 requirements. The SIU must function as the “LOCAL” command node for this network responding with appropriate action. See ATC Controller Unit specification, CPU Field I/O, for protocol and requirements. The SP5 SDLC frame address assignments (Command/Responses) are as follows:
<table>
<thead>
<tr>
<th>Address</th>
<th>SYSTEM ASSEMBLY / UNIT</th>
<th>SIU ADDRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A7</td>
</tr>
<tr>
<td>0</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>14 Pack in position 1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>14 Pack in position 3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>6 Pack in position 4</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>6 Pack in position 1</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>6 Pack in position 2</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>6 Pack in position 3</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Input #1</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>Input #2</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>Input #3</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Input #4</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>Input #5</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>CMU #1</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>CMU #2</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>CMU #3</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>CMU #4</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>CPU</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>FI/O 2A or 8</td>
<td>0</td>
</tr>
<tr>
<td>21 to</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>254</td>
<td>reserved</td>
<td></td>
</tr>
<tr>
<td>255</td>
<td>Broadcast All</td>
<td>1</td>
</tr>
</tbody>
</table>

Note 1: A0 to A3 are Input to SIU with DC ground as common.

Note 2: 0 = open or ground false. 1= closed or ground true (shunted)

1210.4.7.14.7.2 OMIT

1210.4.7.14.7.3 SIU Port 2 Operation.

SIU Port 2 must interface to Serial Bus 2 of the ITS cabinet Modular Bus Assemblies providing a communications path to the ATC Controller Unit for block data retrieval. No connection exists between SIU Port 1 and SIU Port 2. Similarly, no connection exists between SIU Port 2 and the microprocessor/controller unit. All data transfers between SIU Ports 1 and 2 must be accomplished by the ATC Controller Unit. For example, data sent back may include monitor diagnostic status and communication status; input
diagnostics status (detector sensor or isolator); and processed channel inputs data such as rate counts, occupancies, average speeds, speed classification and incident/presence.

1210.4.7.14.7.3.1 Synchronous Operation.

If the ATC Controller Unit is communicating via Logical Port SP3S, SIU Port 2 must communicate in SDLC format and protocol, and the hardware requirements must match Serial Bus 2 (synchronous TX/RX using TxC from the ATC Controller Unit CPU for common clocking).

1210.4.7.14.7.3.2 Asynchronous Operation.

If the ATC Controller Unit is communicating via Logical Port SP3, SIU Port 2 must communicate in an asynchronous START BIT/STOP BIT format and protocol.

1210.4.7.14.7.4 SIU Port 3 Operation.

The SIU Port 3 must be provided for communication to a personal computer via a front panel 9-position subminiature D-type connector and EIA-232 logic. Its purpose is to upload diagnostic information, and to download the SIU program. The SIU Port 3 protocol must be defined by the vendor, and operate with vendor-supplied software. The pin assignments of SIU Port 3 must match that of ATC Controller Unit C60 port.

1210.4.7.14.7.5 SIU Port 4 Operation.

SIU Port 4 consists of Detector Rack signal INBUS TxD, INBUS RxD, INBUS TxC, and INBUS RxC, and must conform to the electrical standards of EIA-485, single-ended. In this scheme, the RxD- and RxC- inputs of the EIA-485 receivers are connected to 2.5 Volts, while the TxD- and TxC- outputs of the EIA-485 drivers are not used. SIU Port 4 receivers must withstand +/-25 Volts, suitable for reception of EIA-232 bipolar signals. All four INBUS signals must be terminated at each receiver with impedance of 6,800 Ohms (+/-5%), connected from signal to +5V Ground on the SIU. The detector vendor must define the SIU Port 4 messages. The detector vendor must define the SIU Port 4 protocol. The SIU provides one inversion to ensure a controller MARK equates to a detector MARK. The SIU must provide an LED indicator for TxD and RxD, such that is illuminated during a MARK (START Bit, for example) and extinguished during a SPACE (STOP Bit, for example). SIU Port 4 provides the buffering to SIU Port 2, allowing the ATC Controller Unit to communicate directly to the detectors, as follows:

1210.4.7.14.5.1 Synchronous Operation.

If the ATC Controller Unit is communicating to detectors via Logical Port SP3S, the SIU Port 4 buffers must convert SIU Port 2 TxD+ and TxD- to EIA-485 which must then be transmitted to the detectors via INBUS TxD. Likewise, the SIU Port 4 buffers must convert SIU Port 2 TxC+ and TxC- to EIA-485, which must then be transmitted to the detectors via INBUS TxC.

If the ATC Controller Unit is communicating to detectors via Logical Port SP3S, the SIU Port 4 buffers must convert INBUS RxD from EIA-485, which must then be transmitted to the ATC Controller Unit via SIU Port 2 RxD+ and RxD-. Likewise, the SIU Port 4 buffers must convert INBUS RxC from EIA-485, which must then be transmitted to the ATC Controller Unit via SIU Port 2 RxC+ and RxC-.
1210.4.7.14.7.5.2 Asynchronous Operation.

If the ATC Controller Unit is communicating to detectors via Logical Port SP3, the SIU Port 4 buffers must convert SIU Port 2 TxD+ and TxD- to EIA-485 which must be transmitted to the detectors via INBUS TxD.

If the ATC Controller Unit is communicating to detectors via Logical Port SP3, the SIU Port 4 buffers must convert INBUS RxD is from EIA-485, which must be transmitted to the ATC Controller Unit via SIU Port 2 RxD+ and RxD-.

Asynchronous operation must not use Port 2 TxC+, TxC-, RxC+, RxC-, nor Port 4 INBUS TxC, or INBUS RxC.

1210.4.7.14.7.8.3 Assembly Address Output.

The SIU must sense the rack address block and generate a square wave on the ASSEMBLY ADDRESS signal as follows:

<table>
<thead>
<tr>
<th>ASSEMBLY ADDRESS</th>
<th>ASSEMBLY ADDRESS FREQUENCY (Hertz)(+/-15%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>7.5</td>
</tr>
<tr>
<td>5</td>
<td>3.75</td>
</tr>
</tbody>
</table>

1210.4.7.14.7.5.4 INBUS RTS Input.

The INBUS RTS line must be pulled to +24 Volts via a 10K Ohm resistor on the SIU. In systems using legacy detectors that do not use INBUS RTS, this line must not be used (no connection). Detectors equipped with INBUS RTS must drive this line low when transmitting data from that detector to the SIU via INBUS. When not transmitting data, this line must not be driven low and is pulled to +24V via the 10K Ohm resistor.

1210.4.7.14.7.5.5 Serial Bus 2 Control.

The controller transmits a message on Serial Bus 2 which must be received by each detector via the SIU INBUS TxD and INBUS TxC. If the detector is asynchronous, INBUS TxC must be ignored. Each detector must compare the address field of the message with its own slot address and assembly address. If the address matches, that detector must respond with data on INBUS RxD and INBUS RxC. If the detector is asynchronous, INBUS RxC must not be used. The SIU of the responding detector must enable its EIA-485 line drivers to transmit the response from INBUS to SB2. This driver must be enabled by any of the three following conditions:

- Activity on INBUS RxD
- Activity on INBUS RxC
- INBUS RTS at low (true)
This driver must be disabled by either of the following two conditions:

- Lack of activity on both INBUS RxD and RxC for 1.5 milliseconds
- Inbus RTS transitions from low (true) to high (false)

1210.4.7.15 Data Communications Protocol.

All communication with the ATC Controller Unit must be SDLC-compatible command-response protocol, support 0-bit stuffing, and operate at a data rate of 614.4 Kilobits per second. The ATC Controller Unit must always initiate the communication and should the command frame be incomplete or in error, no SIU response must be transmitted.

There is no requirement for a command message queue that results in a response stream of messages. An incoming command message may abort a planned or truncate a response already in progress.

Command frame errors shall include microprocessor identified abnormalities, such as CRC errors, bit alignment, or bit stuffing problems. Message irregularities shall include unknown message numbers or improper command lengths.
1210.4.7.15.1 Frame Type.

The frame type must be determined by the value of the first byte of the message. The command frames type values $70 - $7F and associated response frame type values $F0 - $FF are allocated to the Manufacturer diagnostics. All other frame types not called out are reserved. The command-response Frame Type values and message times must be as follows:

**Frame Types**

<table>
<thead>
<tr>
<th>Module Command</th>
<th>I/O Module Response</th>
<th>Description</th>
<th>Minimum Message Time</th>
<th>Maximum Message Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td>177</td>
<td>Request Module Status</td>
<td>250 microseconds</td>
<td>275 microseconds</td>
</tr>
<tr>
<td>50</td>
<td>178</td>
<td>MILLISECOND CTR. Mgmt.</td>
<td>222.5 microseconds</td>
<td>237.5 microseconds</td>
</tr>
<tr>
<td>51</td>
<td>179</td>
<td>Configure Inputs</td>
<td>344.5 microseconds</td>
<td>6.8750 milliseconds</td>
</tr>
<tr>
<td>52</td>
<td>180</td>
<td>Poll Raw Input Data</td>
<td>317.5 microseconds</td>
<td>320 microseconds</td>
</tr>
<tr>
<td>53</td>
<td>181</td>
<td>Poll Filtered Input Data</td>
<td>317.5 microseconds</td>
<td>320 microseconds</td>
</tr>
<tr>
<td>54</td>
<td>182</td>
<td>Poll Input Transition Buffer</td>
<td>300 microseconds</td>
<td>10.25 milliseconds</td>
</tr>
<tr>
<td>55</td>
<td>183</td>
<td>Command Outputs</td>
<td>405 microseconds</td>
<td>410 microseconds</td>
</tr>
<tr>
<td>56</td>
<td>184</td>
<td>Config. Input Tracking Functions</td>
<td>340 microseconds</td>
<td>10.25 milliseconds</td>
</tr>
<tr>
<td>57</td>
<td>185</td>
<td>Config. Complex Output Functions</td>
<td>340 microseconds</td>
<td>6.8750 milliseconds</td>
</tr>
<tr>
<td>58</td>
<td>186</td>
<td>Reserved</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>59</td>
<td>187</td>
<td>Reserved</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>60</td>
<td>188</td>
<td>SIU Identification</td>
<td>222.5 microseconds</td>
<td>222.5 microseconds</td>
</tr>
<tr>
<td>61-62</td>
<td>189-190</td>
<td>Reserved (note below)</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>63</td>
<td>191</td>
<td>Reserved</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>64</td>
<td>192</td>
<td>Reserved</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>65</td>
<td>193</td>
<td>Reserved (note below)</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>66</td>
<td>---</td>
<td>Reserved (note below)</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>67</td>
<td>195</td>
<td>Reserved (note below)</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

Messages 61/189, 62/190, 65/193, and 67/195 must be for ITS Cabinet Monitor Unit. See ITS Cabinet Monitor System Serial Bus #1 for Command and Response Frames. Message 66/No Response is a Broadcast Message to Address 255 containing the current time. Any device may receive and process this message if it has the software capacity.
1210.4.7.15.2 Request Module Status.

The Command must be used to request SIU status information response. Command/Response frames must be as follows:

**Request Module Status Command**

<table>
<thead>
<tr>
<th>Description</th>
<th>ms b</th>
<th>Isb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 49)</td>
<td>0 0 1 1 0 0 1</td>
<td></td>
<td>Byte 1</td>
</tr>
<tr>
<td>Reset Status Bits</td>
<td>P E K R T M L W</td>
<td></td>
<td>Byte 2</td>
</tr>
</tbody>
</table>

**Request Module Status Response**

<table>
<thead>
<tr>
<th>Description</th>
<th>ms b</th>
<th>Isb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 177)</td>
<td>1 0 1 1 0 0 1</td>
<td></td>
<td>Byte 1</td>
</tr>
<tr>
<td>System Status</td>
<td>P E K R T M L W</td>
<td></td>
<td>Byte 2</td>
</tr>
<tr>
<td>SCC Receive Error Count</td>
<td>Receive Error Count</td>
<td></td>
<td>Byte 3</td>
</tr>
<tr>
<td>SCC Transmit Error Count</td>
<td>Transmit Error Count</td>
<td></td>
<td>Byte 4</td>
</tr>
<tr>
<td>MC Timestamp MSB</td>
<td>MC Timestamp MSB</td>
<td></td>
<td>Byte 5</td>
</tr>
<tr>
<td>MC Timestamp NMSB</td>
<td>MC Timestamp NMSB</td>
<td></td>
<td>Byte 6</td>
</tr>
<tr>
<td>MC Timestamp NLSB</td>
<td>MC Timestamp NLSB</td>
<td></td>
<td>Byte 7</td>
</tr>
<tr>
<td>MC Timestamp LSB</td>
<td>MC Timestamp LSB</td>
<td></td>
<td>Byte 8</td>
</tr>
</tbody>
</table>

The response status bits are defined as follows:

- P - Indicates SIU hardware reset
- E - Indicates a communications loss of greater than 2 seconds
- M - Indicates an error with the Millisecond Counter interrupt
- L - Indicates an error in the LINESYNC
- W - Indicates that the SIU has been reset by the Watchdog
- R - Indicates that the EIA-485 receive error count byte has rolled over
- T - Indicates that the EIA-485 transmit error count byte has rolled over
- K - Not Used

Each of these bits must be individually reset by a '1' in the corresponding bit of any subsequent Request Module Status frame, and the response frame must report the current status bits. The SCC error count bytes must not be reset. When a count rolls over (255 - 0), its corresponding roll-over flag must be set.

1210.4.7.15.3 Millisecond Counter Management.

The Millisecond Counter Management Frame must be used to set the value of the Millisecond Counter. The 'S' bit must return status '0' on completion or '1' on error. The 32-bit value must be loaded into the Millisecond Counter at the next 0-1 transition of the LINESYNC signal. The frames must be as follows:
Millisecond Counter Management Command

<table>
<thead>
<tr>
<th>Description</th>
<th>ms</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 50)</td>
<td>0</td>
<td>0</td>
<td>0 1 1 0 0 1 0</td>
</tr>
<tr>
<td>New MC Timestamp MSB</td>
<td>x</td>
<td>x</td>
<td>x x x x x x x x</td>
</tr>
<tr>
<td>New MC Timestamp NMSB</td>
<td>x</td>
<td>x</td>
<td>x x x x x x x x</td>
</tr>
<tr>
<td>New MC Timestamp NLSB</td>
<td>x</td>
<td>x</td>
<td>x x x x x x x x</td>
</tr>
<tr>
<td>New MC Timestamp LSB</td>
<td>x</td>
<td>x</td>
<td>x x x x x x x x</td>
</tr>
</tbody>
</table>

Millisecond Counter Management Response

<table>
<thead>
<tr>
<th>Description</th>
<th>ms</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 178)</td>
<td>1</td>
<td>0</td>
<td>0 1 1 0 0 1 0</td>
</tr>
<tr>
<td>Status</td>
<td>0</td>
<td>0</td>
<td>0 0 0 0 0 0 S</td>
</tr>
</tbody>
</table>

1210.4.7.15.4 Configure Inputs.

The Configure Inputs command frame must be used to change input configurations. The command-response frames must be as follows:

Configure Inputs Command

<table>
<thead>
<tr>
<th>Description</th>
<th>ms</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 51)</td>
<td>0</td>
<td>0</td>
<td>0 1 1 0 0 1 1</td>
</tr>
<tr>
<td>Number of Items (n)</td>
<td>n</td>
<td>n</td>
<td>n n n n n n n n</td>
</tr>
<tr>
<td>Item # - Byte 1</td>
<td>E</td>
<td></td>
<td>Input Number (I0 – I59)</td>
</tr>
<tr>
<td>Item # - Byte 2</td>
<td></td>
<td></td>
<td>Leading edge filter (e)</td>
</tr>
<tr>
<td>Item # - Byte 3</td>
<td></td>
<td></td>
<td>Trailing edge filter (r)</td>
</tr>
</tbody>
</table>

NOTE: In the case of an invalid parameter error, the entire message must be rejected.

Configure Inputs Response

<table>
<thead>
<tr>
<th>Description</th>
<th>ms</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 179)</td>
<td>1</td>
<td>0</td>
<td>0 1 1 0 0 1 1</td>
</tr>
<tr>
<td>Status</td>
<td>0</td>
<td>0</td>
<td>0 0 0 0 0 0 S</td>
</tr>
</tbody>
</table>

Block field definitions must be as follows:

E - Ignore Input Flag. "1" = do not record transition entries for this input, "0" = record transition entries for this input

e - A one-byte leading edge filter specifying the number of consecutive input samples which must be "0" before the input is considered to have entered to "0" state from "1" state (range 1 to 255, 0 = filtering disabled)
A one-byte trailing edge filter specifying the number of consecutive input samples which must be "1" before the input is considered to have entered to "1" state from "0" state (range 1 to 255, 0 = filtering disabled)

S - return status S = '0' on completion or '1' on error

1210.4.7.15.5 Poll Raw Input Data.

The Poll Raw Input Data frame must be used to poll the SIU for the current unfiltered status of all inputs. The response frame must contain 8 bytes (Inputs 0-63) of information indicating the current input status. The frames must be as follows:

**Poll Raw Input Data Command**

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 52)</td>
<td>0 0 1 1 0 1 0 0</td>
<td></td>
<td>Byte 1</td>
</tr>
</tbody>
</table>

**Poll Raw Input Data Response**

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 180)</td>
<td>1 0 1 1 0 1 0 0</td>
<td></td>
<td>Byte 1</td>
</tr>
<tr>
<td>Inputs I0 (lsb) to I7 (msb)</td>
<td>x x x x x x x</td>
<td></td>
<td>Byte 2</td>
</tr>
<tr>
<td>Inputs I8 to I53, I56 to I59</td>
<td>x x x x x x x</td>
<td></td>
<td>Bytes 3 to 9</td>
</tr>
<tr>
<td>MC Timestamp MSB</td>
<td>x x x x x x x</td>
<td></td>
<td>Byte 10</td>
</tr>
<tr>
<td>MC Timestamp NMSB</td>
<td>x x x x x x x</td>
<td></td>
<td>Byte 11</td>
</tr>
<tr>
<td>MC Timestamp NLSB</td>
<td>x x x x x x x</td>
<td></td>
<td>Byte 12</td>
</tr>
<tr>
<td>MC Timestamp LSB</td>
<td>x x x x x x x</td>
<td></td>
<td>Byte 13</td>
</tr>
</tbody>
</table>

1210.4.7.15.6 Poll Filtered Input Data.

The Poll Filtered Input Data frame must be used to poll the SIU for the current filtered status of all inputs. The response frame must contain 8 bytes (Inputs 0-63) of information indicating the current filtered status of the inputs. Raw input data must be provided in the response for inputs that are not configured for filtering. The frames must be as follows:

**Poll Filter Input Data Command**

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 53)</td>
<td>0 0 1 1 0 1 0 1</td>
<td></td>
<td>Byte 1</td>
</tr>
</tbody>
</table>

**Poll Filter Input Data Response**

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 181)</td>
<td>1 0 1 1 0 1 0 1</td>
<td></td>
<td>Byte 1</td>
</tr>
<tr>
<td>Inputs I0 (lsb) to I7 (msb)</td>
<td>x x x x x x x</td>
<td></td>
<td>Byte 2</td>
</tr>
<tr>
<td>Inputs I8 to I53, I56 to I59</td>
<td>x x x x x x x</td>
<td></td>
<td>Bytes 3 to 9</td>
</tr>
<tr>
<td>MC Timestamp MSB</td>
<td>x x x x x x x</td>
<td></td>
<td>Byte 10</td>
</tr>
<tr>
<td>MC Timestamp NMSB</td>
<td>x x x x x x x</td>
<td></td>
<td>Byte 11</td>
</tr>
</tbody>
</table>
1210.4.7.15.7 Poll Input Transition Buffer.

The Poll Input Transition Buffer frame must poll the SIU for the contents of the input transition buffer. The response frame must include a three-byte information field for each of the input changes that have occurred since the last interrogation. The frames are as follows:

### Poll Input Transition Buffer Command

<table>
<thead>
<tr>
<th>Description</th>
<th>ms b</th>
<th>ls b</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 54)</td>
<td>0 0 1 1 0 1 1 0</td>
<td>Byte 1</td>
<td></td>
</tr>
<tr>
<td>Block Number</td>
<td>x x x x x x x x</td>
<td>Byte 2</td>
<td></td>
</tr>
</tbody>
</table>

### Poll Input Transition Buffer Response

<table>
<thead>
<tr>
<th>Description</th>
<th>ms b</th>
<th>ls b</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 182)</td>
<td>1 0 1 1 0 1 1 0</td>
<td>Byte 1</td>
<td></td>
</tr>
<tr>
<td>Block Number</td>
<td>x x x x x x x x</td>
<td>Byte 2</td>
<td></td>
</tr>
<tr>
<td>Number of Entries = N</td>
<td>x x x x x x x x</td>
<td>Byte 3</td>
<td></td>
</tr>
<tr>
<td>Item #</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item # MC Timestamp NLSB</td>
<td>x x x x x x x x</td>
<td>Byte 3(I-1)+4</td>
<td></td>
</tr>
<tr>
<td>Item # MC Timestamp LSB</td>
<td>x x x x x x x x</td>
<td>Byte 3(I-1)+5</td>
<td></td>
</tr>
<tr>
<td>Status</td>
<td>0 0 0 0 C F E G</td>
<td>Byte 3(I-1)+6</td>
<td></td>
</tr>
<tr>
<td>MC Timestamp MSB</td>
<td>x x x x x x x x</td>
<td>Byte 3(I-1)+7</td>
<td></td>
</tr>
<tr>
<td>MC Timestamp NMSB</td>
<td>x x x x x x x x</td>
<td>Byte 3(N-1)+8</td>
<td></td>
</tr>
<tr>
<td>MC Timestamp NLSB</td>
<td>x x x x x x x x</td>
<td>Byte 3(N-1)+9</td>
<td></td>
</tr>
<tr>
<td>MC Timestamp LSB</td>
<td>x x x x x x x x</td>
<td>Byte 3(N-1)+10</td>
<td></td>
</tr>
<tr>
<td>MC Timestamp LSB</td>
<td>x x x x x x x x</td>
<td>Byte 3(N-1)+11</td>
<td></td>
</tr>
</tbody>
</table>

Each detected state transition for each active input is placed in the queue as it occurs. Bit definitions are as follows:

- **S** - Indicates the state of the input after the transition, bit is 1 if the Input is ON after the transition, bit is 0 if the Input is OFF after the transition
- **C** - Indicates the 255 entry buffer limit has been exceeded
- **F** - Indicates the 1024 buffer limit has been exceeded
- **G** - Indicates the requested block number is out of monotonic increment sequence
- **E** - Same block number requested, E is set in response

The entries provided within the Transition Buffer Poll response must be ordered from the start of the reply as the oldest to newest. The very first access provides the oldest
entry. The SIU device must initialize, upon Power Up or Reset, its last Block Number received value to 0xFF in order to facilitate suppression of the G Bit response when the ATC Controller Unit program starts and uses 0x00 as the first Block Number. Subsequent responses are subject to the old-buffer purge mechanism stated below.

The ATC Controller Unit program monotonically increases the Block Number after each command issued to purge the old buffer. When the SIU Module receives this command, it must compare the associated Block Number with the Block Number of the previously received command. If it is the same, the previous buffer must be re-sent to the ATC Controller Unit and the 'E' flag set in the status response frame. If it is not equal to the previous Block Number, the old buffer must be purged and the next block of data sent. If the block number is not incremented by one, the status G bit must be set. The block number received becomes the current number (even if out of sequence). The Block Number byte sent in the response block must be the same as that received in the command block. The Block Number counter rollover (0xFF becomes 0x00) must be considered as a normal increment.

1210.4.7.15.8 Set Outputs.

The Set Outputs frame must be used to command the SIU to set the Outputs according to the data in the frame. If there is any error configuring the outputs, the 'E' flag in the response frame must be set to '1'. If the LINESYNC reference has been lost, the 'L' bit in the response frame must be set. Loss of LINESYNC reference must also be indicated in system status information. These command and response frames are as follows:

### Set Outputs Command

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 55)</td>
<td>0</td>
<td>1</td>
<td>1 1 1 0</td>
</tr>
<tr>
<td>Outputs O0 (lsb) to O7 (msb) Data</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>Outputs O8 to O54 Data</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>Outputs O56 to O63 Data (reserved)</td>
<td>0</td>
<td>0</td>
<td>0 0 0 0</td>
</tr>
<tr>
<td>Outputs O0 (lsb) to O7 (msb) Control</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>Outputs O8 to O54 Control</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>Outputs O56 to O63 Control (reserved)</td>
<td>0</td>
<td>0</td>
<td>0 0 0 0</td>
</tr>
</tbody>
</table>

### Set Outputs Response

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 183)</td>
<td>1</td>
<td>0</td>
<td>1 1 0 1</td>
</tr>
<tr>
<td>Status</td>
<td>0</td>
<td>0</td>
<td>0 0 0 L</td>
</tr>
</tbody>
</table>
1210.4.7.15.9 Configure Input Tracking Functions.

The Configure Input Tracking Functions frame must be used to configure the definition for an output that responds to transitions on a particular input. The maximum number of active definitions is 8. Refer to ‘Tracking Functions Overview’ for additional details.

Please note that Configure Input Tracking Functions is not intended for use with Traffic Signal Control Applications. (Authorized Engineering Information)

1210.4.7.15.9.1 Command and Response Frames.

The command and response frames for Input Tracking Functions must be as follows:

**Configure Input Tracking Functions Command**

<table>
<thead>
<tr>
<th>Description</th>
<th>ms b</th>
<th>Isb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 56)</td>
<td>0 0 1 1 1 0 0 0</td>
<td></td>
<td>Byte 1</td>
</tr>
<tr>
<td>Number of Items</td>
<td>Number of Items</td>
<td></td>
<td>Byte 2</td>
</tr>
<tr>
<td>Item # - Byte 1</td>
<td>E</td>
<td>Output Number (O0 – O054)</td>
<td>Byte 2(I-1)+3</td>
</tr>
<tr>
<td>Item # - Byte 2</td>
<td>I</td>
<td>Input Number (I0 – I59)</td>
<td>Byte 2(I-1)+4</td>
</tr>
</tbody>
</table>

Number of Items: 0-16 Tracking Definitions are contained in this message.

**Field Definitions:**
- **E** ‘1’ - Enable Input Tracking function for this Output
  - ‘0’ - Remove Input Tracking function for this Output
- **I** ‘1’ - Output is OFF when Input is ON, ON when Input OFF
  - ‘0’ - Output is ON when Input is ON, OFF when Input is OFF

Output Number: 0 - Maximum Output Number for the SIU device type.
Input Number: 0 - Maximum Input Number for the SIU device type.

**Configure Input Tracking Functions Response**

<table>
<thead>
<tr>
<th>Description</th>
<th>ms b</th>
<th>Isb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 184)</td>
<td>1 0 1 1 0 0 0</td>
<td></td>
<td>Byte 1</td>
</tr>
<tr>
<td>Status</td>
<td></td>
<td></td>
<td>Byte 2</td>
</tr>
<tr>
<td>MC Timestamp MSB</td>
<td>x x x x x x x</td>
<td>V</td>
<td>Byte 3</td>
</tr>
<tr>
<td>MC Timestamp NMSB</td>
<td>x x x x x x x</td>
<td></td>
<td>Byte 4</td>
</tr>
<tr>
<td>MC Timestamp NLSB</td>
<td>x x x x x x x</td>
<td></td>
<td>Byte 5</td>
</tr>
<tr>
<td>MC Timestamp LSB</td>
<td>x x x x x x x</td>
<td></td>
<td>Byte 6</td>
</tr>
</tbody>
</table>

**Field Definitions:**
- **V** ‘1’ - Maximum number of configurable outputs will be exceeded.
  - ‘0’ - No error
1210.4.7.15.9.2  Timestamp.

The timestamp value must be sampled prior to the response frame.

1210.4.7.15.9.3  Output Updates.

Outputs, which track inputs, must be updated no less than once per millisecond. Input to output signal propagation delay must not exceed 2 milliseconds.

1210.4.7.15.9.4  Tracking Functions Overview.

A maximum of eight different Output numbers may be activated by specifying eight definitions.

One complete definition for an Output that tracks an Input consists of two bytes containing four parameters: 1) the instruction to install or to remove the definition, 2) the Output Number, 3) the relationship of the state of the Output to the Input and 4) the Input Number.

Each definition specifies the controlling Input number for that unique output number. More than one output definition may specify the same Input controlling source. [That is, the same input may be used as the control source for more than one Tracking Output.]

A complete definition is called an Item in the Command Message frame. The ‘Number of Items’ byte specifies the quantity of complete definitions contained in the Command Frame. If the value is 0, all existing active Input Tracking definitions must be removed.

The transmission of a definition may:

(1) install a new active Tracking definition.

(2) remove an existing active Tracking definition. When an Input Tracking definition is removed, the output is set according to the most recently received Set Outputs Command.

(3) convert an active output definition from Complex or Square Wave definition to Tracking. Conversion removes the existing definition and assigns the Tracking definition without a transition through the ‘output is set according to the most recently received Set Outputs Command’ state. The most recent state of the output remains until the new function changes it.

(4) redefine an existing Tracking definition.

If a command frame to be processed by the SIU would result in having more than the maximum number (8) of definitions activated, the entire command frame must be rejected. The response V bit must be set to 1.

The V bit response is based on counting the current active quantity plus the projected Enable definitions after accounting for Remove definitions and invalid Output numbers.
The V bit response evaluation takes the currently active definition quantity, adds the projected Enable definitions, subtracts the Remove definitions, ignores invalid Input and Output numbers and compares the result to the Maximum Number of active Tracking definitions allowed. If the quantity of Active definitions would become greater than the Maximum Number of active Tracking definitions, or if there are more Remove definitions than existing active definitions, the V Bit must be set in the response.

While processing an Enable request, an Out of Range Input number must preclude processing for that definition.

The Out of Range Output and Input numbers must not affect the active definition count. No error response is returned.

The rest of the message must be processed.

The “Number of Items” field is valid from 0 to 16 because the longest message may contain 8 Enable and 8 Remove definitions.

The Input state always comes from the Filtered Input Data source.

Valid Input and Output Number Ranges:

ITS SIU device types: Inputs 0 - 53 & 56 - 59, Outputs 0 – 54

1210.4.7.15.10 Configure Complex Output Functions.

The Configure Complex Output Functions frame must be used to configure the definition for an output that provides a complex operation. The maximum number of active definitions is 8. Refer to ‘Complex Output Functions Overview’ for additional details.

Please note that Configure Complex Output Functions is not intended for use with Traffic Signal Control Applications. (Authorized Engineering Information)

1210.4.7.15.10.1 Command and Response Frames.

The command and response frames must be as follows:

Configure Complex Output Functions Command

<table>
<thead>
<tr>
<th>Description</th>
<th>ms</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 57)</td>
<td>0 0 1 1 1 0 0 1</td>
<td></td>
<td>Byte 1</td>
</tr>
<tr>
<td>Number of Items</td>
<td>Number of Items</td>
<td></td>
<td>Byte 2</td>
</tr>
<tr>
<td>Item # - Byte 1</td>
<td>0</td>
<td>Output Number (O0 – O54)</td>
<td>Byte 7(I-1)+3</td>
</tr>
<tr>
<td>Item # - Byte 2</td>
<td></td>
<td>Primary Duration (MSB)</td>
<td>Byte 7(I-1)+4</td>
</tr>
<tr>
<td>Item # - Byte 3</td>
<td></td>
<td>Primary Duration (LSB)</td>
<td>Byte 7(I-1)+5</td>
</tr>
<tr>
<td>Item # - Byte 4</td>
<td></td>
<td>Secondary Duration (MSB)</td>
<td>Byte 7(I-1)+6</td>
</tr>
<tr>
<td>Item # - Byte 5</td>
<td></td>
<td>Secondary Duration (LSB)</td>
<td>Byte 7(I-1)+7</td>
</tr>
<tr>
<td>Item # - Byte 6</td>
<td>0</td>
<td>Input Number (I0 – I59)</td>
<td>Byte 7(I-1)+8</td>
</tr>
<tr>
<td>Item # - Byte 7</td>
<td>P W G E J F R L</td>
<td></td>
<td>Byte 7(I-1)+9</td>
</tr>
</tbody>
</table>
Number of Items: 0-16 Complex Output Definitions are contained in this message.

Output Number: 0 - Maximum Output Number for the SIU device type.

Primary Duration: MSB & LSB form a 16 bit Hex numerical value 0x0000 - 0xffff.

Secondary Duration: MSB & LSB form a 16 bit Hex numerical value 0x0000 - 0xffff.

Input Number: 0 - Maximum Input Number for the SIU device type.

Field Definitions:

P '1' - The output is configured for single-pulse operation. Once complete, the complex output function must be disabled.
    '0' - The output is configured for continuous oscillation.

W '1' - It is triggered by the specified input. Triggered complex output must commence within 2 milliseconds of the associated trigger recognition.
    '0' - Operation must begin within 2 milliseconds of the command receipt.

G '1' - Operation must be gated active by the specified input.
    '0' - Gating is inactive.

E '1' - Enable complex output function for this output
    '0' - Remove complex output function for this output

J '1' - During primary duration, the output must be written as a logic '1'. During secondary duration, the output must be written as a logic '0'.
    '0' - During primary duration, the output must be written as a logic '0'. During secondary duration, the output must be written as a logic '1'.

F '1' - The trigger or gate must be acquired subsequent to filtering the specified input. The raw input signal must be used if filtering is not enabled for the specified input.
    '0' - The trigger or gate must be derived from the raw input.

R '1' - For triggered output, the output must be triggered by an ON-to-OFF transition of the specified input and must be triggered immediately upon command receipt if the input is OFF. For gated output, the output must be active while the input is OFF.
    '0' - For triggered output, the output must be triggered by an OFF-to-ON transition of the specified input and must be triggered immediately upon command receipt if the input is ON. For gated output, the output must be active while the input is ON.

L '1' - The LINESYNC based clock must be used for the time ticks.
    '0' - The Millisecond Counter must be used for the time ticks.
Configure Complex Output Functions Response

<table>
<thead>
<tr>
<th>Description</th>
<th>ms</th>
<th>Isb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 185)</td>
<td>1 0 1 1 1 0 0 1</td>
<td></td>
<td>Byte 1</td>
</tr>
<tr>
<td>Status</td>
<td>0 0 0 0 0 0 0 V</td>
<td></td>
<td>Byte 2</td>
</tr>
<tr>
<td>MC Timestamp (MSB)</td>
<td>x x x x x x x x</td>
<td></td>
<td>Byte 3</td>
</tr>
<tr>
<td>MC Timestamp (NMSB)</td>
<td>x x x x x x x x</td>
<td></td>
<td>Byte 4</td>
</tr>
<tr>
<td>MC Timestamp (NLSB)</td>
<td>x x x x x x x x</td>
<td></td>
<td>Byte 5</td>
</tr>
<tr>
<td>MC Timestamp (LSB)</td>
<td>x x x x x x x x</td>
<td></td>
<td>Byte 6</td>
</tr>
</tbody>
</table>

Field Definitions:
- V '1' - Maximum number of configurable outputs will be exceeded.
- '0' - No error

1210.4.7.15.10.2 Sampling Rate.

Controlling input signals must be sampled at least once per millisecond.

1210.4.7.15.10.3 Complex Output Functions Overview.

A maximum of eight different Output numbers may be activated by specifying eight definitions.

One complete definition for a Complex Output consists of seven bytes containing fourteen parameters:

1. the Output Number,
2, 3. Primary Duration: MSB & LSB form a 16 bit Hex numerical value,
4, 5. Secondary Duration: MSB & LSB form a 16 bit Hex numerical value,
6. the Input Number,
7. Bit P: One Pulse or Continuous Oscillation,
8. Bit W: Output Operation is Edge Triggered by Input or Not Triggered by Input,
9. Bit G: Output Operation is Gated by Input or is Continuous Oscillation,
10. Bit E: Enable Definition or Remove Definition,
11. Bit J: Defines Primary/Secondary Duration relationship: ON/OFF or OFF/ON,
12. Bit F: Input from Filtered or Raw Data,
13. Bit R: Selects Edge for Triggered by Input ON to OFF or OFF to ON. Bit R: Selects State for Gated to be active by Input OFF or by Input ON, 14)
14. Linesync edges or Millisecond Counter provides tick timing.

Each definition specifies the controlling Input number for that unique output number. The Input is a functional control only when the operation is specified as Triggered (W=1) or Gated (G=1). Otherwise, the Input number is ignored. More than one output definition may specify the same Input controlling source. [That is, the same input may be used as the control source for more than one Complex Output.] If both W=1 and G=1 are set in the definition, the G=1 must be used as if W=0.

The primary duration is the first timed interval of a pulse or the first portion of a continuous oscillation. The first portion follows acquisition of a Trigger or Gated Input. If not Triggered or Gated, the first portion follows the activation of the definition.
The secondary duration follows the Primary duration.

A complete definition is called an Item in the Command Message frame.

The ‘Number of Items’ byte specifies the quantity of complete definitions contained in the Command Frame. If the value is 0, all existing active Complex Output definitions must be removed.

The transmission of a definition may:

(1) install a new active Complex Output definition.

(2) remove an existing active Complex Output definition. When a Complex Output definition is removed, the output is set according to the most recently received Set Outputs Command.

(3) convert an active output definition from Tracking or Square Wave definition to Complex Output. Conversion removes the existing definition and assigns the Complex Output definition without a transition through the ‘output is set according to the most recently received Set Outputs Command’ state. The most recent state of the output remains until the new function changes it.

(4) redefine an existing Complex Output definition.

If a command frame to be processed by the SIU would result in having more than the maximum number (8) definitions activated, the entire command frame must be rejected. The response V bit must be set to 1.

The V bit response evaluation takes the currently active definition quantity, adds the projected Enable definitions, subtracts the Remove definitions, ignores invalid Input and Output numbers and compares the result to the maximum number of active Complex definitions allowed. If the quantity of active definitions would become greater than the maximum number of active Complex Output definitions, or if there are more Remove definitions than existing active Complex Output definitions, the V Bit must be set in the response.

While processing an Enable request that requires Triggered or Gated operation, an Out of Range Input number must preclude processing for that definition.

The Out of Range Output and Input numbers must not affect the active definition count. No error response is returned.

The rest of the message must be processed.

The “Number of Items” field is valid from 0 to 16 because the longest message may contain 8 Enable and 8 Remove definitions.

The Input state comes from the Filtered or Raw Input Data source as specified by the Bit F value.

Valid Input and Output Number Ranges:
ITS SIU device types: Inputs 0 - 53 & 56 - 59, Outputs 0 – 54
The LINESYNC based clock must used both the rising and falling edges providing a nominal 8.33 millisecond time tick.

1210.4.7.15.11 Module Identification.

The SIU Identification command frame must be used to request the SIU Identification value for ITS Cabinet SIUs and CMUs. Reply message must use the following addresses: ATC Controller Unit Field I/Os must respond with address 20. SIUs respond with their own address ranging from 0-14. CMUs respond with their own addresses, ranging from 15-18.

The command and response frames must be shown as follows:

### I/O Module Identification Command

<table>
<thead>
<tr>
<th>Description</th>
<th>ms</th>
<th>Isb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number= 60)</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

### I/O Module Identification Response

<table>
<thead>
<tr>
<th>Description</th>
<th>ms</th>
<th>Isb</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number= 188)</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>SIU I D byte</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

1210.4.7.16 Address Select Inputs.

The Address Select input bits must define the logical position of each SIU. No connection must be logical False, while a connection to Logic Ground must be a logical True. There must be sixteen unique address positions selected with a binary code, using bit 0 as least significant and bit 3 as most significant.

1210.4.7.17 SIU/BIU Input.

The SIU must contain one input that must be read directly by microprocessor. When not connected, this input must be logical False, while a connection to Ground must be a logical True.
1210.4.7.18 Hardware Requirements.

1210.4.7.18.1 Size.

The SIU Module must be physically composed of a printed circuit board, 4.5 in. high by 6.5 in. long, a front panel 2.25 in. wide by 4.5 in. high with a DIN 96-pin connector on the connector end (opposite the front panel).

1210.4.7.18.2 SIU Insertion and Extraction.

A “U” handle must be mounted on the front panel for insertion/extraction.

1210.4.7.18.3 LED Indicators.

Six LED indicators must be provided on the front panel, as follows:

<table>
<thead>
<tr>
<th>SIU Active</th>
<th>SIU Power</th>
<th>Serial Bus 1 TxD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial Bus 2 TxD</td>
<td>Serial Bus 1 RxD</td>
<td>Serial Bus 2 RxD</td>
</tr>
</tbody>
</table>

The Serial Bus 1 indicators must be sensed on the microprocessor/controller pins. Serial Bus 2 indicators must be sensed on the Port 4 (EIA-485) signal lines. The SIU Power LED must indicate that the +24 VDC power supply is within regulation. The SIU Active LED must be controlled via SIU I/O 55.

1210.4.7.18.4 Push Buttons.

The SIU front panel must provide a RESET pushbutton that must provide a hardware RESET to the microprocessor/controller unit.

1210.4.7.18.5 9-position Subminiature D-type Connector.

A 9-position subminiature D-type connector must be mounted on the front panel for Port 3 entry. The connector pin assignment is Pin 2- RxD, Pin 3- TxD and Pin 5- Signal Ground.

1210.4.7.18.6 SIU Input Connector.

The SIU Input Connection pin assignments must be as shown in drawing 4-11-8.

1210.4.7.19 SIU Input and Output Assignments.

<table>
<thead>
<tr>
<th>SIU</th>
<th>Set Output Command Type 55</th>
<th>Raw Input Data Response Type 180</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O 0</td>
<td>BYTE 2</td>
<td>BIT 0</td>
</tr>
<tr>
<td>I/O 1</td>
<td>BYTE 2</td>
<td>BIT 1</td>
</tr>
<tr>
<td>I/O 2</td>
<td>BYTE 2</td>
<td>BIT 2</td>
</tr>
<tr>
<td>I/O 3</td>
<td>BYTE 2</td>
<td>BIT 3</td>
</tr>
<tr>
<td>I/O 4</td>
<td>BYTE 2</td>
<td>BIT 3</td>
</tr>
<tr>
<td>I/O 5</td>
<td>BYTE 2</td>
<td>BIT 5</td>
</tr>
<tr>
<td>SIU</td>
<td>Set Output Command Type</td>
<td>Raw Input Data Response Type</td>
</tr>
<tr>
<td>------</td>
<td>-------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>I/O 6</td>
<td>BYTE 2 BIT 6</td>
<td>BYTE 2 BIT 6</td>
</tr>
<tr>
<td>I/O 7</td>
<td>BYTE 2 BIT 7</td>
<td>BYTE 2 BIT 7</td>
</tr>
<tr>
<td>I/O 8</td>
<td>BYTE 3 BIT 0</td>
<td>BYTE 3 BIT 0</td>
</tr>
<tr>
<td>I/O 9</td>
<td>BYTE 3 BIT 1</td>
<td>BYTE 3 BIT 1</td>
</tr>
<tr>
<td>I/O 10</td>
<td>BYTE 3 BIT 2</td>
<td>BYTE 3 BIT 2</td>
</tr>
<tr>
<td>I/O 11</td>
<td>BYTE 3 BIT 3</td>
<td>BYTE 3 BIT 3</td>
</tr>
<tr>
<td>I/O 12</td>
<td>BYTE 3 BIT 4</td>
<td>BYTE 3 BIT 4</td>
</tr>
<tr>
<td>I/O 13</td>
<td>BYTE 3 BIT 5</td>
<td>BYTE 3 BIT 5</td>
</tr>
<tr>
<td>I/O 14</td>
<td>BYTE 3 BIT 6</td>
<td>BYTE 3 BIT 6</td>
</tr>
<tr>
<td>I/O 15</td>
<td>BYTE 3 BIT 7</td>
<td>BYTE 3 BIT 7</td>
</tr>
<tr>
<td>I/O 16</td>
<td>BYTE 4 BIT 0</td>
<td>BYTE 4 BIT 0</td>
</tr>
<tr>
<td>I/O 17</td>
<td>BYTE 4 BIT 1</td>
<td>BYTE 4 BIT 1</td>
</tr>
<tr>
<td>I/O 18</td>
<td>BYTE 4 BIT 2</td>
<td>BYTE 4 BIT 2</td>
</tr>
<tr>
<td>I/O 19</td>
<td>BYTE 4 BIT 3</td>
<td>BYTE 4 BIT 3</td>
</tr>
<tr>
<td>I/O 20</td>
<td>BYTE 4 BIT 4</td>
<td>BYTE 4 BIT 4</td>
</tr>
<tr>
<td>I/O 21</td>
<td>BYTE 4 BIT 5</td>
<td>BYTE 4 BIT 5</td>
</tr>
<tr>
<td>I/O 22</td>
<td>BYTE 4 BIT 6</td>
<td>BYTE 4 BIT 6</td>
</tr>
<tr>
<td>I/O 23</td>
<td>BYTE 4 BIT 7</td>
<td>BYTE 4 BIT 7</td>
</tr>
<tr>
<td>I/O 24</td>
<td>BYTE 5 BIT 0</td>
<td>BYTE 5 BIT 0</td>
</tr>
<tr>
<td>I/O 25</td>
<td>BYTE 5 BIT 1</td>
<td>BYTE 5 BIT 1</td>
</tr>
<tr>
<td>I/O 26</td>
<td>BYTE 5 BIT 2</td>
<td>BYTE 5 BIT 2</td>
</tr>
<tr>
<td>I/O 27</td>
<td>BYTE 5 BIT 3</td>
<td>BYTE 5 BIT 3</td>
</tr>
<tr>
<td>I/O 28</td>
<td>BYTE 5 BIT 4</td>
<td>BYTE 5 BIT 4</td>
</tr>
<tr>
<td>I/O 29</td>
<td>BYTE 5 BIT 5</td>
<td>BYTE 5 BIT 5</td>
</tr>
<tr>
<td>I/O 30</td>
<td>BYTE 5 BIT 6</td>
<td>BYTE 5 BIT 6</td>
</tr>
<tr>
<td>I/O 31</td>
<td>BYTE 5 BIT 7</td>
<td>BYTE 5 BIT 7</td>
</tr>
<tr>
<td>I/O 32</td>
<td>BYTE 6 BIT 0</td>
<td>BYTE 6 BIT 0</td>
</tr>
<tr>
<td>I/O 33</td>
<td>BYTE 6 BIT 1</td>
<td>BYTE 6 BIT 1</td>
</tr>
<tr>
<td>I/O 34</td>
<td>BYTE 6 BIT 2</td>
<td>BYTE 6 BIT 2</td>
</tr>
<tr>
<td>I/O 35</td>
<td>BYTE 6 BIT 3</td>
<td>BYTE 6 BIT 3</td>
</tr>
<tr>
<td>I/O 36</td>
<td>BYTE 6 BIT 4</td>
<td>BYTE 6 BIT 4</td>
</tr>
<tr>
<td>I/O 37</td>
<td>BYTE 6 BIT 5</td>
<td>BYTE 6 BIT 5</td>
</tr>
<tr>
<td>I/O 38</td>
<td>BYTE 6 BIT 6</td>
<td>BYTE 6 BIT 6</td>
</tr>
<tr>
<td>I/O 39</td>
<td>BYTE 6 BIT 7</td>
<td>BYTE 6 BIT 7</td>
</tr>
<tr>
<td>SIU</td>
<td>Set Output Command Type</td>
<td>Raw Input Data Response Type</td>
</tr>
<tr>
<td>----------</td>
<td>-------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>I/O 40</td>
<td>BYTE 6 BIT0</td>
<td>BYTE 6 BIT 0</td>
</tr>
<tr>
<td>I/O 41</td>
<td>BYTE 7 BIT1</td>
<td>BYTE 7 BIT 1</td>
</tr>
<tr>
<td>I/O 42</td>
<td>BYTE 7 BIT2</td>
<td>BYTE 7 BIT 2</td>
</tr>
<tr>
<td>I/O 43</td>
<td>BYTE 7 BIT3</td>
<td>BYTE 7 BIT 3</td>
</tr>
<tr>
<td>I/O 44</td>
<td>BYTE 7 BIT4</td>
<td>BYTE 7 BIT 4</td>
</tr>
<tr>
<td>I/O 45</td>
<td>BYTE 7 BIT5</td>
<td>BYTE 7 BIT 5</td>
</tr>
<tr>
<td>I/O 46</td>
<td>BYTE 7 BIT6</td>
<td>BYTE 7 BIT 6</td>
</tr>
<tr>
<td>I/O 47</td>
<td>BYTE 7 BIT7</td>
<td>BYTE 7 BIT 7</td>
</tr>
<tr>
<td>I/O 48</td>
<td>BYTE 8 BIT0</td>
<td>BYTE 8 BIT 0</td>
</tr>
<tr>
<td>I/O 49</td>
<td>BYTE 8 BIT1</td>
<td>BYTE 8 BIT 1</td>
</tr>
<tr>
<td>I/O 50</td>
<td>BYTE 8 BIT2</td>
<td>BYTE 8 BIT 2</td>
</tr>
<tr>
<td>I/O 51</td>
<td>BYTE 8 BIT3</td>
<td>BYTE 8 BIT 3</td>
</tr>
<tr>
<td>I/O 52</td>
<td>BYTE 8 BIT4</td>
<td>BYTE 8 BIT 4</td>
</tr>
<tr>
<td>I/O 53</td>
<td>BYTE 8 BIT5</td>
<td>BYTE 8 BIT 5</td>
</tr>
<tr>
<td>Active LED (O54)</td>
<td>BYTE 8 BIT6</td>
<td></td>
</tr>
<tr>
<td>Opto Input 1 (I56)</td>
<td></td>
<td>BYTE 9 BIT 0</td>
</tr>
<tr>
<td>Opto Input 2 (I57)</td>
<td></td>
<td>BYTE 9 BIT 1</td>
</tr>
<tr>
<td>Opto Input 3 (I58)</td>
<td></td>
<td>BYTE 9 BIT 2</td>
</tr>
<tr>
<td>Opto Input 4 (I59)</td>
<td></td>
<td>BYTE 9 BIT 3</td>
</tr>
<tr>
<td>A000</td>
<td></td>
<td>BYTE 9 BIT 4</td>
</tr>
<tr>
<td>A001</td>
<td></td>
<td>BYTE 9 BIT 5</td>
</tr>
<tr>
<td>A002</td>
<td></td>
<td>BYTE 9 BIT 6</td>
</tr>
<tr>
<td>A003</td>
<td></td>
<td>BYTE 9 BIT 7</td>
</tr>
</tbody>
</table>

A000 to A003 must be the address of the SIU.

1210.4.7.20 Block Diagrams.

1210.4.7.20.1 SIU Structure.

Each SIU must contain 54 Input/Outputs and each must be connected as follows:
When the SIU is powered, all outputs must be initialized OFF and fifty-four inputs must be available. Without jumpers or firmware changes, the Controller software must be able to turn ON any of the fifty-four outputs. Each output must be able to be read back as an input in order to check integrity.

1210.4.7.20.2 Existing CALTRANS-style Detectors.

In Figure 5, twelve legacy CALTRANS-style detectors may be installed in the Input Assembly. The twenty-four CALLS must be read by twenty-four SIU inputs, while detectors must be able to be reset by six SIU outputs, two detectors at a time.
1210.4.7.20.3 Existing NEMA-style Detectors.

In Figure 6, twelve legacy NEMA detectors may be installed in the Input Assembly. The twenty-four CALLS must be read by twenty-four SIU inputs, while the twenty-four STATUS must be read by another twenty-four SIU inputs. The detectors must be able to be reset by six SIU outputs, two detectors at a time, same as NEMA.

1210.4.7.20.4 Existing Detectors with Serial Ports.

Circuitry shown in Figure 7 must be included in each SIU, providing a direct serial connection from the controller to each individual serial detector. This serial connection must be in addition to all of the NEMA CALL and STATUS lines shown in Figure 6.
1210.4.7.20.5  Future Advanced Detectors.

Status information must be retrieved from each detector via Serial Bus 2 as described in Figure 7, eliminating the need for the NEMA STATUS inputs. The NEMA STATUS inputs must become individual RESTART outputs from the SIU. The RESET and RESTART outputs differ as follows. RESET must be connected directly to the microprocessor RESET pin of each detector, generating a “hard” reset, used as a last resort to recover stalled detectors. RESTART must be a “soft” signal to the detector to clear all tuning and programming for that individual detector channel, without affecting others.

1210.4.7.20.6  Switch Packs.

Figure 9, 42 SIU outputs must be used to control fourteen Switch Packs, with enough outputs remaining to control four more. Each output must be able to be read back by the controller.

1210.4.8  Cabinet Details.
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Model 212 Cabinet Monitor Unit (CMU) Figure 10
Model 214 Auxiliary Monitor (AMU) Figure 11
Model 216 ITS Cabinet Power Supply Unit Figure 12
Model 216 EP Cabinet External Power Supply Figure 13
Model 218 Serial Interface Unit (SIU) Figure 14
Transfer Relay Wiring and Outline Dimension Figure 15
Detector Sensor Units and Isolators Figure 16
MODEL 200 SWITCH PACK & 204 FLASHER UNITS

CROSS SECTION A-A

MODEL PLUG CONNECTORS LIST (OR EQUAL)

MODEL 200 - BEAU P-5412-LAB
MODEL 204 - BEAU P-5406-LAB

MODEL 200, 204, CONNECTOR DETAIL

<table>
<thead>
<tr>
<th>PIN</th>
<th>FUNCTION</th>
<th>PIN</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AC+</td>
<td>7</td>
<td>Load Circuit #1</td>
</tr>
<tr>
<td>2</td>
<td>Equip. Ground</td>
<td>8</td>
<td>Load Circuit #2</td>
</tr>
<tr>
<td>3</td>
<td>Red Output</td>
<td>9</td>
<td>Equip. Ground</td>
</tr>
<tr>
<td>4</td>
<td>Not Assigned</td>
<td>10</td>
<td>AC-</td>
</tr>
<tr>
<td>5</td>
<td>Yellow Output</td>
<td>11</td>
<td>AC+</td>
</tr>
<tr>
<td>6</td>
<td>Red Input</td>
<td>12</td>
<td>Not Assigned</td>
</tr>
<tr>
<td>7</td>
<td>Green Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Yellow Input</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>+24 VDC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Green Input</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>AC-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Not Assigned</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REV DATE 06-21-05

Figure 9
Model 200 Switchpack & 204 Flasher Units
**Figure 10**

Model 212 Cabinet Monitor Unit (CMU)

---

**Model 212 Cabinet Monitor Unit (CMU) Details**

<table>
<thead>
<tr>
<th>Port</th>
<th>Pin Assignment (DB9S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>NA</td>
</tr>
<tr>
<td>3</td>
<td>NA</td>
</tr>
<tr>
<td>4</td>
<td>NA</td>
</tr>
<tr>
<td>5</td>
<td>DC GND</td>
</tr>
</tbody>
</table>

---

**Notes:**
- LED Indicator
- Momentary Push Button Switch
- DB9S Connector
- SB – Serial Bus
- MC – Main Contactor
- FTR – Flash Transfer Relay
- NA – Not Applicable
- LFSA – Latched Fail State Action
Figure 11
Model 214 Auxiliary Monitor (AMU)
Figure 12
Model 216 ITS Cabinet Power Supply Unit
Note:
DC power cable shall contain (4) #14 gauge wires arranged as follows:
13 +12VDC 14 +24VDC 15 and 16 DC Ground.
The +24VDC Power Supply shall have a jumper between the +12 and +24VDC terminals. If both the +12 and +24VDC power supplies are installed, the jumper shall be removed.
Typical cable length shall be 24 inches.

Figure 13
Model 216 EP Cabinet External Power Supply
Figure 14
Model 218 Serial Interface Unit (SIU)
**OUTLINE DIMENSION DRAWING**

**PIN** | **Function**
--- | ---
1 | Coil
2 | Coil
3 | NC CKT1
4 | NC CKT2
5 | Common CKT1
6 | Common CKT2
7 | NO CKT1
8 | NO CKT2

**WIRING DIAGRAM**

- Pin 1 is connected to Pin 8
- Pin 5 is connected to Pin 6
- Pin 3 is connected to Pin 4

**Figure 15**
Transfer Relay Wiring and Outline Dimension
Figure 16
Detector Sensor Units and Isolators
1210.5 Detector sensor units, elements and isolators.

1210.5.1 General Requirements.

1210.5.1.1.1 The sensor and isolator channels must be operationally independent from each other.

1210.5.1.1.2 Each sensor unit or AC isolator channel must draw no more than 100 milliamperes from the +24 VDC cabinet power supply and must be insensitive to 700 millivolts RMS ripple on the incoming +24 VDC line.

1210.5.1.1.3 The sensor unit or isolator front panel must be provided with a hand pull to facilitate insertion and removal from the Input Assembly.

1210.5.1.1.4 All control switches, gain dials and channel indicators must be mounted on the front panel. Each sensor unit or isolator channel must have an indicator to provide visual indication of detector or incoming signal.

1210.5.1.1.5 Each sensor unit or isolator channel output must be an opto-isolated NPN Open Collector capable of sinking 50 milliamperes at 30 VDC. The output must be compatible with the controller unit inputs.

1210.5.1.1.6 A valid channel input must cause a channel Ground True Output to the controller unit of a minimum 100 milliseconds in duration. An onboard physical switching mechanism must be provided to disable this feature when the mechanism is in an OPEN position. Said switching mechanism must eliminate the minimum timing requirement.

1210.5.1.1.7 The output transistor must switch from OFF to ON state or ON to OFF state in 20 microseconds or less.

1210.5.1.1.8 Onboard protection must be provided to enable the sensor unit or isolator to comply with ANSI/IEEE C62.41 (100 Kilohertz Ring Wave and the EFT Burst) at voltages and currents specified at “Location Category A1” (i.e. up to 2.0 Kilovolts, 0.07 Kiloamperes for the 100 Kilohertz Ring Wave) and at “Test Severity” level I (i.e. up to 1.0 Kilovolts, open-circuit) for the EFT Burst.
1210.5.1.1.9

Detector Sensor Units and Isolators must have a front panel mounted test switch for each channel to simulate valid input. The test switch must be a single-pole double-throw, three position CONTROL test switch: The position assignment must be UP = Constant ON; MIDDLE = Normal Operation; and DOWN = Momentary ON.

1210.5.2 Model 222 & 224 Loop Detector Sensor Unit.

1210.5.2.1 General Requirements.

1210.5.2.1.1

The sensor unit channel must produce an output signal when a vehicle passes over or remains over loop wires embedded in the roadway. The method of detection must be based upon a design that renders the output signal when a metallic mass (vehicle) enters the detection zone causing a change of 0.02% minimum decrease in inductance of the circuit measured at the input terminals of the sensor unit.

1210.5.2.1.2

An open loop must cause the sensor unit channel to output a signal indicating a non-detect situation.

1210.5.2.1.3

Each sensor unit channel must be capable of detecting all types of licensed motor vehicles when connected to the loop configuration/lead-in requirements.

1210.5.2.1.4

The sensor unit must comply with all performance requirements when connected to an inductance (loop plus lead-in) from 50 to 700 micro Henries with a Q-parameter as low as 5 at the sensor unit operating frequency.

1210.5.2.1.5

Loop inputs to each channel must be transformer isolated.

1210.5.2.1.6

Each individual channel must have a minimum of 4 switch selectable operating frequencies.

1210.5.2.1.7

The sensor unit channel tuning circuits must be automatic and must be so designed that drift caused by environmental changes or changes in applied power must not cause an actuation.
1210.5.2.1.8

A switch or switch position must be provided on the front panel to disable each channel output.

1210.5.2.2 Mode Selection Requirements.

Each sensor unit channel must have PULSE and PRESENCE selectable modes.

1210.5.2.2.1 Pulse Mode.

1210.5.2.2.1.1

In the PULSE MODE, each new vehicle presence within the detection zone must initiate a sensor unit channel output pulse of 125 milliseconds (+/-25 milliseconds) in duration.

1210.5.2.2.1.2

Should a vehicle remain in a portion of the detection zone for a period in excess of 2 seconds, the sensor unit channel must automatically “tune out” the presence of said vehicle. The sensor unit channel must then be capable of detecting another vehicle entering the same detection zone. The recovery time to full sensitivity between the first vehicle pulse and channel capability to detect another vehicle must be 3 seconds maximum.

1210.5.2.2.2 Presence Mode.

1210.5.2.2.2.1

In the PRESENCE MODE, the sensor unit channel must recover to normal sensitivity within 1 second after termination of vehicle presence in the detection zone regardless of the duration of the presence.

1210.5.2.2.2.2

The channel sensitivity settings must provide presence detection of a vehicle in the detection zone for a specified time period and inductance change(s). The conditions are as follows:

<table>
<thead>
<tr>
<th>MINIMUM TIME</th>
<th>DETECTOR INPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>DURATION IN</td>
<td>INDUCTANCE</td>
</tr>
<tr>
<td>CHANGE</td>
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<tr>
<td>MINUTES</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>SETTING 6 or more</th>
<th>3</th>
<th>0.02%</th>
</tr>
</thead>
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<tr>
<td>10 or more</td>
<td>0.06%</td>
<td></td>
</tr>
<tr>
<td>SETTING 2 or more</td>
<td>4</td>
<td>1.00%</td>
</tr>
</tbody>
</table>
1210.5.2.3 Sensitivity.

1210.5.2.3.1

This section and included subsections contain example inductive loop detector configurations with which Loop Detector Sensor Units must properly function. Reference is made to California Standard Plan ES-5A & B Loop Configurations described in the California Department of Transportation Standard Plans. The configurations described herein are meant to be representative examples of inductive loop detector configurations.

1210.5.2.3.1.1

Single Type A, B, Q or Round Loop with a 250 foot lead-in cable.

1210.5.2.3.1.2

Single Type A, B, Q or Round Loop with a 1000 foot lead-in cable.

1210.5.2.3.1.3

4 Type A, B, or Q Loops connected in series/parallel with a 250 foot lead-in cable.

1210.5.2.3.1.4

4 Type A, B, Q or Round Loops connected in series with a 1000 foot lead-in cable.

1210.5.2.3.1.5

One 50 foot Type C Loop with a 250 foot lead-in cable.

1210.5.2.3.2

Each sensor unit channel must be equipped with 7 selectable sensitivity setting(s) in presence and pulse modes to accomplish the following under operational and environmental requirements of this Item:

1210.5.2.3.2.1

Each sensor unit channel must respond while in Setting 2 to a nominal change in inductance between 0.15% to 0.4% (median sensitivity of 0.32%) while connected to the loop configurations described in this Item.

1210.5.2.3.2.2

Each sensor unit channel must respond while in Setting 6 to an inductance of 0.02% while connected to the loop configurations described in this Item.

1210.5.2.3.3

All sensitivity settings must not differ +/-40% from the nominal value chosen.
1210.5.2.3.4

Each sensor unit channel must not detect vehicles, moving or stopped, at distances of 3 feet or more from any loop perimeter, in all configurations listed in this Item.

1210.5.2.4 Response Time.

Response time of the sensor unit channel for Sensitivity Setting 2 must be less than 5 +/-1 millisecond at an approximate loop frequency of 40 KiloHertz. That is, for any decreased inductive change that exceeds its sensitivity threshold, the channel must output a ground true logic level within 5 millisecond (+/-1 millisecond). When such change is removed, the output must become an open circuit within 5 millisecond (+/-1 millisecond).

1210.5.2.5 Beginning of Normal Operation.

The sensor unit channels must begin normal operation within 2 seconds after the application of power or after a reset signal of 30 microseconds.

1210.5.2.6 Tracking Rate.

The sensor unit must be capable of compensating or tracking for an environmental change up to 0.001% change in inductance per second.

1210.5.2.7 Tracking Range.

1210.5.2.7.1

The sensor unit must be capable of normal operation as the input inductance is changed from +/-5.0% from the quiescent tuning point regardless of internal circuit drift.

1210.5.2.7.2

The sensor unit must be capable of normal operation as the input resistance is changed from +/-0.5% from the quiescent tuning point regardless of internal circuit drift.

1210.5.2.8 Temperature Change.

The operation of the sensor unit must not be affected by changes in the inductance and/or capacitance of the loop caused by environmental changes, with the rate of temperature change not exceeding 1 degree C per 3 minutes. The opening or closing of the controller cabinet door with a temperature differential of up to 18 degrees C between the inside and outside air must not affect the proper operation of the sensor unit.
1210.5.3 Magnetic Detector Requirements.

1210.5.3.1 Model 231 Magnetic Detector Sensing Element.

1210.5.3.1.1 Each sensing element shall be designed for ease of installation, repositioning, and removal. The sensing element shall be 2.25 inches maximum in diameter and have no sharp edges along its length. The overall length shall not exceed 21 inches.

1210.5.3.1.2 Each sensing element, including lead-in shall have a DC resistance of less than 3500 ohms.

1210.5.3.1.3 The sensing element shall be constructed of nonferrous material and shall be moisture proof. The element shall contain no moving parts or active components. The element shall have a 50 feet lead-in cable. Leakage resistance shall be a minimum of 10 megohms when tested with 400 VDC between lead wire, including lead wire entrance, and fluid of a salt-water bath after the device has been entirely immersed in the bath for a period of 24 hours at 20 degrees C (+/-3 degrees C). The salt-water bath concentrate shall be one-fourth ounce of salt per gallon of water.

1210.5.3.1.4 Each sensing element including lead-in shall have a DC resistance of less than 3500 Ohms and an inductance of 20 Henrys (+/-15%).

1210.5.3.2 Model 232 Two Channel Magnetic Detector Sensing Unit

1210.5.3.2.1 The Model 232 Two-Channel Magnetic Detector Sensor Unit must provide 2 channels of detection. When resident in an energized cabinet Input Assembly, and each channel connected to its associated Model 231 Magnetic Detector Sensing Element(s), the channel must produce a continuous output signal to the controller unit when a voltage is induced in the sensing element by a vehicle passing over the sensing element.

1210.5.3.2.2 Each channel must detect vehicles passing within 6 feet of the Model 231 Sensing Element with 1000 feet of lead-in cable, at all speeds between 3 and 80 miles per hour.

1210.5.3.2.3 A single control knob for adjusting the sensitivity of each channel must be mounted on the front panel and must be readily adjustable without the use of tools.
1210.5.3.2.4

A momentary switch or switch position must be provided to place a call on each channel, on an individual basis.

1210.5.4 Model 242 Two-Channel DC Isolator.

1210.5.4.1 General Requirements.

1210.5.4.1.1

The Model 242 Two-Channel DC Isolator must contain 2 isolation channels which provide isolation between electrical contacts external to the module and the controller unit input. The method of isolation must be based upon a design which must provide reliable operation.

1210.5.4.1.2

The isolator must have an internal power supply supplying 20 VDC (+/-4 VDC) to the field input side of the isolation channels. The isolator must not draw more than 2.5 Watts of AC power. No current must be drawn from the cabinet power supply.

1210.5.4.1.3

A channel contact closure input of 5 milliseconds or less must not cause an output (ground true) to the controller. An input of 25 milliseconds or greater must cause an output to the controller. An input of duration between 5 and 25 milliseconds may or may not cause an output to the controller. The channel circuitry must be able to react to a new input closure within 25 milliseconds of an input opening.

1210.5.4.1.4

Each isolation channel field input must be turned ON (TRUE) when a contact closure causes an input voltage of less than 8 VDC, and must be turned OFF (FALSE) when the contact opening causes the input voltage to exceed 12 VDC. Each input must deliver no less than 15 milliamperes, nor more than 40 milliamperes, to an electrical contact closure or short from the power supply.

1210.5.5 Model 252 Two-Channel AC Isolator.

1210.5.5.1 General Requirements.

1210.5.5.1.1

The Model 252 Two-Channel AC Isolator must contain 2 isolation channels which provide isolation between external 120 VAC input circuits and the controller unit input circuits. The method of isolation must be based upon a design that provides reliable operation.
1210.5.5.1.2
A channel input voltage “Von” of 80 VAC (+/-5 VAC) applied for a minimum duration of 120 milliseconds (+/-10 milliseconds) must cause an output (Ground True) to the controller unit.

1210.5.5.1.3
A channel input voltage “Voff” (Von minus 10 VAC) applied for a minimum duration of 120 milliseconds (+/-10 milliseconds) must cause an output (Ground False) to the controller unit.

1210.5.5.1.4
A two-post jumper must be provided to select inverted output states for Von and Voff. When in CLOSED position (Grounded), Von must cause a Ground False output. An indicator must be provided on the front panel labeled ‘RR” which must indicate a Voff input, Ground True output.

1210.5.5.1.5
The input impedance of each channel must be between 6,000 - 15,000 Ohms at 60 Hertz.

1210.5.5.1.6
The minimum isolation must be 1000 Megohms between the input and output terminals at 500 AC applied voltage.
1210.6 Cabinet system requirements.

1210.6.1.1 General.

1210.6.1.1.1

The Intelligent Transportation System (ITS) Serial Interconnected Cabinet Family is a group of cabinets designed to fulfill a variety of applications. This chapter describes the functional and physical requirements of said cabinets.

1210.6.1.1.2

There are common parts to all cabinets, such as Modular Bus and Power Assemblies, ATC Controller Unit, Power Distribution Assembly (PDA ITS), and Input and Output Assemblies. The Housing and the Cage(s) must depend on the housing configuration.

1210.6.1.1.3

The ATC Controller Unit is serially connected to the Cabinet via two serial synchronous ports located at the Field I/O C12 Connector or the CPU-1B C13 Connector (Serial Bus 1 only). These two communication links use EIA-485 Drivers/Receivers and Synchronous Data Link Control (SDLC) Protocol to interface with Serial Bus #1 and #2.

1210.6.1.2 Cabinet Model Number and Consistency.

1210.6.1.2.1

The ITS Cabinets must consist of a package of items needed to carry out a specific Application. Cabinet Versions provided here are EXAMPLES of possible cabinet configurations. A Product Implementation Conformance Statement is provided as an Annex to this standard:

<table>
<thead>
<tr>
<th>Package Items</th>
<th>340</th>
<th>342</th>
<th>346</th>
<th>Drawings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Housing #1 /Cage #1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>6-5-4</td>
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<tr>
<td>2 Housing #2 /Cage #2</td>
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<tr>
<td>3 Housing #3 (2) Cage #1</td>
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<td>-</td>
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<tr>
<td>4 “J” Panel Cage #1</td>
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<tr>
<td>5 “J” Panel Cage #2</td>
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<td>2</td>
<td>6-6-9</td>
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<td>6 Service Panel Assembly w/ AC/EG Bus</td>
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<td>6-5-11</td>
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<td>7 Raw/Clean AC Power Assembly 2 socket</td>
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<td>1</td>
<td>6-5-15A</td>
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<td>8 Raw/Clean AC Power Assembly 4 socket</td>
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<td>-</td>
<td>6-5-15</td>
</tr>
<tr>
<td>9 Raw/Clean AC Power Extension</td>
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<td>-</td>
<td>-</td>
<td>6-5-15</td>
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<td>11 DC Power/ COMM Assembly</td>
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<td>12 DC Power/ COMM Extension</td>
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<tr>
<td>13 Cabinet Shelf Assembly</td>
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<td>-</td>
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<td>6-5-10</td>
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<tr>
<td>14 Drawer Assembly</td>
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<tr>
<td>15</td>
<td>Input Assembly</td>
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<td>2</td>
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<tr>
<td>16</td>
<td>Six Pack Output Assembly</td>
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<tr>
<td>17</td>
<td>Fourteen Pack Output Assembly</td>
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<td>1</td>
</tr>
<tr>
<td>18</td>
<td>PDA5 IP w 12 and 24V DC Power Supplies</td>
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<td>-</td>
</tr>
<tr>
<td>19</td>
<td>PDA 5 EP with rack mount power supply</td>
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<td>20</td>
<td>Rack Mount 24V Power Supply</td>
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<td>21</td>
<td>Rack Mount 12V Power Supply (option**)</td>
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<tr>
<td>22</td>
<td>Fiber Optic Termination Panel</td>
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<td>1</td>
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<td>23</td>
<td>Input Terminal Panel (Optional 342*)</td>
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<td>-</td>
<td>*</td>
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<tr>
<td>24</td>
<td>Manual Advance Pushbutton Cable</td>
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<td>1</td>
</tr>
<tr>
<td>25</td>
<td>Field Input Panel with Mounting Brackets</td>
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<td>-</td>
</tr>
<tr>
<td>26</td>
<td>Field Output Panel with Mounting Brackets</td>
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<td>2</td>
<td>-</td>
</tr>
<tr>
<td>27</td>
<td>Luminaire Wiring and Assembly (option**)</td>
<td></td>
<td>1**</td>
<td>-</td>
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<tr>
<td></td>
<td>** See Plans</td>
<td></td>
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</tr>
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</table>

Notes: Provide each major assembly with the following:

1. **14 Pack Output Assembly:**
   - (14) Model 200 Switch Pack Units
   - (6) Model 205 Flash Transfer Relay Unit (FTRs) (these relays must be designed for continuous operation in the energized position)
   - (12) Red Flash Program Blocks
   - (4) White Flash Program Blocks
     - (1) Type 218 Serial Interface Unit
     - (1) Type 214 Auxiliary Monitor Unit
     - (1) Serial Bus 3 cable
     - (1) Control Serial Bus (SB1/SB2) Cable
     - (1) Address Block (Output Assembly)
     - (7) Transient Protector Assemblies

2. **6 Pack Output Assembly:**
   - (6) Model 200 Switch Pack Units
   - (3) Model 205 Flash Transfer Relay Unit (FTRs) (these relays must be designed for continuous operation in the energized position)
   - (6) Red Flash Program Blocks
   - (2) White Flash Program Blocks
(1) Type 218 Serial Interface Unit
(1) Type 214 Auxiliary Monitor Unit
(1) Serial Bus 3 cable
(1) Control Serial Bus (SB1/SB2) Cable
(1) Address Block (Output Assembly)
(3) Transient Protector Assemblies

3) Input Assembly Number One (1):
   (10) Type 222 – Loop Detector Sensors Unit
   (2) Type 242 Two Channel DC Isolator Units
   (1) Type 218 Serial Interface Unit
   (1) Address Block (Input Assembly)
   (1) Control Serial Bus (SB1/SB2) Cable

3b) Input Assembly Number Two (2):
   (10) Type 222 – Loop Detector Sensors Unit
   (2) Type 242 Two Channel DC Isolator Units
   (1) Type 218 Serial Interface Unit
   (1) Address Block (Input Assembly)
   (1) Control Serial Bus (SB1/SB2) Cable

3c) Input Assembly Number Three (3):
   (2) Type 252 Two Channel AC Isolator Units
   (1) Type 218 Serial Interface Unit
   (1) Address Block (Input Assembly)
   (1) Control Serial Bus (SB1/SB2) Cable

4) Power Distribution Assembly must be PDA #5 EP with:
   __________ (1) Rack Mountable Model 216-24 Power Supply
   __________ (2) Model 204 Flasher Units
   __________ (1) Model 212 Cabinet Monitor Unit
   __________ (1) Address Block (CMU)
5) Power Distribution Assembly must be PDA #5 IP with:

- (1) Model 216-24 Power Supply
- (1) Model 216-12 Power Supply
- (2) Model 204 Flasher Units
- (1) Model 212 Cabinet Monitor Unit
- (1) Address Block (CMU)
- (1) CC Harness
- (1) Serial bus 3 Cable
- (1) DC Power Harness (DCP)
- (1) Control Serial Bus (SB1/SB2) Cable

6) Service Panel Assembly:

- (1) EDCO SHA-1250 ITS, or approved equal

7) Field Wire Support Brackets. (Not required when Field Panel are used.)

   Cage 1 units require one deep support bracket for each Input and Output Assembly required

   Cage 2 Units require one shallow support for each Input and Output Assembly

8) Series 340 Cabinet (Housing 3) must be provided with the following:

   a) Two (2) Field Input Termination Panels in accordance with Drawings and mounted at the bottom of the rack. They must be attached to the rack with an angle bracket and each panel attached to the angle bracket with captive thumb-screws.

   b) A total of twenty four (24) EDCO MRA–6IC–6 (12) units for each Input Panel are required.

   c) Two (2) Field Output Termination Panels in accordance with Drawings and be mounted at the bottom of the rack. They must be attached to the rack with an angle bracket and each panel attached to the angle bracket with captive thumb-screws as shown in the drawings.
d) Type 222 – Loop Detector Sensors Unit must have a front panel mounted test switch per channel to simulate valid input. The test switch must be a single-pole double-throw, three position CONTROL test switch. The position assignment must be UP – constant ON; MIDDLE – NORMAL; and DOWN – momentary ON

1210.6.1.2.2 Cabinet Cage Configuration Drawings

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<table>
<thead>
<tr>
<th>Drawing Name</th>
<th>Drawing No.</th>
</tr>
</thead>
<tbody>
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<td>MODEL 340 CAGE 1 (DUAL) ASSEMBLY REQUIREMENTS</td>
<td>340-I</td>
</tr>
<tr>
<td>MODEL 340 CAGE 1 INPUT WITH CONTROLLER DRAWER ASSY (DUAL) ASSY REQUIREMENTS</td>
<td>340-1D</td>
</tr>
<tr>
<td>MODEL 340 CAGE 1 OUTPUTS (DUAL) ASSEMBLY REQUIREMENTS</td>
<td>340-O</td>
</tr>
<tr>
<td>MODEL 340 CAGE 1 OUTPUTS WITH CONTROLLER DRAWER ASSY (DUAL) ASSY REQUIREMENTS</td>
<td>340-OD</td>
</tr>
<tr>
<td>MODEL 340 CAGES (DUAL) CABLE ASSEMBLY REQUIREMENTS</td>
<td>340-DD</td>
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<td>MODEL 342 CAGE 1 ASSEMBLY REQUIREMENTS</td>
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<td>MODEL 346 CAGE 1 ASSEMBLY REQUIREMENTS</td>
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<td>MODEL 356 CAGE 1 ASSEMBLY REQUIREMENTS</td>
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</table>
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Model 340 Cage 1 (Dual) Assembly Requirements
Figure 18
Model 340 Cage 1 Input w/ Controller Drawer Assy (Dual) Assy Requirements
CAGE 1 OUTPUT (DUAL)

Figure 19
Model 340 Cage 1 Outputs (Dual) Assembly Requirements
Figure 20
Model 340 Cage 1 Outputs w/ Controller Drawer Assy (Dual) Assy Requirements
Figure 21
Model 340 Cages (Dual) Cable Assembly Requirements
Figure 22
Model 342 Cage 1 Assembly Requirements
Figure 23
Model 346 Cage 2 Assembly Requirements
Figure 24
Model 354 Cage 1 Assembly Requirements
Figure 25
Model 356 Cage 2 Assembly Requirements
1210.6.1.3  Serial Bus #1 System.

1210.6.1.3.1

Serial Bus #1 must function as a distributed real-time cabinet control and communications bus. The Bus Commands are generated in the ATC Controller Unit. They must be passed to the assembly Model 218 SIU Units and Model 212 CMU Monitor Unit using EIA 485 COMM/SDLC Protocol Frame Address/Message Packets. The SIU Units must read the Address Connector for Assembly Address Number. The CMU must read the Address Connector of the PDA. The AMU units must read address information as part of the Output Assembly address connector.

1210.6.1.3.2

The following Address Frame numbers must be assigned to the assemblies and monitor as:

<table>
<thead>
<tr>
<th>Address</th>
<th>SYSTEM ASSEMBLY / UNIT</th>
<th>ADDRESS</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
<td>SIU</td>
</tr>
<tr>
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<td>A7</td>
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<tr>
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<td>2</td>
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<tr>
<td>3</td>
<td>14 Pack in position 3</td>
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</tr>
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<td>4</td>
<td>6 Pack in position 4</td>
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<td>6 Pack in position 2</td>
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<td>7</td>
<td>6 Pack in position 3</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
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<tr>
<td>9</td>
<td>Input #1</td>
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</tr>
<tr>
<td>10</td>
<td>Input #2</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>Input #3</td>
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<tr>
<td>11</td>
<td>Input #4</td>
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<td>13</td>
<td>Input #5</td>
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<td>14</td>
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<td>15</td>
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</tr>
<tr>
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<td>CMU #2</td>
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</tr>
<tr>
<td>17</td>
<td>CMU #3</td>
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</tr>
<tr>
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<td>Addresses</td>
<td>SYSTEM ASSEMBLY / UNIT</td>
<td>ADDRESS</td>
</tr>
<tr>
<td>-----------</td>
<td>------------------------</td>
<td>--------</td>
</tr>
<tr>
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<td>A7 A6 A5 A4 A3 A2 A1 A0</td>
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</tr>
<tr>
<td>AMU</td>
<td>A7 A6 A5 A4 A3 A2 A1 A0</td>
<td></td>
</tr>
</tbody>
</table>

21to 254 Reserved

255 Broadcast All 1 1 1 1 1 1 1 1

*A2 Jumpered on Assembly

1210.6.1.3.3

If the Command Address Frame matches the Unit, the Unit must read the message for processing and response. The Message First Byte must be the message name. The Unit must set the Response Packet First Byte to Command Message plus 128 and the appropriate data.

1210.6.1.4 Serial Bus #2 System.

1210.6.1.4.1

Serial Bus #2 must be dedicated to gathering preprocessed data from the Cabinet Smart Input Devices resident in the input assemblies. This serial bus must be for off-line use in operations with the ATC Controller Unit controlling data collection. Serial Bus #2 must be designed to operate Asynchronous EIA 485 lines at selected data rates up to 19,200 bits per second. See section on SIU Port 2 Operation for communication, interface and message protocol.

1210.6.1.4.2

Typical Command/Response Messages must use similar message format as Serial Bus #1, collecting Operational Status, Detection Speed reports, Occupancy reports, Counts, etc.

1210.6.1.5 Cabinet Control/Emergency Override System (CCEOS).

1210.6.1.5.1 System Description.

The Control and Emergency Override System is composed of the Police Panel Switches, Door Switches, ITS Power Distribution Assembly with resident Cabinet Monitor Unit, Serial Bus #1, Modular Bus Assemblies and cables, and the Output Assemblies with Transfer Relays Program Block Connectors and AMU Units. The purpose of the Emergency Override system is to transfer control from the ATC Controller Unit to the Cabinet Monitoring System. The Emergency Override system may also be manually controlled by switches either on the ITS PDA Assembly or Police Panel. The action taken depends upon the application. The Transfer Relays in the Output Assemblies, when de-energized, must transfer from Switch Pack Control to the EOS control. When the Cabinet is in the SIGNALS OFF condition the Main Contactor...
must be OFF and the FTR’s are energized. If the intersection is FLASH Mode when in the Ramp Metering application, the display is NO INDICATION or BLANK Mode.

1210.6.1.5.2 Cabinet Monitoring System.

The Cabinet Monitoring System must use two serial Bus systems for the interface; Serial Bus #1, links the ATC Controller Unit via a Serial Bus Harness to the DC Power/Communications Assembly. A Serial Bus Harness plugged into the DC Power/Communications Assembly must connect to the 212 Cabinet Monitor Unit with application serial memory key resident in the PDA ITS.

Serial Bus #3 Harnesses must provide the interconnection between the Output Assembly’s 214 Auxiliary Monitor Units and the CMU. The Bus Harnesses must be daisy chained between the Output Assemblies and the PDA ITS. See sections CMU and AMU sections for operations, functions, protocol, Message frames and bit rate.

1210.6.2 Housings.

1210.6.2.1 Housing Package.

The housings must include, but not be limited to, the following:

- Enclosure & Doors
- Gasketing
- Lifting Eyes & External Bolt Heads
- Door Latches & Locks
- Ventilation
- Cage Supports & Mounting
- Door Hinges & Catches
- Police Panel
- Aluminum Surfaces

1210.6.2.2 Housing Construction.

The housing must be rainproof. It must have front and rear doors, each equipped with a lock and handle. The enclosure top must be crowned to prevent standing water. The aluminum surface must be either coated with a Mill Finish or Anti-Graffiti Paint.

1210.6.2.2.1 Material Thickness.

The enclosure, doors, lifting eyes, gasket channels, police panel door, spacer supports and all supports welded to the enclosure and doors must be fabricated of 0.125 in. minimum thickness aluminum sheet. The filter shell, filter trough, fan support and police panel enclosure must be fabricated of 0.080 in. minimum thickness aluminum sheet. The spacer supports must have the option to use 0.059 in. minimum stainless steel sheet.
1210.6.2.2.2 Welds.

All exterior seams for enclosure and doors must be continuously welded and must be smooth. All edges must be filled to a radius of 0.03125 in. minimum. Exterior cabinet welds must be done by gas Tungsten arc TIG process only. ER5356 aluminum alloy bare welding electrodes conforming to AWS A5.10 requirements must be used for welding on aluminum. Procedures, welders and welding operators must conform to the requirements and practices in AWS B3.0 and C5.6 for aluminum. Internal cabinet welds must be done by gas metal arc MIG or gas Tungsten arc TIG Process.

1210.6.2.2.3 Aluminum Surface Protection.

ALUMINUM SURFACE PROTECTION must be either MILL FINISH or ANTI-GRAFFITI Paint.

1210.6.2.2.3.1 Anti – Graffiti Paint.

The aluminum surface must be cleaned, etched and rinsed. The cleaning and etching procedure must be to immerse in inhabited alkaline cleaner at 71 degrees C for five minutes (Oakite 61A, Diversey 909 or equivalent in mix of the 6 to 8 ounces per gallon to distilled water). Rinse in cold water. Etch in a sodium solution at 66 degrees C for 5 minutes 90.5 ounce sodium fluoride plus 5 ounces of sodium hydroxide mix per gallon to distilled water. Rinse in cold water. Desmut in a 50% by volume nitric acid solution at 20 degrees C for 2 minutes. Rinse in cold water. Dry surfaces by preheating in an oven for 15 minutes at 400 degrees F. Remove and coat the surfaces using TCI Wheel Silver # 9811- 0110 with a minimum film build of not more than 2 mils total thickness. Place back into preheated oven for 10 minutes minimum at 360 degrees F to gel the base coat. Remove and coat the surfaces using TCI Anti-graffiti Clear # 9810-0231. Place back into oven and fully cure at 380 degrees F for 40 minutes.

1210.6.2.2.4 Enclosure Door Frames and Door Seals.

The enclosure door frames must be double flanged out on all four sides and must have strikers to hold tension on, and form a firm seal between, the door gasketing and the frame. The dimension between the door edge and the enclosure external surface when the door is closed and locked must be 0.156 in. (+/-0.08 in.).

1210.6.2.3 Gasketing.

Gasketing must be provided on all door openings and must be dust-tight. Gaskets must be 0.25 in. minimum thickness closed cell neoprene or silicone (BOYD R- 108480 or equal) and must be permanently bonded to the metal. A gasket top and side channels must be provided to support the top gasket on the door to prevent gasket gravitational fatigue.

1210.6.2.4 Cage Mounting Supports.

Cage mounting supports must be provided on either side, level with the bottom edge of the door opening, for horizontal support and bolt attachment; side cage supports provided for the bracket cage supports; and bracket cage support attachments.
1210.6.2.5 Lifting Eyes and Exterior Bolt Heads.

The housing must be provided with 2 lifting eyes for placing the cabinet on its foundation. Each eye opening must have a minimum diameter of 0.75 in.. Each eye must be able to support the weight load of 1000 lbs. All bolt heads must be tamperproof type.

1210.6.2.6 Door Latches and Locks.

The latching handles must have provision for padlocking in the closed position. Each handle must be 0.75 in. minimum diameter stainless steel with a minimum of 0.50 in. shank. The padlocking attachment must be placed at 4 in. from the handle shank center. An additional 4 in. minimum gripping length must be provided.

1210.6.2.6.1 Latch/Lock Mechanism.

The latching mechanism must be a three-point draw roller type. The pushrods must be turned edgewise at the outward supports and have a cross-section of 0.25 in. thick by 0.75 in. wide minimum. Rollers must have a minimum diameter of 0.875 in. with nylon wheels and steel ball bearings. When the door is closed and latched, the door must be locked. The lock and lock support must be rigidly mounted on the door. The lock must be mounted in the upper quadrant, above the handle when in its full open position. In the locked position, the bolt throw must extend a minimum of 0.25 in. (+/-0.03125 in.) into the latch cam area. A seal must be provided to prevent dust or water entry through the lock opening.

1210.6.2.6.2 Lock and Keys.

The locks must be Corbin 2 type. One key must be supplied with each lock. The keys must be removable in the locked position only. The locks must have rectangular, spacing loaded bolts. The bolt must have a 0.281 in. throw and must be 0.75 in. wide by 0.375 in. thick. Tolerance is 0.035 in.. A swing away cover must be placed over the key entrance to protect the lock mechanism.

1210.6.2.6.3 Cam.

The center latch cam must be fabricated of a minimum thickness of 0.188 in. aluminum, or 11 gauge steel. The bolt surface must horizontally cover the cam thickness. The cam must be structured to only allow the door to open when the handle is moved toward the center of the door.

1210.6.2.7 Housing Ventilation.

Housing Ventilation must including intake, exhaust, filtration, and continuous running fan assembly, or a thermostat controlled fan.

1210.6.2.7.1 Intake & Filter.

The louvered vent depth must be a maximum of 0.25 in.. A removable and reusable air filter must be housed behind the door vents. The filter filtration area must cover the vent opening area. A filter shell must be provided that fits over the filter providing mechanical support for the filter. This shell must be louvered to direct the incoming air.
downward. The shell sides and top must be bent over a minimum of 0.25 in. to house the filter. The filter resident in its shell must be held firmly in place with a bottom trough and spring loaded upper clamp. No incoming air must bypass the filter. The bottom filter trough must be formed into a waterproof sump with drain holes to the outside housing. The filter must be 16 in. wide by 12 in. high by 0.875 in. thick. The filter must be an ECO-AIR Product E35S or equal. The intake (including filter with shell) and exhaust areas must pass a minimum of 60 cubic feet of air per minute for Housing #1; 120 cubic feet of air per minute for Housing #3; and 26 cubic feet of air per minute for Housing #2.

1210.6.2.7.2 Fan.

Each electric fan must be equipped with ball or roller bearings and must have a minimum capacity of 100 cubic feet of free air delivery per minute. The fan must be mounted within the housing and protected with a finger guard.

1210.6.2.8 Hinges.

Stainless Steel hinges (Two-bolts per leaf) must be provided to bolt the enclosure to the doors. Housing #1 & Housing #3 must have four hinges per door and Housing #2 must have three hinges per door. Each hinge must be 3-1/2 in. minimum length and have a fixed pin. The pin ends must be welded to hinge and ground smooth. The pins and bolts must be covered by the door edge and not accessible when the door is closed. A ground strap between the door and the main cabinet housing must be required when 120 VAC components are mounted on the door.

1210.6.2.9 Door Catches.

Front and rear doors must be provided with catches to hold the door open at both 90 and 165 (+/-10 degrees). The catch minimum diameter must be 0.375 in. aluminum rods. The catches must be capable of holding the door open at 90 degrees in a 60 mph wind acting at an angle perpendicular to the plane of the door.

1210.6.2.10 Police Panel.

A police panel assembly must be provided to allow the limited control access. The panel door must be equipped with a lock and master police key. The front and back of the panel must be enclosed with a rigid metal covering so that no parts having live voltage are exposed. The panel assembly must have a drain to prevent water from collecting within the assembly. The drain must be channeled to the outside. The series 35X Cabinets must have one switch provided and labeled "SIGNALS ON - OFF ". The series 34X Cabinets must have one switch labeled "SIGNALS ON - OFF" and the other "FLASH/AUTO". The MANUAL CONTROL ENABLE ON-OFF switch and a receptacle for the INTERVAL ADVANCE cord must be provided. A 12 VAC transformer must be provided in advance of the INTERVAL ADVANCE receptacle. An INTERVAL ADVANCE cord, six feet in length, must be provided.

1210.6.3 Rack Cage.

A Standard Rack Cage must be installed inside the housing for mounting of the ATC Controller Unit and cabinet assemblies. The EIA rack portion of the cage must consist
of four continuous, adjustable equipment mounting angles. The mounting angle nominal thickness must be 11 gauge plated steel. The mounting angles must be tapped with 10-32 threads with EIA universal spacing. The mounting angle must comply with standard EIA-310-B and must be supported at the top and bottom by either welded or bolted support angles to form a cage. The mounting angles must provide holes to mount the "J" panels.

1210.6.3.1 Clearance Between Rails.

Clearance between rails for mounting assemblies must be 17.75 in..

1210.6.3.2 Cage Connection.

The cage must be bolted to the cabinet at 4 points via the housing cage supports and 4 points via associated spacer brackets (top and bottom).

1210.6.3.3 Cage Location.

The cage(s) must be centered within the cabinet door opening(s).

1210.6.4 Cabinet Assemblies.

1210.6.4.1 General.

1210.6.4.1.1 Cabinet Assemblies.

The cabinet assemblies must be completely removable from or installable in the cabinet cage without removing any other equipment and using only a Standard Slotted or Phillips Screwdriver.

1210.6.4.1.2 Visible and Accessible Devices.

All fuses, circuit breakers, switches (except Police Panel Switches and Fan Fuse) and indicators must be readily visible and accessible when the cabinet front door is open.

1210.6.4.1.3 Labels and Marker Strips.

All equipment in the cabinet must be clearly and permanently labeled. The marker strips must be made of material that can be easily and legibly written on using a pencil or ballpoint pen. Marker strips must be located immediately below the item they are to identify and must be clearly visible with the items installed.

1210.6.4.1.4 Resistor/Capacitor Suppression.

Suppression must be provided at all relay sockets (across relay coil), except for the Transfer Relays (TR) in the output assemblies where one suppression device may be common for all.

1210.6.4.1.5 PDA, Output and Input Assemblies.

PDA, Output and Input Assemblies Depth must include terminal sockets, plug-in units and strain relief bar (Field Wire Support Bracket). The Width must be 17.5 in. maximum including side screws. The maximum Depth, including connectors, must not exceed
14.0 in. The assembly housing top and bottom must be slotted for vertical ventilation. Assembly Thickness - Side ends must be fabricated of 0.080 in. minimum thickness aluminum sheet. All other surfaces must be fabricated of 0.0625 in. minimum thickness aluminum sheet. The aluminum metal surface must be treated with clear chromate.

1210.6.4.1.6 Connector Sockets.

Flasher and Switch Pack Unit sockets must be mounted with their front face 7.50 in. from the assembly front panel.

1210.6.4.1.7 Nylon Guides.

Guides (top and bottom) must be provided for assembly Plug-in units (Power Supply Units guide on bottom only). The guides must begin 0.50 in. from the assembly front panel face.

1210.6.4.2 “J” Panel Assemblies.

The “J” Panels must be mirror images of each other when mounted in the cabinet cage. They must be bolted to the cage with the matching shelf unit bolted to the panel. Two ten position minimum AC- Raw & Equipment Ground Copper Bus Bars must be provided on the lower right position of the J Panel when viewed from the rear door for interconnect to the Service Panel and provide the termination of AC- Raw and Equipment Ground wiring within the Cage and Cabinet.

1210.6.4.2.1 Input Termination Panel Assembly.

An optional Input Termination Panel must be provided that uses ten twelve-position terminal blocks and 4 copper bus bars. Eight of the twelve position terminal blocks and the four copper bus bars must be used for termination of field inputs. Two of the twelve position terminal blocks must be used for termination of the CDC interface. Input transient protection devices may be used for input termination. Terminal blocks one through four provide termination for Input Assembly #1 and terminal blocks five through eight provide termination for Input Assembly #2. A ground lug must be provided on the panel assembly to terminate an 8 AWG green wire that is attached to the Equipment Ground copper bus bar on the “J” panel assembly. The Input Termination Panel must be mounted on the left side of the Rack Assembly, when viewing from the rear.

1210.6.4.3 Cabinet Shelf Assemblies.

A Shelf Assembly must be provided unless otherwise called out in the contract special provisions. One alternative is a shelf/drawer assembly.

1210.6.4.4 Service Panel Assembly.

1210.6.4.4.1 General Requirements.

A Service Panel Assembly must be provided. The assembly must function as the entry point for AC Power to the cabinet including main and secondary circuit breakers, cabinet transient and voltage surge protection, clean power filtering, Raw and Clean AC Power Source.
1210.6.4.4.2 Location.
The assembly must be located on the lower right J Panel when viewed from the back door.

1210.6.4.4.3 Service Terminal Block.
The terminals of the Block must be labeled AC+, AC- and EG and must be covered with a clear insulating material to prevent inadvertent contact. The Terminating Lugs must be large enough to accommodate # 2 conductors.

1210.6.4.4.4 AC+ Raw, AC- Raw and Equipment Ground Bus Termination.
This assembly must provide two 8 in. #8 gauge wire extensions for AC- Raw and Equipment Ground, for attachment to the AC- and Ground busses mounted on the “J” panel.

1210.6.4.4.5
The DC Ground and Equipment Ground Bus must be electrically isolated by 500 Megohms when tested at 250 VDC.

1210.6.4.4.6
The AC- copper terminal bus must not be grounded to the cabinet or connected to logic ground. Nylon screws with a minimum diameter of 0.25 in. or nylon spacers must be used for securing the bus to the J Panel.

1210.6.4.5 Raw/Clean AC Power Assembly.
This Assembly must be provided in each cabinet. It must provide Six Clean AC Power Receptacles for assemblies and cabinet units; Raw AC Power to the Output Assemblies; and both logic and power to the Fan and Light system, door opening circuitry and logic interface (all via CCIN and CCOUT Connectors).

1210.6.4.5.1 Raw/Clean AC Power Extension.
The Extension must provide a minimum of five additional NEMA 5-15 receptacles with harness plug connector for plugging into the main assembly. The extension may be an option in Housing #1, and must be required in Cage 2 of the Housing #3.

1210.6.4.6 DC Power/Communications Assembly.
This assembly must function as the DC Power bus, providing Six VDC BEAU S5404-SB Receptacles and communications interface between the ATC Controller Unit and other assemblies. This assembly must interface with ATC Controller Unit Logic Lines (Power Down, NRESET and LINESYNC) and Seven System Serial Bus signals via DB-25S Connectors.

1210.6.4.6.1 DC Power/Communications Extension.
The Extension must provide additional Serial Bus Connectors and DC Receptacles. The extension may be an option.
1210.6.4.6.2 Terminator Unit.

A Serial Bus #1 and #2 Terminator Unit must be provided and plugged into the DC POWER / COMMUNICATIONS ASSEMBLY DB 25S End Connector. The Terminator Unit must provide a 150 ohm termination resistor between the RxD+ and RxD-, the TxD+ and TxD-, the RxC+ and RxC-, and the TxC+ and TxC- pairs for both Serial Bus #1 and Serial Bus #2.

The Terminator Unit must also provide 1K ohm DC bias resistors from +5VDC ISO to the RxD+, the RxC+, the TxD+, and the TxC+ of both Serial Bus #1 and Serial Bus #2. The Terminator Unit must provide 1K ohm DC bias resistors from ISO GND to the RxD-, the RxC-, the TxD-, and the TxC- of both Serial Bus #1 and Serial Bus #2.

1210.6.4.7 Power Distribution Assembly ITS.

1210.6.4.7.1

The Power Distribution Assembly ITS is an EIA-310B rack mounted assembly that provides for the protection and distribution of AC power and DC power. Additionally:

- Logic control circuits, including a Main Contactor for control of the load circuits;
- Fault sensing field Circuit Breakers, eight for Traffic applications and four for Traffic Management systems.
- Production and distribution of DC power, using +12VDC and 24VDC pluggable power supplies.
- A resident Cabinet Monitor Unit (CMU).
- Maintenance service, consisting of a circuit breaker in line with GFI equipment power receptacles.
- Two Model 204 Flasher Units, protected by a ganged two pole 20 A Circuit Breaker when operating in a Traffic Signal application.
- A 25 Pin D Socket must be provided for communication with the ATC Controller Unit. This Socket must be mated with an 18in. Communications Cable. This Cable must be attached to the Assembly by slotted 4:40 screws. See Serial Bus Harnesses Detail 6-5-39.
- A four position Address Socket and plug must be provided to provide addressing to the CMU.

1210.6.4.7.2

A CDC Connector must be provided on the rear panel of the Output Assembly for isolated signal outputs from the police panel. The CDC Socket is a 9 Pin “D” connector that contains the Manual Control Enable, Stop Time, Interval Advance, and Manual Flash switch signals. The Manual Control Enable and Manual Flash switch signals must be a 120 VAC signal in series with a 27K Ohm resistor. The Interval Advance and Stop Time switch signals must be 12 VAC signals from a transformer located in the PDA.
The secondary output of the 12 VAC transformer must be tied to AC- RAW. CDC pin 5 Common must be referenced to AC- RAW. CDC pins 8 must provide an interface for the external reset signal and 9 must provide an interface for DC Ground.

1210.6.4.7.3

The PDA must be provided with eight field load circuit breakers and two Model 204 Flasher Units with ganged circuit breaker protection. The Load Circuit Breakers located on the PDA that are used to control the Output Assembly Model 200 Switch Pack Units must have auxiliary switches. The auxiliary switches must “open” when the load breaker has tripped and the system will transfer the power from the Main Contactor to the Flash or Blank condition.

1210.6.4.7.4

The amperage rating of breakers must be shown on the face of the breaker or handle. Breaker function must be labeled below the breakers on the front panel. Ganged Circuit Breakers must be assembled by the circuit breaker manufacturer and certified that their circuit breakers must gang trip.

1210.6.4.7.5

The maintenance equipment circuit must include a 15-Ampere Circuit Breaker in line with GFCI receptacles on both the front and back of the assembly. The back receptacle must be the first with GFCI Protection device as defined in the National Electrical Code. Circuit interruption must occur on 6 milliamperes of ground fault-current and must not occur less than 4 milliamperes of ground-fault current. The front receptacle must be attached to the load side of the GFCI device.

1210.6.4.7.6

The AUTO/FLASH Switch when placed in FLASH position must de-energize the Main Contactor and the Transfer Relays (TR) Coils. When the switch is placed in the AUTO position must energize the Main Contactor and the TR Coils. The switch must be a SPST Control Switch.

1210.6.4.7.7

The DC Power must be brought to the back panel using a BEAU S5404-SB Receptacle. An 18 in. DC Power (DCP) Harness, with sheath, consisting of 4 #18 cables, with a BEAU P5404-LAB Connector on each end, must be provided with the Assembly. The harness must be plugged in to an adjacent plug on the DC/COMM Assembly. See Detail 6-5-40 of this Item.

1210.6.4.7.8

Three 36 in. minimum length #8 gauge wires, one black for AC+, one white for AC- and one green or green/yellow for Equipment Ground, must be attached to the rear of the assembly at the AC Raw Power Terminating Block. The cables must be routed between the Service Panel Assembly AC+ terminal, the AC-Bus and the Equipment Ground Bus.
The PDA Assembly must have a resident 18 in. ACP Harness with sheath and strain relief. The other end must contain a BEAU P5412-CCE connector. This harness must be plugged into the P1 connector on the Raw/Clean AC Power Assembly. The ACP harness must provide Flasher input and AC power to the Switch Packs.

An 18 in. long CC Harness must be provided with sheath and strain relief. When plugged into the Raw/Clean AC Power Assembly (CC IN) this harness must provide AC Raw voltage and control logic between the ITS PDA Assembly and the Police Panel control switches.

An 18 in. long ACCP power cord with strain relief and a NEMA 5-15 plug must provide AC Clean power to the PDA ITS Assembly when plugged into the Raw/Clean Power Assembly.

1210.6.4.7.9

A capacitive load of 1 microFarad at 400 VAC must be provided across each Flasher Unit Output.

1210.6.4.8 Input Assembly.

1210.6.4.8.1

The Input Assembly must be an EIA-310B rack mounted assembly providing twelve slots of 22/44 pin PCB sockets. A Model 218 Serial Interface Unit (SIU) must be provided in its location mated to a DIN 96-Pin Connector. The SIU must provide interface and control between the ATC Controller Unit and the input units via System Serial Bus #1 and #2. See Section Model 218 SIU for System Operation and Interface. A 25 Pin D Socket must be provided for communication with the ATC Controller Unit. This Socket must be mated with an 18 in. Communications Cable. This Cable must be attached to the Assembly by slotted 4:40 screws. See Serial Bus Harnesses Detail.

1210.6.4.8.2

The input assembly must be wired to accept Model 222 and 224 ILD Sensor Units, Model 232 Magnetic Sensor Unit, Model 242 and 252 Isolator Units and Slot mounted NEMA Detectors. Each slot connector is a PCB 22/44 Pin Socket type wired for 2 and 4 channel devices. The F and W Unit Output pins must provide the 24 Inputs to the SIU Channel 1 (Serial Bus #1). In addition, NEMA Status inputs must be provided on pins 7 and 20. INBUS must be provided on pin 19 and 21 with four slots address lines matching NEMA pin outs.

1210.6.4.8.3

The SIU Unit must provide 6 detector RESET Outputs, one for every two slots and should the NEMA Status not be required, a RESTART Output from the SIU to the sensor units as a soft reset per channel via pins 7-20. See Input Assembly Wiring Diagram 6-5-37.
1210.6.4.8.4

The INBUS must interface with the SIU Channel 2 to provide communications between “Smart Input Units” and Serial Bus #2. The SIU functions as a hardware driver interface only between the ATC Controller Unit and Input Units installed in the Input Assembly. See Type 218 SIU section 4.

1210.6.4.8.5

A 25 Pin DB Connector must be provided on the left assembly side (rear panel) to interface the assembly (SIU) to the DC/COMM Assembly Serial Bus #1 and #2. A 32 Pin DB (Socket) must be provided for the Test Function. For Test Connector wiring, see Input Wiring Diagrams 6-5-37.

1210.6.4.8.6

Four special function Inputs must be provided via 9-position subminiature D-type connector to the SIU. These are electrically isolated and may handle 12V DC/AC inputs and are referenced to a separate isolated ground. Note: In the ITS Cabinet interface wiring 120 VAC inputs must be routed to the Isolated SIU inputs through a 27K Ohm, 1 watt, resistor located in the PDA ITS Assembly.

1210.6.4.8.7

The assembly height must be 5.25 in. (3 U).

1210.6.4.8.8

An 18 in. harness cable, with strain relief and sheath and terminated with a BEAU S5404-SB connector, must be supplied for interconnect of +24/+12VDC power.

1210.6.4.8.9

Pins D, E, J, K, and L on each PCB Connector slot must be routed to their associated field terminal, i.e. FT1-12 Additionally, an Equipment Ground Lug must be provided on the back panel for termination of a #8 AWG conductor.

1210.6.4.8.10

Each Input Assembly must contain a 4-bit address code plug and socket. The Input Assembly address must be provided by a plug with jumpers installed to produce a binary code 1, 2, 4, and 8. The address receptacle must be installed on the back panel of the Input Assembly, Ground True Logic must be used with Ground True equaling Logic “1”. See instructions on Input Assembly Connectors Detail 6-5-38.

1210.6.4.8.11 Securing PDB Connectors.

All connectors mounted on the PCB must be mechanically secured to the chassis or frame of the unit or assembly.
1210.6.4.9 Output Assembly.

1210.6.4.9.1

The Output Assembly must be an EIA-310B rack mounted assembly delivered in six Switch Pack or fourteen Switch Pack configurations. This assembly may provide eighteen load circuits or forty-two load circuits. Either configuration is designed to interface with a plug in Model 200 Switch Pack Unit. The SIU must be provided resident in its connector to provide interface and control. In addition, a Model 214 AMU Unit must be provided in its connector to sense voltage and current for the CMU. A 25 Pin D Socket must be provided for communication with the ATC Controller Unit. This Socket must be mated with an 18 in. Communications Cable. This Cable must be attached to the Assembly by slotted 4:40 screws. See Serial Bus Harnesses Detail 6-5-39.

1210.6.4.9.2

The Model 205 relay units and Program Blocks must be provided to select control and color state of the Emergency Override State (red, yellow, or no indication output). The programming connectors must be Molex Type 1375 or equal. The relay units and program blocks must be mounted on the rear of the Output Assembly. Program Block Pins must be crimped and soldered. The Model 205 transfer relays must be accessible on the rear of the Output Assembly without the use of tools.

1210.6.4.9.3

An Address Plug and Socket must be provided on Output Assembly for defining the Serial Bus #1 and #3 addressing. See 6/14 Pack Output Assembly Connectors Detail.

1210.6.4.9.4

Transformers must be provided on the incoming AC source for each Switch Pack to measure the load current. See AMU Current Sensing.

1210.6.4.9.5

Field Termination must be provided on the rear panel of the assembly consisting of six-position sockets and plugs.

1210.6.4.9.6

Transient suppression must be provided at the field terminals, for the protection of the Switch Packs, on rear panel of the assembly consisting of three nine-position sockets and plugs for a 6 Pack Output Assembly. A 14 Pack Output Assembly requires seven nine-position sockets and plugs. Each socket must provide protection for two Switch Packs. Protection devices must be terminated to Equipment Ground.

1210.6.4.9.7

A Serial Bus #1 DB25 female connector must be provided on the upper left rear panel of the Output Assembly for serial interconnection to the DC Power/Communication Assembly. This Socket must be mated with an 18 in. Communications Cable. This
Cable must be attached to the Assembly by slotted 4:40 screws. See Serial Bus Harnesses Detail.

1210.6.4.9.8

A CDC Connector must be provided on the rear panel of the Output Assembly for signal interconnection to the unit. The CDC Socket is a 9 Pin “D” connector. These inputs are electrically isolated and may handle 120 VAC signals when wired to the PDA ITS Assembly and 12 VAC inputs that are referenced to a separate isolated ground. This Cable must be attached to the Assembly by slotted 4:40 screws.

1210.6.4.9.9

Two RJ-11S Connectors must be provided on the rear panel of the Output Assembly for signal interconnection of Serial Bus #3.

1210.6.4.9.10

An equipment ground lug must be provided on the rear panel for termination of a #8 green wire.

1210.6.4.9.11

The 6-Pack Output Assembly height must be 5.25 in. (3 U) and the 14-Pack Output Assembly must be 10-1/2 in.

1210.6.4.10 Cabinet Harnesses.

Cabinet Harnesses are supplied with each cabinet configuration. See Serial Bus and DCP Harness Details.

1210.6.4.11 External Communications Termination Assembly.

This assembly requirements have not yet been defined, In the near future there will be need for Copper/Fiber external interface.

1210.6.5 Cabinet Details.

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Field Output Wiring Diagram Labels for Phases 1 Through 7
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Field Output Wiring Diagram for 14 and 6 Pack
AMU to Output Assembly Interconnect
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Bus Assembly and Shelve Attachment Detail
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Luminaire Assembly
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<td>Police Panel and CC Schematic General</td>
<td>73</td>
</tr>
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</table>
Figure 26

Cabinet Housings #1 and #2

NOTES:
1. CABINET BASE TO DOOR OPENING.
2. ALL HOLE PATTERNS CENTERED ON CABINET BOTTOMS.

CABINET HOUSING 1 DETAIL

CABINET HOUSING 2 DETAIL

CABINET HOUSING 1 BOTTOM DETAIL C

CABINET HOUSING 2 BOTTOM DETAIL D

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6-5-1
CABINET HOUSING 3
EXHAUST DETAIL

NOTE 1: SEE Cabinet Housing #3 Detail 2

NOTE 2

NOTE 3

NOTE 4

NOTE 5

Figure 27
Cabinet Housing #3 – Detail 1

NOTES:
1. PERFORATED SCREEN .125 DIA HOLES WITH .187 STAGGER
2. FROM CABINET BASE TO DOOR LIP
3. AFTER CENTER POST IS INSTALLED A SEALANT SHALL BE APPLIED TO PREVENT LEAKAGE
4. TO AVOID INTERFERENCE WITH THE CONTROLLER MOUNT FRONT DOOR SWITCHES AT DRAWER/SHELF HEIGHT
5. CABINET HOUSING FLANGE DETAIL B HOUSINGS 1&2 DETAILS

159-233
CABINET HOUSING #3 POLICE PANEL DETAIL

POLICE LOCK COVER

POLICE PANEL SHALL BE 3.00" DEEP

CABINET HOUSING #3 BOTTOM DETAIL

CAGE SUPPORT DETAIL (TOP VIEW)

NOTES:
1. Hole Slot Detail A see Cabinet Housings 1&2 Details
2. Hole Slot Detail B see Cabinet Housings 1&2 Details
3. Tack Weld Cage Support to bottom assembly front and rear. See Cage Support Assembly Detail.

Figure 28
Cabinet Housing #3 – Detail 2
Figure 29
Cabinet Cages # 1 and # 2
Cabinet Cages #2 – Drawer Modification Location

Figure 30a

NOTES:
1. RACK SHALL INCLUDE A C1/C11 INTERFACE CABLE ASSEMBLY
2. THREE FIELD WIRE SUPPORT BRACKETS ARE REQUIRED ONE FOR THE INPUT ASSEMBLY AND TWO FOR THE 14 PACK.

FIELD WIRE SUPPORT BRACKET ONE REQUIRED PER ASSY.
NOTES:
1. Hole Slot Detail B see Cabinet Housings 1 & 2 Details
2. Lower rack slot dimension will increase by .125 if the lower rack support is part of the pan.

Figure 31
Cabinet Cage to Housing #1 and #2 Supports
Figure 32
Cabinet Cage to Housing # 3 Supports
164-233
Figure 33
Cabinet Housing #2/Adapters and Shipping Pallet

NOTES
1. Hole Slot Detail A
See Cabinet Housings 1&2 Details
Figure 34
“J” Panels – Cage 1

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Figure 35
“J” Panels – Cage 2
Figure 36
Controller Shelf/Drawer Support Assembly
Figure 37
Service Panel Assembly Cage 1 and 2
Figure 38
Service Panel Assembly Schematic
NOTE 1: Slot, mounting holes and shelf holes are the same as the "U" Panel Cage I shown on Drawing 6-5-9.

NOTE 2: Equipment Ground wire shall be terminated here.

NOTE 3: Protective device slips under two screw terminals and the Equipment Ground pigtail is attached to the Equipment Ground bus bar.

NOTE 4: 10 Position Terminal Blocks are equivalent to Marathon PN 679B2121.
4-32 Screw spaced at 9/16".

NOTE 5: Four 10 position Equipment Ground copper bus bars.

Figure 39
Input Termination Panel Housing #1
Figure 40a
Termination Angle Brackets
Figure 41
AC Clean Module Assembly and Harness
Figure 42
Raw/Clean AC Power Assembly and Extension 4 Socket
Figure 43
Raw/Clean AC Power Assembly and Extension 2 Socket
Figure 44
Raw/Clean AC Power Assembly Wiring Diagram 4 Socket
Figure 45
Raw/Clean AC Power Assembly Wiring Diagram 2 Socket
Figure 46
DC Power/Communications Assembly and Extension
DC/COMM ASSEMBLY (COM WIRING)
S1 through S7 are daisy chained within the assembly.
Pins 1/14, 2/15, 3/16, 4/17, 5/18, 6/19, 7/20, 8/21, 9/22, 10/23, 11/24, 12/25 and 13/spare are twisted pairs within the cable harness.

COMM HARNESS EXTENSION CABLE LENGTH 52”

NOTES:
1. DC power cable shall be 14 Gauge Minimum.
2. Communications Interface shall meet CAT 5 electrical characteristics.
3. DC Power/Communications Assembly DB25 D Sub Connectors shall be mounted with 4-40 jack female sockets.
Figure 48
PDA 5 IP ITS – Front View

180-233
Figure 49
PDA 5 EP ITS – Front View
Figure 51
PDA 5 IP ITS/Cabinet – Wiring Diagram
Figure 52
PDA 5 EP ITS/Cabinet – Wiring Diagram
### PDA ITS CONNECTORS and PIN ASSIGNMENTS

#### DCP (Socket)

<table>
<thead>
<tr>
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<td>1</td>
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#### ACP (Socket)

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#### CDC (Socket)

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#### SB3 (Socket)

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#### SB1/SE2 (Socket)

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#### CMU ADDRESS

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#### CMU ADDRESS

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#### 12VAC ISO TERMINAL BLOCK

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<td>4</td>
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#### DCP CONNECTOR

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#### ACP CONNECTOR

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#### CC (Cabinet) CONNECTOR

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#### PDA ITS CDC

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#### SB3 CONNECTOR

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<td>WHITE ORANGE</td>
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<tr>
<td>2</td>
<td>ORANGE</td>
<td>ORANGE</td>
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<tr>
<td>3</td>
<td>WHITE GREEN</td>
<td>WHITE GREEN</td>
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<td>BLUE</td>
<td>BLUE</td>
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<tr>
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<td>WHITE BLUE</td>
<td>WHITE BLUE</td>
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<tr>
<td>6</td>
<td>GREEN</td>
<td>GREEN</td>
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<td>7</td>
<td>WHITE BROWN</td>
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<tr>
<td>8</td>
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**Figure 53**

PDA 5 IP/EP ITS – Connectors

<table>
<thead>
<tr>
<th>Rev Date</th>
<th>6-5-22</th>
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</thead>
</table>
Figure 54
6/14 Pack Output Assembly – Front View

Notes:
1. Model 200 Switchpack Sockets shall be BEAU S-5412-S3 or equal
2. AMU and SIU Connectors shall be DIN 96 S with location same for 6 & 14 pack assemblies
3. Switchpack dimensions are "Typical"
Figure 55
6/14 Pack Output Assembly – Rear Views

NOTES:
1. Maximum Assembly Depth including Transfer Relays resident shall be 13.75".
2. Wire termination take-downs have been replaced with brackets attached to the rail.
3. All connectors called out shall be or equal.
4. Transfer Relay Sockets shall be BEAU S-5458-53.
5. FIELD TERMINAL Plugs shall be Phoenix 7.60 mm (18-04-94-6).
6. Transient Sockets shall be Phoenix 1.00 mm (07-10-24-6).
7. ADDRESS Sockets shall be 12 position Phoenix 3.81 mm (18-20-13-9).
8. ADDRESS Plugs shall be 12 position Phoenix 3.81 mm (18-20-13-9).
9. Program Block Sockets shall be MLEX 1375 (03-09-1154).
10. Program Block Plugs shall be MLEX 1375 (03-09-2159).
11. DC Power Harness shall be min. 18" with BEAU P9-5453-A48 with cover.
12. AC Power Harness shall be min. 18" with BEAU P-5412-CDE Connector.
13. CE and POST shall mate with a max. #10 wire.

6/14 PACK OUTPUT ASSEMBLY
REAR VIEWS

Rev Date 06-22-05 6-5-24
Figure 56
6/14 Pack Output Assembly – Wiring Diagram
NOTE: 6/14 PACK LOCATION ASSIGNMENT REQUIREMENTS:

1. SIXPACK 1 PLUGS INTO S1 (Address 5)
2. SIXPACK 2 PLUGS INTO S2 (Address 6)
3. SIXPACK 3 PLUGS INTO S3 (Address 7)
4. SIXPACK 4 PLUGS INTO S4 (Address 4)
5. 14 PACK 1 PLUGS INTO S1 (Address 1)
6. 14 PACK 2 PLUGS INTO S3 (Address 3)

Figure 57
6 Pack O/A – CB/Flasher Diagram and Assignment Note
Figure 58
14 Pack O/A – CB/Flasher Diagram
Figure 59
6/14 Pack Output Assembly Connectors
1. The terminal block shall be a 6 position #10 feed thru brass nickel plated screw lug - solder 10 to 16 AWG 600v 35A. The terminals are brass tin plated and designed to prevent twisting.

2. The terminal block shall be a Magum A48130604 or approved equivalent.

3. The panel shall be made of alluminite (thickness .060)

4. The panel shall be silk screened as per drawing for phase 1 thru phase 7 and for phase 8 thru phase 14. The terminal blocks shall be silk screened with the terminal number and signal head face color as per drawings.

5. The surge suppressor shall be an Edco MPA-303-8 or approved equivalent.

6. The thumb screws that hold the panel to the angle brackets shall be TSD Screws #8/32.

7. The cable from the output panel to the output assemblies shall be long enough to install a output panel at the top of the 19" rack.

8. All cables shall be marked with a permanent label showing the field panel termination at the end near the Phoenix Connector.

9. Each cable shall be terminated with a Phoenix Connector.

---

**FIELD OUTPUT PANEL**

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**Figure 60a**

Field Output Panel Mechanical
Figure 61b
Field Output Wiring Diagram Labels for Phases 1 Through 7
Figure 62c
Field Output Wiring Diagram Labels for Phases 8 Through 14
## AMU to Output Assembly Interconnect

<table>
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<th>Pin #</th>
<th>Function</th>
<th>Pin #</th>
<th>Function</th>
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<tr>
<td>A1</td>
<td>VCC Ground</td>
<td>B1</td>
<td>+24 VCC in</td>
<td>C1</td>
<td>Address Common</td>
</tr>
<tr>
<td>A2</td>
<td>SB3 Rx+</td>
<td>B2</td>
<td>SB3 Rx+</td>
<td>C2</td>
<td>SB3 Tx+</td>
</tr>
<tr>
<td>A3</td>
<td>SB3 Rx-</td>
<td>B3</td>
<td>SB3 Rx-</td>
<td>C3</td>
<td>SB3 Tx-</td>
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<td>ADDR 1</td>
<td>C4</td>
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<td>A5</td>
<td>SP3 Coll 3+</td>
<td>B5</td>
<td>SP2 Coll 2+</td>
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<td>SP1 Coll 1+</td>
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<td>SP7 Coll 7+</td>
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<td>SP8 Coll 8-</td>
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<td>SP11 Coll 11+</td>
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<td>SP1 Yellow FT1 3/4</td>
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<td>SP1 Red FT1 1/2</td>
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<td>SP2 Green FT2 5/6</td>
<td>B17</td>
<td>SP2 Yellow FT2 3/4</td>
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<td>SP2 Red FT2 1/2</td>
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<td>SP3 Green FT3 5/6</td>
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<td>SP3 Yellow FT3 3/4</td>
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<td>SP3 Red FT3 1/2</td>
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**Figure 64**

AMU to Output Assembly Interconnect

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**Page 196-233**

**AMU to Output Assembly Interconnect**

Rev Date: 06-22-05

6-5-29
Figure 65
Serial Bus #1 and #2 Terminator Unit
The bus assembly is hooked on the "J panel" for rear support and attached to the 1/4 rail for front support with #10-32 screws through the slots.

The shelf assembly is mounted on the "J panel" with #10-32 bolts in four places for support.

Figure 66
Bus Assembly and Shelve Attachment Detail
Figure 67

CDC Harness/Manual Advance Push Button Cable
Figure 68
Luminaire Assembly

NOTES:
TB1-8Position with #8 Binder head screws.
FTR Flash Transfer Relay and Socket.
Switch SPDT 20A rated.
**Figure 69**

Luminaire Assembly Wiring

**WIRE JUMPERS WITH LUGS**

---

Rev Date 07-24-08

SPECIAL
Figure 70
Input Assembly – Front View
1. Address Socket shall be an 8-position Phoenix 3.81mm socket (18-27-59-6) or (18-30-65-1). Address Plug shall be an 8-position Phoenix 3.81mm plug (18-27-76-1).

2. Field Termination Socket shall be a 10-position Phoenix 5.08mm plug (17-55-81-7). Field Termination Plug shall be a 10-position Phoenix 5.08mm plug (17-57-09-3).

3. Communications cable shall be attached to the assembly and to the bus with screws.

Figure 71
Input Assembly – Rear View
Figure 72
Input Assembly – Wiring Diagram
204-233
**Input Assembly SIU Pin Assignments**

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<tr>
<td>2</td>
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<tr>
<td>3</td>
<td>U/O 7</td>
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**Figure 73**

Input Assembly – Connectors

---

**CDF 15**

Column 1: Function

1. Address 3
2. BD GROUND
3. Address 2
4. BD GROUND
5. Address 1
6. BD GROUND
7. Address 0
8. BD GROUND
9. BD GROUND

---

**Input Assembly Connectors**

- **Rev Date**: 05-22-05
- **MIL**: 6-5-38

---

**Jumpers Settings**

- Initial jumper for J1.
1. The Terminal Blocks are 8 position #6 feed thru type with Brass Nickel Plated screws.
2. The pluggable surretors are EDCO MRA 61C-6, designed for loop operation, or equal.
3. The Thumb Screws that hold the panel to the mounting bracket are TSD #6-32 devices.
4. The panel shall be made of .01, H32-5052 aluminum.
5. Sizing of the panels is shown on the drawings and shall include the Loop number.
6. Individual cables shall be 22 gauge shielded twisted pair with drain wire (UL 2092 or equivalent).
7. Each cable shall have enough length to be terminated from the Field Panel to an Input Assembly located at the further most location.
8. All cables shall be marked with a permanent label showing the field panel termination at the end near the Phoenix Connector.
9. Cables shall be terminated with a Phoenix Connector.
10. All unterminated cables shall be bundled and the group bagged.

Figure 74a
Field Input Panel Mechanical
Figure 75b
Field Input Panel #1 Terminal and Labeling
Figure 76c
Field Input Panel #2 Terminal and Labeling
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### TITLE: INPUT ASSEMBLY ASSIGNMENT TO FIELD PANELS

**No Scale**

**July 18, 2008**

special
Figure 78
Serial Bus Harness
Figure 79
DC Power/Police Panel Harnesses

NOTES: CC HARNESS
1. The CC Harness consists of two Molex 1.275 03-09-2158 connectors parallel wired (pin to pin) with #18 gauge minimum wire size. Cable length with connectors is a minimum of 18 inches. The cable shall be shielded.

NOTES: DCP HARNESS
1. The DCP Harness consists of two BEAU F5404-LAB connectors parallel wired (pin to pin) with #18 gauge wire size. The cable length with connectors is a minimum of 18 inches. Cable ends shall be covered with low profile right angle cable clamp ends. The cable shall be shielded. Housing #3 requires a cable 3.5 feet long.
Figure 80
Field Wire Support Bracket/Transient Protector Assembly

MATERIAL: D225 ALUM.

TRANSIENT PROTECTOR ASSEMBLY

MOVISTORS V150–LA20

PLUG is Phoenix 17–34–20–7 or equal

FIELD WIRE SUPPORT BRACKET
TRANSIENT PROTECTOR ASSEMBLY

Rev Date 06-22-05  6–5–41
Figure 81
Fiber Optic Termination Panel
Figure 82
Police Panel and CC Schematic (CMU Bypass)
Figure 83
Police Panel and CC Schematic General
1210.7 Side Mounted Battery Backup System (BBS).

1210.7.1 General.

This is for establishing the minimum requirements for a complete emergency battery backup system for use with Light Emitting Diode Traffic Signal Modules at intersections with Harris County ITS Controller Cabinet Assemblies. The Side Mounted Battery Backup System, herein described as (BBS) shall include, but not be limited to the following: Inverter/Charger, Batteries, a separate automatic and manually operated Bypass Switch and all necessary hardware and interconnect wiring. The BBS shall be capable of providing power for full run-time operation for an “LED-only” intersection (all colors: red, yellow, green and pedestrian heads) or flashing mode operation and intersection Red LED’s. The BBS shall be designed for outdoor applications. The system shall be designed such that all electronics may either be populated in either supplied side-mounted cabinet or in the existing ITS Controller Cabinet Assembly.

1210.7.1.1 Warranty.

Manufacturers shall provide a three (3) year factory-repair warranty for parts and labor on the BBS from date of acceptance but not more than 6 months from ship date. Batteries shall be warranted for full replacement for five (5) years from date of purchase. A battery shall be considered bad should it not deliver 80% of its original capability within the stated warranty period. The warranty shall be included in the total bid price of each BBS supplied.

1210.7.2 Installation Configuration.

The BBS configuration shall have the UPS Power Module installed into the existing traffic control cabinet along with the bypass manual/automatic transfer switch. The batteries shall be installed into its own side mounted battery compartment. The side mounted battery compartment will house the batteries and battery balancer. The cabinet must meet the requirements for NEMA 3R enclosures. The housing must have the dimensions so that it may easily be attached the side of an M, P or 332 Type cabinet. Dimensions of the enclosure shall not exceed 48”H x 20” W x 10” D. The side mounted battery compartment must not interfere with the opening of the traffic cabinet door. The complete side mount compartment and door must be made from .125” thick aluminum.

(1) Door: The side mount battery compartment door shall provide access to the complete cabinet interior. A continuous neoprene gasket must be used to weatherproof the enclosure when the door is closed.

(2) Lock: The lock shall be a Corbin lock with #2 keys.

(3) Finish: The entire enclosure must be a natural aluminum.

(4) Mounting: The battery side mount compartment will be mounted to the traffic control cabinet with minimum six ¼” aluminum rivets and two #10-32 x ¾” stainless
steel pan-head screws. All holes will be field drilled by the Contractor to accommodate the specific mounting requirements as directed by Engineer. A 1” galvanized close nipple, 1” galvanized locknut and 1” plastic bushing shall be included to provide cable through hole access to the controller cabinet assembly.

1210.7.2 Battery System.

1210.7.2.1

Individual batteries shall be:
12 VDC Voltage Rating
Minimum 100 Amp-hour rating
Minimum Group Size 31
Batteries shall be easily replaced and commercially available.

1210.7.2.2

Four (4) batteries will be supplied with each BBS. All batteries must meet their specifications out of the box immediately after the initial 24-hour top off charge. Batteries that require cycling to meet the AH rating specifications are not acceptable.

1210.7.2.3

Batteries shall be deep discharge, sealed prismatic lead-calcium based GEL/VRLA (Gelled Electrolyte/ Valve Regulated Lead Acid). Batteries designed for Cycle applications, such as Solar, are not acceptable. The battery must be designed for Power Standby / BBS applications.

1210.7.2.4

Batteries shall be certified by the manufacturer to operate over a temperature range of –40 °C to +71 °C.

1210.7.2.5

Batteries shall have a Manufactures Warranty of five (5) years. The warranty shall cover any battery that does not meet 80% of its original reserve capability during the warranty period. Full replacement of battery will be required for each battery that does not meet warranty requirement.

1210.7.2.6

The batteries shall be provided with appropriate interconnect wiring for the cabinet into which they will be installed.
1210.7.2.7
Batteries shall indicate maximum recharge data and recharging cycles.

1210.7.3 Battery Harness.

1210.7.3.1
Battery interconnect wiring shall be via two-part modular harness.

1210.7.3.1.1
Part I shall be equipped with red (+) and black (-) cabling that can be permanently connected to the positive and negative posts of each battery. Each red and black pair shall be terminated into an Anderson style Power Pole connector or equivalent.

1210.7.3.1.2
Part II shall be equipped with the mating Power Pole style connector for the batteries and a single, insulated Power Pole style connection to the inverter/charger unit. Harness shall be fully insulated and constructed to allow batteries to be quickly and easily connected in any order to ensure proper polarity and circuit configuration.

1210.7.3.1.3
Power Pole connectors may be either one-piece or two-piece. If a two-piece connector is used, a locking pin shall be used to prevent the connectors from separating.

1210.7.3.1.4
All battery interconnect harness wiring shall be UL Style 1015 CSA TEW all of proper gauge with respect to design current and with sufficient strand count for flexibility and ease of handling.

1210.7.3.1.5
Battery terminals shall be covered and insulated with molded boots so as to prevent accidental shorting.

1210.7.4 Battery Balancer.

1210.7.4.1
Remote Battery Management System: Each BBS will be supplied with a permanently installed Remote Battery Management System, herein identified as RBMS that will monitor each independently installed battery and provide current battery condition and values. The RBMS shall have the ability to monitor, read and record both the battery
string and individual battery voltages, admittance (internal battery resistance), individual battery temperatures and to provide a real-time evaluation of the battery bank health.

The RBMS shall have a built in web interface for communications over Ethernet. The device shall be hardened and operate at a temperature range of -40C to +65C. The device shall include individual 12 volt battery sensors and operate in the range of -40C to +80C. Communications shall be SNMP via TCP/IP.

The RBMS shall include software to automatically poll each intersection, up to 100 per software program, reading individual battery voltage, admittance and temperature, confirming each is within its user programmable parameters. The system shall have the ability to program the intervals as to when each reading is taken, by days, weeks or months. The software will provide for reliable diagnostic of each battery with a predictability value for end of life of each independently installed battery. The software shall be provided as part of the BBS cost.

The RBMS shall also perform as a battery balancer, continuously monitoring all batteries in the string and to interface with the UPSs charger voltage/current so to keep the batteries equal with all batteries within the battery string. The battery balancer shall be provided that automatically balances the battery charge voltage on all batteries in the string to within ±100mV between any two batteries.

1210.7.5 Battery Backup System Operation.

1210.7.5.1

The BBS shall be rated for 2000VA / 2000 watts and provide a minimum three (3) hours of full run-time operation for an “LED-only” intersection, with a maximum 900W active output load capacity. The inverter, when on batteries, shall operate with a minimum efficiency of 80%. The BBS shall operate at 98% or higher when operating under normal condition (utility power is available).

1210.7.5.2

The BBS, for safety and efficiency shall operate with a nominal 48 VDC buss. A DC level higher than 56 VDC shall be considered unsafe and not acceptable.

1210.7.5.3

The maximum transfer time allowed, from disruption of normal utility line voltage to stabilized inverter line voltage from batteries, shall be 5 milliseconds. 5 milliseconds maximum allowable transfer time shall also apply when switching from inverter line voltage to utility line voltage

1210.7.5.4

The BBS shall include a Fail Safe Automatic/Manual Bypass Switch, herein identified as FS-UATS for bypassing the UPS for maintenance. The FS-UATS bypass switch
labelled “UPS” and “Bypass”. The FS-UATS Bypass Switch shall be supplied with mounting attachments for 19” rack mount, rail mount and shelf mount.

1210.7.5.5

The BBS shall provide the user with 5-sets of normally open (NO) and normally closed (NC) single-pole double-throw (SPDT) individually programmable dry relay contact closures, available on a front panel-mounted terminal block, rated at a minimum 120V/1A, and labeled so as to identify each contact.

1210.7.5.5.1

One set of NO and NC contact closures shall be energized whenever the unit switches to battery power. Contact shall be labeled or marked “On Batt.”

1210.7.5.5.2

A second and third set of NO and NC contact closures shall be energized whenever the battery approaches approximately 40% of remaining useful capacity. Contact shall be labeled or marked “Low Batt.” This setting must be adjustable from 10% to 90% via the RS232 connection.

1210.7.5.5.3

A second and third set of NO and NC contact closures shall be energized whenever the battery approaches approximately 40% of remaining useful capacity. Contact shall be labeled or marked “Low Batt.” This setting must be adjustable from 10% to 90% via the RS232 connection.

1210.7.5.5.4

A fourth set of NO and NC contact closures shall be energized two hours after the unit switches to battery power. Contact shall be labeled or marked “Timer.” This setting must be adjustable from 1 Min. to 8 Hours via the RS232 connection.

1210.7.5.5.5

A fifth set of NO and NC contact closures shall be energized in the event that an Alarm condition occurs. Contact shall be labeled “Alarm”.

1210.7.5.5.6

A sixth set of contacts shall provide a 48 VDC output for operating an external fan.
1210.7.5.5.7

Relay contact activation shall be annunciated on the front panel via a visual indication. This can be either discreet LED, or part of LCD screen, etc.

1210.7.5.6

The BBS shall have (2) independently programmable timers 0 to 8 hours with (2) times-of-day restrictions on each timer, providing dry contacts to provide Red Flash operation at user definable times of day.

1210.7.5.7

The BBS shall provide 3 user inputs to support Intrusion Alarm, Emergency Power Off (EPO) and external Self Test (Battery Test).

1210.7.5.8

Operating temperature for both the inverter/charger, and manual bypass switch shall be –40 °C to +74 °C with a load of 850 watts.

1210.7.5.9

The Fail Safe ATS Bypass Switch shall be rated at 120VAC/30 amps, minimum

1210.7.5.10

The BBS shall use a temperature-compensated battery charging system. The charging system shall compensate over a range of 2.5 – 6.0 mV/ °C per cell. The temperature sensor shall be external to the inverter/charger unit. The temperature sensor shall come with 3 meters (9’10”) of wire.

1210.7.5.11

Batteries shall not be recharged when battery temperature exceeds 50 °C ± 3 °C.

1210.7.5.12

BBS shall bypass the utility line power whenever the utility line voltage is outside of the following voltage range: 85VAC to 175VAC (± 2VAC). During a utility input from 85 VAC to 175 VAC the UPS shall utilize its internal double buck, double boost regulation to maintain a 108 to 131 VAC output to the controller cabinet, without the use of the batteries. The BBS shall go into Boost Mode 1 when the AC Line voltage reaches below 110 VAC, +/- 2volts. When the AC line drops below 96 VAC, +/- 2 volts the BBS shall go into Boost Mode 2. When the AC line voltage reaches 131 volts, +/- 2volts the BBS shall go into Buck Mode 1. When the AC Line voltage reaches 150 volts the BBS shall go into Boost Mode 2.
When utilizing battery power, the BBS output voltage shall be between 110 VAC and 128 VAC, pure sine wave output, ≤ 3% THD, 60Hz ± 3Hz.

BBS shall be compatible with NEMA, 170 or 2170 Controllers, and cabinet components for full time operation. All loads to the maximum rating of the BBS shall be powered through the BBS system to utilize the UPS internal Buck/Boost regulation.

In cases of low (below 85VAC) or absent utility line power, when the utility line power has been restored to normal for more than 3 seconds, the BBS shall transfer from the Boost Regulation Mode or the battery backed inverter mode back to utility line mode.

In cases of high utility line power (above 175VAC), when the utility line power has been restored to normal for more than 3 seconds, the BBS shall transfer from the Buck Regulation Mode or battery backed inverter mode back to utility line mode.

BBS shall be equipped to prevent a malfunction feedback to the cabinet or from feeding back to the utility service. For conformation the UPS module must be UL/CSA approved and labeled. “Tested to” or “Built to” UL/CSA is not acceptable.

In the event of inverter/charger failure, battery failure or complete battery discharge, the Fail Safe Transfer Switch shall revert to the NC (and de-energized) state, where utility line power or generator power, if available, is connected to the cabinet.

Recharge time for the battery, from “protective low-cutoff” to 90% or more of full battery charge capacity, shall not exceed eight (8) hours, unless limited by the Temperature Regulated charger due to excessive battery heat that could damage the integrity of the battery string.

Maintenance, Display, Controls and Diagnostics.

The BBS shall include a display and/or meter to indicate current battery charge status and conditions.
1210.7.6.1.1

The BBS shall provide voltmeter standard probe input-jacks (+) and (-) to read the exact battery voltage drop at the inverter input.

1210.7.6.2

The BBS shall have lightning surge protection compliant with IEEE/ANSI C.62.41 Cat. A & B.

1210.7.6.3

The BBS shall be equipped with an integral system to prevent battery from destructive discharge and overcharge.

1210.7.6.4

The BBS and batteries shall be easily replaced with all needed hardware and shall not require any special tools for installation.

1210.7.6.5

The BBS shall display via an LCD panel to indicate the number of times the BBS was activated and the total number of hours the unit has operated on battery power. The LCD display shall show the UPS mode, Alarm status, Input and output voltages, Output current, Battery voltage, battery charger current and last event. It shall allow for programming of the battery charger from 3, 6 and 10 amp charger setting.

1210.7.6.6

The BBS shall include two separate communication ports on the front panel of the UPS, a factory installed internal Ethernet port for SNMP/WEB communications along with an RS 232 port for local communications.

1210.7.6.7

The BBS shall include a Microsoft Windows® Graphical User Interface for programming and monitoring the BBS. This must be provided in addition to the use of Hyper Terminal and can be downloaded from the manufacturer’s website at no cost.

1210.7.6.8

Manufacturer shall include a set of operation manuals with each BBS that includes installation, test and troubleshoot procedures.
1210.7.7 Acceptance and Testing.

1210.7.7.1

Each BBS shall be manufactured in accordance with a manufacturer Quality Assurance (QA) program. The QA program shall include two Quality Assurance procedures: (1) Design QA and (2) Production QA. The Production QA shall include statistically controlled routine tests to ensure minimum performance levels of BBS units built to meet this specification and a documented process of how problems are to be resolved. The manufacturer, or an independent testing lab hired by the manufacturer, shall perform Design Qualification Testing on new BBS system(s) offered, and when any major design change has been implemented on an existing design. A major design change is defined as any modification, of either material, electrical, physical or theoretical, that changes any performance characteristics of the system, or results in a different circuit configuration.

Production Quality Control tests shall be performed on each new system prior to shipment. Each system shall be visually inspected for any exterior physical damage or assembly anomalies. Any defects shall be cause for rejection. Each BBS supplied will have certificate of compliance certificate showing date tested, location of test, and system components that were tested. Failure to meet this requirement shall be cause for rejection.

1210.8 Special Cabinet Requirements.

1210.8.1

All fans, lights in cabinet shall have suppression to prevent noise.

1210.8.2

Cam Unit on the door shall be positioned in a way that any part of the handle will not interfere with the key operation.

1210.8.3

Cabinet Lighting shall be provided on the front and back of the ITS Cabinet. LED (Light-Emitting Diode) strip lighting will be provided within the cabinet on both front and rear of cabinet.

1210.8.4

All wiring shall be neatly wrapped and routed to the satisfaction of the engineer.

1210.8.5

The cabinet shall be shipped with all components contained within the cabinet.
1210.8.6

CMU referenced in this Item shall have the following additional requirements:

(1) In lieu of serial port, CMU supplied for both ITS and ATC cabinets shall be provided with Ethernet port for module configuration, remote communication and diagnostics.

(2) Each supplied CMU will be provided with two (2) red-colored “Datakey” memory device.

(3) CMU firmware shall support flashing yellow operation, configured for operation within either ITS or ATC cabinets supplied to Harris County, programmable through software interface.

(4) At minimum the firmware shall support the following Output File Configuration in ITS cabinets:
   1 - 14 pack
   1 - 14 pack plus, 1 - 6 pack auxiliary file
   3 - 6 pack
   2 - 14 pack

1210.8.7

For each cabinet supplied to Harris County, will be delivered with (1) Auxiliary Display Unit (ADU). Each Auxiliary Display Unit (ADU) will be supplied with one-meter length Serial Bus #3 Cable. Red, Yellow and Green status LED indicators along with Blue LED indicator for each of the thirty two channels supported by CMU. Auxiliary Display Unit (ADU) shall be provided with a Liquid Crystal Display (LCD) based menu-driven display to provide detailed status information from CMU.

1210.8.8

CMU firmware shall support connection to Auxiliary Display Unit (ADU).

1210.9 Legacy Device Implementation.

1210.9.1

A prototyping effort was conducted along with the development of this ITS Cabinet Standard. During the early stages of the prototyping effort, there were no SIU, AMU, and CMU devices available. As a result, a C1 and C11 interconnect list was developed to establish a method for using legacy 2070 controller applications. The list was developed with the Caltrans Model 332 and Model 336 Housing 2 Cabinets in mind. ITS Cabinet Housing #3 (with two internal racks) was the target prototype model being deployed in Harris County Texas, Housing 1 and Housing 2 ITS Cabinets have been deployed in small numbers.
The Input Assemblies and Output Assemblies are equipped with “Test Connectors” that are tied to the Detector Pins F and W on the Input Assembly and to the DC Switch Pack drives on the Output Assembly. While not specifically prototyped, the NEMA “A,” “B,” and “C” connectors could be assigned in-lieu of the C1 and C11 connectors to provide an interconnection of legacy NEMA devices within the ITS Cabinet.

Additionally, the prototyping effort did explore the use of a NEMA Malfunction Management Unit (MMU) in-lieu of the AMU and CMU. To accomplish this, the MMU cable was attached to the Field Terminals, thus replacing the AMU and CMU.

The PDA contains a CDC Connector with the STOP TIME, MANUAL CONTROL ENABLE, INTERVAL ADVANCE, and MANUAL FLASH switch signals coming from the Police Panel. By attaching the PDA CDC Connector to Output Assembly #1, as shown in drawing A-1-2, and installing an isolator within this Output Assembly, signals were routed to the C1 and C11 connector interface. With this configuration, an SIU was not required for the internal cabinet communications. A special Isolation Module was developed to convert the AC Switch outputs to DC (ON/OFF) signals conditioned for the Controller.

These modifications were made using a Cable Assembly that was removable. As such, the ITS Cabinet supported legacy devices, while retaining its serial interfaces.

1210.10 Substitution of Materials.

1210.10.1

Set forth in these specifications are definite models, materials, etc. of particular manufacture, however, items of equal appearance, durability, performance and design will be accepted upon approval by the County Engineer. The successful bidder is required to submit to the Harris County Engineering Department, Transportation and Planning Division, engineering brochures and information on all materials he desires to furnish and install which are of different manufacture or model number specified herein. The submittal is for approval or disapproval by the County Engineer. The submittals shall be furnished no later than two (2) days after bid opening.

1210.11 Guarantees.

1210.11.1

The Supplier shall burn in each ITS Traffic Controller Assembly for a period of forty-eight (48) hours at a temperature of 140 degrees Fahrenheit or for a period of ninety-six (96) hours at a temperature of 75 degrees Fahrenheit. A certification shall be included with each controller cabinet indicating the dates of the burn in period, number of hours, burn in temperature, and results.

The Supplier, by accepting this contract, guarantees all workmanship, materials, and equipment performed or furnished under this specification for a period of two (2) years from date of delivery. The Supplier shall at his expense and within said term of guarantee repair, replace, or adjust all faulty, broken, or maladjusted materials and/or equipment furnished under this contract. Vandal damage and damage due to automobile accidents or acts of nature will not be included under contractor’s guarantee.
1210.12 Glossary.

1210.12.1 Terms and Abbreviations

Wherever the following terms or abbreviations are used, the intent and meaning is interpreted as follows:

- A - Ampere
- AC - Alternating Current
- AC+ - 120 Volts AC, 60 hertz ungrounded power source
- AC- - 120 Volts AC, 60 hertz grounded return to the power source
- AGENCY - The AGENCY director, acting either directly or through properly authorized agents, such agents acting within the scope of the particular duties delegated to them.
- ANSI - American National Standard Institute
- ASCII - American Standard Code for Information Interchange
- Assembly - A complete machine, structure or unit of a machine that was manufactured by fitting together parts and/or modules
- ASTM - American Society for Testing and Materials
- AWG - American Wire Gage
- C - Celsius
- C Language - The ANSI C Programming Language
- Cabinet - An outdoor enclosure generally housing the controller unit and associated equipment
- Certificate of Compliance - A certificate signed by the manufacturer of the material or the manufacturer of assembled materials stating that the materials involved comply in all respects with the requirements of the specifications
- Channel - An information path from a discrete input to a discrete output.
• Component - Any electrical or electronic device

• Contractor - The person or persons, Manufacturer, firm, partnership, corporation, vendor or combination thereof, who have entered into a contract with the AGENCY, as party of the second part or legal representative

• Controller Unit - That portion of the controller assembly devoted to the operational control of the logic decisions programmed into the assembly

• CPU - Central Processing Unit

• CTS - Clear To Send

• DAT Program Test Program - The AGENCY’s Diagnostic and Acceptance Test Program

• dB - Decibel

• dBa - Decibels above reference noise, adjusted

• DC - Direct Current

• DCD - Data Carrier Detect (Receive Line Signal Detector)

• DIN - Deutsche Industrie Norm

• DRAM - Dynamic random access memory. Random access means that the processor can access any part of the memory or data storage space directly rather than having to proceed sequentially from some starting place. DRAM is dynamic in that it needs to have its storage cells refreshed or given a new electronic charge every few milliseconds.

• EG - Equipment Ground

• EIA - Electronic Industries Association

• EMI - Electro Magnetic Interference
• EPROM - Ultraviolet Erasable, Programmable, Read Only Memory Device

• EEPROM - Electrically Erasable, Programmable, Read Only Memory Device

• Equal - Connectors: comply with physical dimensions, contact material, plating and method of connection. Devices: comply to function, pin out, electrical and operating parameter requirements, access times and interface parameters of the specified device

• ETL - Electrical Testing Laboratories, Inc.

• Firmware - A computer program or software stored permanently in PROM, EPROM, ROM or semi-permanently in EEPROM

• FLASH - A +5 VDC powered IC Memory Device with nonvolatile, electrically erasable, programmable, 100K read/write minimum cycles and fast access time features

• FPA - Front Panel Assembly

• HEX - Hexadecimal

• Hz - Hertz

• IC - Integrated Circuit

• I.D. - Identification

• IEEE - Institute of Electrical and Electronics Engineers

• ISO - Isolated

• Jumper - A means of connecting/disconnecting two or more conductive by soldering/desoldering a conductive wire or by PCB post jumper

• KB - Kilobytes

• Keyed - Means by which like connectors can be physically altered to prevent improper insertion.
• Laboratory - The established laboratory of the AGENCY or other laboratories authorized by the AGENCY to test materials involved in the contract

• LCD - Liquid Crystal Display

• LED - Light Emitting Diode

• LOGIC - Negative Logic Convention (Ground True) State

• LSB - Least Significant Byte

• Lsb - Least Significant Bit

• MB - megabyte

• MSB - Most Significant Byte

• msb - Most Significant Bit

• m - Milli

• MCU/MPU/IMP - Micro Controller Unit, Microprocessor Unit, or Integrated Multiprotocol Processor

• MIL - Military Specifications

• MODEM - Modulation/Demodulation Unit

• Module - A functional unit that plugs into an assembly

• Motherboard - A printed circuit connector interface board with no active or passive components

• MOS - Metal-Oxide Semiconductor

• MOV - Metal-Oxide Varistor

• MS - Military Standards

• N - Newton: SI unit of force
• N.C. - Normally closed contact

• N.O. - Normally open contact

• NA - Presently Not Assigned. Cannot be used by the Manufacturer for other purposes

• NEMA - National Electrical Manufacturer's Association

• NETA - National Electrical Testing Association, Inc.

• n - nano

• NLSB - Next Least Significant Byte

• nlsb - Next Least Significant Bit

• NMSB - Next Most Significant Byte

• nmsb - Next Most Significant Bit

• PCB - Printed Circuit Board

• PDA - Power Distribution Assembly

• PLA/PAL - Programmable Array Logic Device

• Power Failure - A Power Failure is said to have occurred when the incoming line voltage falls below 92 +/- 2 VAC for 50 milliseconds. See Power Conditions.

• Power Restoration - Power is said to be restored when the incoming line voltage equals or exceeds 97 +/- 2 VAC for 50 milliseconds. See Power Conditions.

• Power Conditions - 16.7 ms (one 60 Hertz cycle) reaction period is allowed to be included in the 50 milliseconds timing or added to (67 milliseconds duration). The hysteresis between power failure and power restoration voltage settings must be a min. of 5 VAC with a threshold drift of no more than 0.2 VAC.

• ppm - Parts per million
• PWM - Pulse Width Modulation
• RAM - Random Access Memory
• RF - Radio Frequency
• RMS - Root-Mean-Square
• ROM - Read Only Memory Device
• RTS - Request to Send
• R/W - Controller Unit Read/Write Control Line
• RxD - Received Data
• SCI - Serial Communications Interface
• SDLC - Synchronous Data Link Control
• S - Logic State
• s - second
• Second Sourced - Produced by more than one Manufacturer
• SRAM - Static Random Access Memory Device
• SW - Switch
• TB - Terminal Block
• TOD - Time Of Day Clock
• Triac - Silicon-Controlled Rectifier which controls power bilaterally in an AC switching circuit
• TTL - Transistor-Transistor Logic
• Thumb Screw Device (TSD) - A retractable screw fastener with projecting stainless steel screw, spring and natural aluminum knob finish. (TSD No.2 must be flat black.)
TSD No.1 - 8-32 SOUTHCO #47-62-301-20 or equal.
TSD No.2 - 8-32 SOUTHCO #47-62-301-60 or equal.
TSD No.3 - M3 SOUTHCO #47-82-101-10 or equal.

- TxD - Transmitted Data
- u - Micro
- UL - Underwriter's Laboratories, Inc.
- VAC - Voltage Alternating Current (root mean square)
- VDC - Voltage Direct Current
- VME - Versa Module Eurocard, VMEbus Standard IEEE P1014/D1.2
- x - Number Value
- XX - Manufacturer's Option
- WDT - Watchdog Timer: A monitoring circuit, external to the device watched, which senses an Output Line from the device and reacts

1210.13 MEASUREMENT AND PAYMENT.

Intelligent Transportation System (ITS) Controller Cabinet Assembly shall be paid by each controller cabinet assembly and shall include full compensation necessary to furnish and deliver the specified equipment, as called for in these specifications.

END OF ITEM 1210
2000 ITEMS

• 2070 – Advanced Transportation Controller
ITEM 2070
ADVANCED TRANSPORTATION CONTROLLER

2070.1 Description. Furnish Type 2070 Advanced Transportation Controller (ATC) unit. The Advanced Transportation Controller (ATC) is a general purpose programmable controller that is intended for continuous unattended operation in harsh environments.

This Item defines specific, interchangeable modules that are combined to form a Type 2070 ATC that is capable of running control software that might be provided from a variety of providers. This Item defines several module options that can be arranged in a variety of composition configurations to meet the needs of the user.

This Item lays out compositions for Full, NEMA, Lite, and ITS configurations. The Type 2070 version of the ATC is designed such that all components are fully standardized and are therefore interchangeable.

2070.2 Definitions. The Type 2070 Controller Housing defines a controller housing that is intended to fit an EIA 19 in. rack mounted form commonly found in the Type 332 and ITS family of cabinets. A NEMA base module is defined for those NEMA TS1 and TS2 shelf mounted applications.

(2) CPU Module. The CPU module consists of the main CPU, memory, software and interfaces to the remainder of the controller. There are three CPU module configurations identified in this standard. The Type 2070-1A is a two-board configuration that has a VME-based CPU board and a Transition Board. The Type 2070-1B configuration consists of a single board module. The Type 2070-1C configuration is intended to interface with the "engine board" specified by the ATC v5.0 standard.

(3) Field I/O Module. The Field I/O Module provides a mechanism for input and output interfaces. There are three options for the Field I/O Module. The Type 2070-2A Modules is intended to provide a parallel I/O interface with the Type 332 family of cabinets using the C1S connector. The Type 2070-2B Module is intended to provide a serial I/O interface to the ITS cabinet family and the NEMA interface to TS1 cabinets. The Type 2070-2N is for the NEMA TS2 Type 1 cabinets.

(4) Front Panel Module. A controller Front Panel usually contains a keyboard and display that comprise the user field interface. The Front Panel on the Type 2070 controller is optional. This standard identifies three front panel options: the Type 2070-3A Front Panel includes a large character (4 lines of 40 characters) Liquid Crystal Display (LCD), the Type 2070-3B Front Panel includes a small character (8 lines of 40 characters) LCD, and the Type
2070-3C contains only a serial connection for interfacing with a notebook computer or some other handheld computing device.

(5) Power Supply Module. A power supply module is used to convert 120 volt power to voltages required to operate the electronics inside the Type 2070 controller unit. This power supply must meet certain minimum electrical characteristics defined herein for its intended use. This standard identifies two options for the Power Supply: The Type 2070-4A identifies a 10 ampere power supply that is needed for those cases there is a need to support the VME cage assembly, or other modules. The Type 2070-4AN identifies the corresponding power supplies needed to support the NEMA TS1 and TS2 standards. This power supply has the Power-up and Power-down signals adjusted to meet NEMA specifications.

(6) Cage Assembly. The Cage Assembly is an optional expansion module for the Type 2070 ATC.

(7) Communications Modules. This standard includes a variety of serial and modem communications modules. The 2070-6 series of modules are for internal modems and the Type 2070-7 series of modules are for serial communications.

(8) NEMA Interface. This standard includes requirements for an optional module to interface with the NEMA TS1 and NEMA TS2 Type 2 cabinets. The Type 2070-8 NEMA Field I/O Module is an external module that attaches to the bottom of the 2070 and provides for the typical “A,” “B,” and “C” NEMA connectors.

2070.3  General Requirements.

(1) General. All furnished equipment must be new and unused. Vacuum or gaseous tubes and electro-mechanical devices (unless specifically called out) must not be used.

(2) Interchangeability. Assemblies and their associated devices must be electrically and mechanically interchangeable at both the assembly and device levels:

2070.4  Assemblies and associated modules

(1) Type 2070-L Controller Unit

- Type 2070-1B CPU
- Type 2070-2A Field I/O Module
- Type 2070-3 Front Panel Assembly
Type 2070-4A Power Supply
Type 2070-7 Serial MA Module

(2) Type 2070-LS Controller Unit
- Type 2070-1B CPU Module
- Type 2070-2B Field I/O Module
- Type 2070-3 Front Panel Assembly
- Type 2070-4A Power Supply
- Type 2070-7 Serial MA Module

(3) Type 2070-LC Controller Unit
- Type 2070-1C CPU Module
- Type 2070-2A Field I/O Module
- Type 2070-3 Front Panel Assembly
- Type 2070-4A Power Supply
- Type 2070-7 Serial MA Module

(4) Type 2070-LCS Controller Unit
- Type 2070-1C CPU Module
- Type 2070-2B Field I/O Module
- Type 2070-3 Front Panel Assembly
- Type 2070-4A Power Supply
- Type 2070-7 Serial MA Module

(5) Type 2070-N1B Controller Unit
- Type 2070-1B CPU Module
- Type 2070-2B Field I/O Module
- Type 2070-3 Front Panel Assembly
- Type 2070-4AN Power Supply Module
- Type 2070-7 Serial MA Module
- Type 2070-8 NEMA Module

(6) Type 2070-N2 Controller Unit
- Type 2070-1B CPU Module
- Type 2070-2N Field I/O Module – this module contains 120VAC outlet (accommodates 2070-4 line cord) and has a built-in CPU and memory emulating the 2070-8 NEMA base.
- Type 2070-3 Front Panel Assembly
- Type 2070-4AN Power Supply Module
- Type 2070-7 Serial Comm. Module

(7) Type 2070-N1C Controller Unit
- Type 2070-1C CPU Module
- Type 2070-2B Field I/O Module
- Type 2070-3 Front Panel Assembly
- Type 2070-4AN Power Supply Module
- Type 2070-7 Serial MA Module
- Type 2070-8 NEMA Module

(8) Type 2070-N2C Controller Unit
- Type 2070-1C CPU Module
- Type 2070-2N Field I/O Module – this module contains 120VAC outlet (accommodates 2070-4 line cord) and has a built-in CPU and memory emulating the 2070-8 NEMA base.
- Type 2070-3 Front Panel Assembly
- Type 2070-4BN Power Supply Module
- Type 2070-7 Serial MA Module

2070.5 Documentation Manuals. Two copies of Manual Documentation must be supplied for each item purchased up to 200 manuals per order. The manual must be bound in durable covers made of either 65 pound stock paper or
clear plastic. The manual must be printed on 8-1/2 in. by 11 in. paper, with the exception that schematics, layouts, parts lists and plan details may be on 11 in. by 17 in. sheets, with each sheet neatly folded to 8-1/2 in. by 11 in. size. A minimum of Times New Roman or Arial 10 point font must be used for all manual text, excluding drawings and schematics. Drawing text may use a smaller font size.

Manual Contents. Each manual must include the following sections in the order listed:

Table of Contents

- Glossary
- Manufacturer Contact Information
- Address
- Telephone Number
- Fax Number
- General Email Address
- General Description
- General Characteristics
- Installation
- Adjustments
- Theory of Operation
- Systems Description (include block diagram).
- Detailed Description of Circuit Operation.
- Maintenance
- Preventive Maintenance.
- Trouble Analysis.
- Trouble Shooting Sequence Chart.
- Wave Forms.
- Voltage Measurements.
Alignment Procedures.

Parts List (include circuit and board designation, part type and class, power rating, component manufacturer, mechanical part manufacturer, data specification sheets for special design components and original manufacturer's part number).

2070.6 Electrical Interconnection Details & Drawings. Schematic and Logic Diagram

Assembly Drawings and a pictorial diagram showing physical locations and identification of each component or part.

The date, serial numbers, model numbers and revision numbers of equipment covered by the manuals must be printed on the front cover of the manuals.

Draft Manual. A preliminary draft of the manual must be submitted, when required, to the DEPARTMENT for approval prior to final printing.

Packaging. Each item delivered must be individually packed in its own shipping container. When loose Styrofoam is used for packing the item, the item must be sealed in a plastic bag to prevent direct contact with the Styrofoam.

Delivery. Each item delivered for testing must be complete, including manuals, and ready for testing.

Metals. All sharp edges and corners must be rounded and free of any burrs.

Aluminum. Sheet must be 63 gauge American Standard (0.060-in.) minimum thick Type 3003-H14 or Type 5052-H32 ASTM B209 “Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate” aluminum alloy. Rod, Bar and Extruded must be Type 6061-T6, or equal.

Stainless Steel. Sheet must be annealed or one-quarter-hard complying with the ASTM Designation: A666 “Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar” for Type 304, Grades A or B, stainless steel sheet.

Cold Rolled Steel. Sheet, Rod, Bar and Extruded must be Type 1018/1020.

Plating. All cold roll steel must be plated. All plating must be either cadmium plating meeting the requirements of Federal Specification QQ-P-416C, Type 2 Class I or zinc plating meeting the requirements of ASTM B633 “Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel” Type II SC4.
Mechanical Hardware. All bolts, nuts, washers, screws, hinges and hinge pins must be stainless steel unless otherwise specified.

Electrical Isolation. Within the circuit of any device, module, or Printed Circuit Board (PCB), electrical isolation must be provided between DC logic ground, equipment ground and the AC-conductor. They must be electrically isolated from each other by 500 megohms, minimum, when tested at the input terminals with 500 VDC.

Daughter Boards. Keyboards and LCD/LED Displays are considered daughter boards. Daughter boards must be mechanically secured with a minimum of four spacers/metal screws. Connectors must be either Flat Cable or PCB Headers. Components are to be mounted under the daughter board.

2070.7 Components. All components must be second sourced and must be of such design, fabrication, nomenclature or other identification as to be purchased from a wholesale distributor or from the component manufacturer. When a component is of such special design that it precludes the purchase of identical components from any wholesale distributor or component manufacturer, one spare duplicate component must be furnished with each 20, or fraction thereof, components used. The electronic circuit design must be such that all components of the same generic type, regardless of manufacturer, must function equally in accordance with the specifications.

2070.8 Electronic Components. No device to be socket mounted unless specifically called out. No component to be operated above 80% of its maximum rated voltage, current or power ratings. Digital components must not be operated above 3% over their nominal voltage, current or power ratings.

No component to be provided where the manufactured date is three years older than the contract award date. The design life of all components, operating for twenty-four hours a day and operating in their circuit application, must be ten years or longer.

Components must be arranged so they are easily accessible, replaceable and identifiable for testing and maintenance. Where damage by shock or vibration exists, a clamp, fastener, retainer, or hold-down bracket must support the component mechanically.

The Manufacturer must submit detailed engineering technical data on all components at the request of the Department. The Manufacturer must certify that the component application meets the requirements of this standard.

Capacitors. The DC and AC voltage ratings as well as the dissipation factor of a capacitor must exceed the worst-case design parameters of the circuitry by 150%. Capacitor encasements must be resistant to cracking, peeling and discoloration. All capacitors must be insulated and must be marked with their
capacitance values and working voltages. Electrolytic capacitors must not be used for capacitance values of less than 1.0 microfarad and must be marked with polarity.

Potentiometers. Potentiometers with ratings from 1 to 2 watts must meet Military Type RV4 requirements. Under 1 Watt potentiometers must be used only for trimmer type function. The potentiometer power rating must be at least 100\% greater than the maximum power requirements of the circuit.

Resistors. Fixed carbon film, deposited carbon, or composition-insulated resistors must conform to the performance requirements of Military Specifications MIL-R-11F or MIL-R-22684. All resistors must be insulated and be marked with their resistance values. Resistance values must be indicated by the EIA color codes, or stamped value. The value of the resistors must not vary by more than 5\% between -37 degrees C and 74 degrees C.

a. Special ventilation or heat sinking must be provided for all 2- watt or greater resistors. They must be insulated from the PCB.

2070.9 Semiconductor Devices. All transistors, integrated circuits, and diodes must be a standard type listed by EIA and clearly identifiable.

All metal oxide semiconductor components must contain circuitry to protect their inputs and outputs against damage due to high static voltages or electrical fields.

Device pin "1" locations must be properly marked on the PCB adjacent to the pin.

2070.10 Transformers and Inductors. All power transformers and inductors must have the manufacturer's name or logo and part number clearly and legibly printed on the case or lamination. All transformers and inductors must have their windings insulated, be protected to exclude moisture, and their leads color coded with an approved EIA color code or identified in a manner to facilitate proper installation.

2070.11 Triacs. Each triac with a designed circuit load of greater than 0.5 Amperes at 120 VAC must be mounted to a heat sink with thermal conductive compound or material, in addition to being mechanically secured.

2070.12 Circuit Breakers and Fuses. Circuit breakers must be listed by UL or ETL. The trip and frame sizes must be plainly marked (marked on the breaker by the manufacturer), and the ampere rating visible from the front of the breaker. Contacts must be silver alloy and enclosed in an arc-quenching chamber. An ambient air temperature range of from -18 degrees C to 50 degrees C must not influence overload tripping. The minimum Interrupting Capacity must be 5,000 amperes, RMS when the breaker is secondary to a UL approved fuse
or primary circuit breaker and both breakers in concert provide the rated capacity. For circuit breakers 80 amperes and above, the minimum interrupting capacity must be 10,000 amperes, RMS. Circuit breakers must be the trip-free type with medium trip delay characteristic (Carlingswitch Time Delay Curve #24 or equal).

Load Circuit Breaker Auxiliary Internal Switches. The Load Circuit Breakers used to power Switch Packs must have auxiliary switches. The auxiliary switches must “open” when the load breaker has tripped and the system will transfer the power from the Main Contactor to the Flash or Blank condition.

Fuses. All Fuses that are resident in a bayonet style fuse holder must have the fuse size rating labeled on the holder or on the panel adjacent to the holder. Fuses must be easily accessible and removable without use of tools.

2070.13 Switches. Dip. Dual-inline-package, quick snap switches must be rated for a minimum of 30,000 operations per position at 50 mA, 30 VDC. The switch contact resistance must be 100 milliohms maximum at 2 mA, 30 VDC. The contacts must be gold over brass.

Logic. The switch contacts must be rated for a minimum of 1-ampere resistive load at 120 VAC and must be silver over brass (or equal). The switch must be rated for a minimum of 40,000 operations.

Control. The switch contacts must be rated for a minimum of 5 amperes resistive load at 120 VAC or 28 VDC and be silver over brass (or equal). The switch must be rated for a minimum of 40,000 operations.

Power. Ratings must be the same as CONTROL, except the contact rating must be a minimum of 10 amperes at 125 VAC.

2070.14 Terminal Blocks. The terminal blocks must be barrier type, rated at 20 amperes and 600 VAC RMS minimum. The terminal screws must be 0.3125 in. minimum length nickel-plated brass binder head type with screw inserts of the same material. Screw size is called out under the associated file, panel or assembly.

Screw Lug and Cam Driven Connectors. Provided the connectors mate, screw lug cam driven devices or crimp pin connectors must be allowable if the interface is part of a harness. For field termination, screw lug and cam driven assemblies are interchangeable for field wiring termination, provided they both accommodate 22 gauge wire on the inputs and 22 gauge wire on the outputs.

2070.15 Wiring, Cabling and Harnesses. Wiring, Cabling and Harnesses must be neat, firm and properly bundled with external protection. They must be tie-wrapped and routed to minimize crosstalk and electrical interference. Each harness must be of adequate length to allow any conductor to be connected...
properly to its associated connector or termination point. Conductors within an encased harness have no color requirements. Printed circuit motherboards are to be used where possible to eliminate or reduce cabinet wiring.

Wiring containing AC must be bundled separately or shielded separately from all DC logic voltage control circuits.

Wiring must be routed to prevent conductors from being in contact with metal edges. Wiring must be arranged so that any removable assembly may be removed without disturbing conductors not associated with that assembly.

All conductors, except those that can be readily traced, must be labeled. Labels attached to each end of the conductor must identify the destination of the other end of the conductor.

All conductors must conform to MIL-W-16878E/1 or better and have a minimum of 19 strands of copper. The insulation must be polyvinyl chloride with a minimum thickness of 10 mils or greater. Where insulation thickness is 15 mils or less, the conductor must conform to MIL-W-16878/17.

Conductor color identification must be as follows:

AC- circuits – white

Equip. Ground - solid green or continuous green color with 1 or more yellow stripes

DC logic ground - continuous white with a red stripe

AC+ circuits - continuous black or black with colored stripe

DC logic ungrounded or signal - any color not specified

2070.16 Indicators and Character Displays. All indicators and character displays must be readily visible at a radius of up to 4 feet within the cone of visibility when the indicator is subjected to 97,000 lux (9,000 foot-candles) of white light with the light source at 45 degrees (+/-2 degrees) to the front panel.

All indicators and character displays must have a minimum 90 degrees cone of visibility with its axis perpendicular to the panel on which the indicator is mounted. All indicators must be self-luminous. All indicators must have a rated life of 100,000 hours minimum. Each LED indicator must be white or clear when off. Indicators supplied on equipment requiring handles must be mounted such that a horizontal clearance is provided. Liquid Crystal Displays (LCD) must be readable at temperatures of -20 degrees C to +70 degrees C. All controller unit functions are required to operate at temperatures of –37 degrees C to +74 degrees C.
2070.17 Connectors. Connectors must be keyed to prevent improper insertion of the wrong connector where equipment damage or operator injury may result. The mating connectors must be designated as the connector number and male/female relationship, such as C1P (plug or PCB edge connector) and C1S (socket).

2070.1 Type T. Type T connector must be a single row, 10 position, feed through terminal block. The terminal block must be a barrier type with 6-32, 0.25 in. or longer, nickel plated brass binder head screws. Each terminal must be permanently identified as to its function.

Plastic Circular and Type M. Pin and socket contacts for connectors must be beryllium copper construction subplated with 1.27 microns nickel and plated with 0.76 microns gold. Pin diameter must be 0.0618 in. All pin and socket connectors must use the AMP #601105-1 or #91002-1 contact insertion tool and the AMP #305183 contact extraction tool or equal.

2070.18 Card Edge and Two Piece PCB. Edge connectors must have bifurcated gold-plated contacts. The PCB receptacle connector must meet or exceed the following:

- Operating Voltage: 600 VAC (RMS)
- Current Rating: 5.0 Amperes
- Insulation Material: Diallyl Phthalate or Thermoplastic
- Insulation Resistance: 5,000 Megohms
- Material: Copper alloy plated with 0.00005 in. of nickel and 0.000015 in. of gold
- Contact Resistance: 0.006 Ohm maximum

The two-piece PCB connector must meet or exceed the DIN 41612. The PCB 22/44 Connector must have 22 independent contacts per side; dual sided with 0.156 in. contact centers.

2070.19 Wire Terminal. Each wire terminal must be solderless with PVC insulation and a heavy-duty short -locking spade type connector. Crimp terminal connectors using a Controlled-Cycle type crimping tool.

2070.20 Flat Cable. Each flat cable connector must be designed for use with 26 AWG cable; have dual cantilevered phosphor bronze contacts plated with 0.00015 in. of gold over 0.00005 in. of nickel; and have a current rating of 1 Ampere minimum and an insulation resistance of 5 Megohms minimum.
2070.21 PCB Header Post. Each PCB header post must be 0.025 in. square by 0.3425 in. high from the plane of the PCB to the end of the pin; be mounted on 0.10 in. centers; and be tempered hard brass plated with 0.00015 in. of gold over 0.00005 in. of nickel.

2070.22 PCB Header Socket. Each PCB header socket block must be nylon or diallyl phthalate. Each PCB header socket contact must be removable, but crimp-connected to its conductor. List the part number of the extraction tool recommended by its manufacturer. Each PCB header socket contact must be brass or phosphor bronze plated with 0.0015 in. of gold over 0.00005 in. of nickel.

2070.23 Surge Protection Device. The surge suppression device must comply with ANSI/IEEE C62.41 (100 Kilohertz Ring Wave, the 1.2/50 microseconds – 8/20 Combination Wave and the EFT Burst) at voltages and currents specified at “Location Category B2” and at “Test Severity” level III (i.e. up to 4.0 Kilovolts, open-circuit).

2070.24 Mechanical Requirements. Assemblies. All assemblies must be modular, easily replaceable and incorporate plug-in capability for their associated devices or PCBs. Assemblies must be provided with two guides for each plug-in PCB or associated device (except relays). The guides must extend to within 0.75 in. from the face of either the socket or connector and front edge of the assembly. If Nylon guides are used, attach the guides securely to the file or assembly chassis.

Locking Devices. All screw type fasteners must utilize locking devices or locking compounds except finger screws, which are captive.

PCB Design and Connectors. No components, traces, brackets or obstructions are to be within 0.125 in. of the board edge (guide edges). The manufacturer's name or logo, model number, serial number, and circuit issue or revision number must appear and be readily visible on all PCBs.

2070.25 Model and Serial Numbers. The manufacturer's model number and circuit issue or revision number must appear on the rear panel of all equipment supplied (where such panel exists). In addition to any assignment of model numbers by the manufacturer, the TYPE number must be displayed on the front panel in bold type, at least 0.25 in. high.

A permanent label must be affixed to the inside near and center floor of the Type 2070 unit chassis when viewed from the front. The label must display the unit's serial number and be permanent and easy to read.

2070.26 Workmanship. Workmanship must conform to the requirements of this Item and be in accordance with the highest industry standards.
2070.27 Tolerances. The following tolerances must apply, except as specifically shown on the plans or in these specifications:

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DIMENSIONAL TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet Metal</td>
<td>+/-0.0525 in.</td>
</tr>
<tr>
<td>PCB</td>
<td>+0 in., - 0.010 in.</td>
</tr>
<tr>
<td>Edge Guides</td>
<td>+/-0.015 in.</td>
</tr>
</tbody>
</table>

*Note: These dimensional tolerances do not apply to material gauge or thickness.

2070.28 Engineering. Human Engineering. The equipment must be engineered for simplicity, ease of operation and maintenance.

Knobs must be a minimum of 0.5 in. in diameter and a minimum separation of 0.5 in. edge to edge.

PCBs must slide smoothly in their guides while being inserted into or removed from the frame and fit snugly into the plug-in PCB connectors. PCBs must require a force no less than 5 pounds-force or greater than 50 pounds-force for insertion or removal.

2070.29 Design Engineering. The design must be inherently temperature compensated to prevent abnormal operation. The circuit design must include such compensation as is necessary to overcome adverse effects due to temperature in the specified environmental range. The design must take into consideration the protection of personnel from all dangerous voltages.

Generated Noise. No item, component or subassembly is to emit an audible noise level exceeding the peak level of 55 dBA when measured at a distance of one meter away from its surface, except as otherwise noted. No item, component or subassembly is to emit a noise level sufficient to interfere with processing and communication functions of the controller circuits.

2070.30 Printed Circuit Boards. Design, Fabrication and Mounting.

All contacts on PCBs must be plated with a minimum thickness of 0.00003 in. gold over a minimum thickness of 0.000075 in. nickel.

PCB design must be such that when a component is removed and replaced, no damage is done to the board, other components, conductive traces or tracks.

Fabrication of PCBs must be in compliance with Military Specification MIL-P-13949, except as follows:
NEMA FR-4 glass cloth base epoxy resin copper clad laminates 0.0625 in. minimum thickness must be used. Inter-component wiring must be by laminated copper clad track having a minimum weight of 0.2 ounces per square foot with adequate cross section for current to be carried. All copper tracks must be plated or soldered to provide complete coverage of all exposed copper tracks. Jumper wires to external PCB components must be from plated-through padded holes and as short as possible.

All PCBs must conform to Section 3.3 of Military Specification MIL-P-13949G Grade of Pits and Dents and be of Grade B quality (3.5.1.3) or better. The class of permissible bow or twist must be Class C (Table V) or better. The class of permissible warp or twist must be Class A (Table II) or better.

Omit Sections 4.2 through 6.6 of Military Specification MIL-P-13949G (inclusive) except as referenced in previous sections of this Item.

The mounting of parts and assemblies on the PCB must conform to Military Specification MIL-STD-275E, except as follows:

Semiconductor devices that dissipate more than 250 milliWatts or cause a temperature rise of 10 degrees C or more must be mounted with spacers, transipads or heat sinks to prevent contact with the PCB.

When completed, remove all residual flux from the PCB.

The resistance between any two isolated, independent conductor paths must be at least 100 Megohms when a 500 VDC potential is applied.

All PCBs must be coated with a moisture resistant coating.

Where less than 0.25 in. lateral separation is provided between the PCB (or the components of a PCB) and any metal surface, a 0.0625 in. (+/-0.0005 in.) Thick Mylar (polyester) plastic cover must be provided on the metal to protect the PCB.

Each PCB connector edge must be chamfered at 30 degrees from board side planes. The key slots must also be chamfered so that the connector keys are not extracted upon removal of board or jammed upon insertion. The key slots must be 0.045 in. (+/-0.005 in.) for 0.1 in. spacing and 0.055 in. (+/-0.005 in.) for 0.156 in. spacing.


Automatic flow soldering must be a constant speed conveyor system with the conveyor speed set at optimum to minimize solder peaks or points. Temperature must be controlled to within +/- 8 degrees C of the optimum temperature. The soldering process must result in the complete coverage of
all copper runs, joints and terminals with solder except that which is covered by an electroplating process. Wherever clinching is not used, provide a method of holding the components in the proper position for the flow process.

If exposure to the temperature bath is of such a time-temperature duration, as to come within 80% of any component's maximum specified time-temperature exposure, that component must be hand soldered to the PCB after the flow process has been completed.

2070.32 Definitions. Definitions for the purpose of this section on PCBs must be taken from MIL-P-55110D Section 3.3 and any current addendum.

Jumpers. Jumpers are not allowed unless called out in the specifications or approved by the Department.

2070.33 Quality Control.

Components. All components must be lot sampled to assure a consistent high conformance standard to the design specification of the equipment.

Subassembly, Unit or Module. Complete electrical, environmental and timing compliance testing must be performed on each module, unit, printed circuit or subassembly. Components will be tested as a complete controller assembly. Housing, chassis, and connection terminals must be inspected for mechanical sturdiness, and harnessing to sockets to be electrically tested for proper wiring sequence. The equipment must be visually and physically inspected to assure proper placement, mounting, and compatibility of subassemblies.

2070.34 Pre-delivery Repair. Any defects or deficiencies found by the inspection system involving mechanical structure or wiring must be returned through the manufacturing process or special repair process for correction.

PCB flow soldering is allowed a second time if copper runs and joints are not satisfactorily coated on the first run. Do not flow solder a PCB more than twice.

Hand soldering is allowed for printed circuit repair.

2070.35 Electrical, Environmental and Testing Requirements. The framework of this section, along with the specific test requirements contained herein, is excerpted with modifications from NEMA TS2-2003 - Section 2 by permission of NEMA. Excerpt © 2002 AASHTO / ITE / NEMA.

General. This section establishes the limits of the environmental and operational conditions in which the Controller Assembly will perform. This section defines the minimum test procedures that may be used to demonstrate conformance of a device type with the provisions of the
standard. These test procedures do not verify equipment performance under every possible combination of environmental requirements covered by this standard. Nothing in this testing profile must be construed as to relieve the requirement that the equipment provided must fully comply with these standards/specifications under all environmental conditions stated herein.

The Department may wish to extend the testing profile or introduce additional tests to verify compliance. (Authorized Engineering Information).

Inspection. A visual and physical inspection must include mechanical, dimensional and assembly conformance to all parts of this standard.

2070.36 Testing Certification.

A complete quality control / final test report must be supplied with each item. Quality control procedures must be submitted to the Department prior to production. The test report must indicate the name of the tester and be signed by a responsible manager.

The quality control procedure and test report format must be supplied to the Department for approval upon request. The quality control procedure must include the following, in the order shown:

Design Acceptance testing of all supplied components.

Physical and functional testing of all modules and items.

Environmental testing reports for all equipment.

Physical and functional testing of all items.

Separate certifications must be provided for Design and Production. Design Acceptance testing must be performed with a fully loaded and functional Cabinet Assembly. Production testing must be performed as part of the Department’s procurement delivery procedures and that testing should be performed at the Major Unit level. (Authorized Engineering Information).

Certain portions of the test procedures contained in this standard may cause damage to the unit (e.g. protection devices may be aged) and are not recommended for routine Production testing. (Authorized Engineering Information)

Definitions of Major Units of the Cabinet Assembly. For the purpose of this section, "Major units of the Cabinet Assembly" must include the Controller Unit, Application Software for implementing the desired functionality, Cabinet Monitor Unit (CMU), Auxiliary Monitor Unit (AMU), Serial Interface Units (SIUs), Power Distribution Unit (PDA), Switch Packs, Flasher(s), and Detector(s).
Environmental and Operating Requirements. The requirements (voltage, temperature, etc.) of this section must apply in any combination.

Voltage and Frequency.

Operating Voltage. The nominal voltage must be 120 VAC, unless otherwise noted.

Operating Frequency. The operating frequency range must be 60 hertz (+/- 3.0 hertz), unless otherwise noted.

Transients, Power Service. The Test Unit must maintain all defined functions when the independent test pulse levels specified below occur on the alternating-current power service.

High Repetition Noise Transients.

The test pulses must not exceed the following conditions:

Amplitude: 300 Volts, both positive and negative polarity.

Peak Power: 2500 watts.

Repetition: 1 pulse approximately every other cycle moving uniformly over the full wave in order to sweep across 360 degrees of the line cycle once every 3 seconds.

Pulse Rise Time: 1 microsecond.

Pulse Width: 10 microseconds.

This test is performed without protection in place or operational.

This test is considered to be a minimum test requirement for the Test Unit complying with ANSI/IEEE C62.41. Regional conditions may warrant additional testing as described in ANSI/IEEE C62.41. (Authorized Engineering Information)

Low Repetition High Energy Transients.

The test pulses must not exceed the following conditions:

Amplitude: 600 Volts (+/-5 percent), both positive and negative polarity.

Energy Source: Capacitor, oil filled, 10 microfarads (+/-10 percent), internal surge impedance less than 1 ohm.

Repetition: 1 discharge every 10 seconds.
Pulse Position: Random across 360 degrees of the line cycle.

This test is performed with protection in place and operational.

This test is considered to be a minimum test requirement for the Test Unit complying with ANSI/IEEE C62.41. Regional conditions may warrant additional testing as described in ANSI/IEEE C62.41. (Authorized Engineering Information)

Nondestructive Transient Immunity.

The Test Unit (with protection in place and operational) must be capable of withstandiing a high energy transient having the following characteristics repeatedly applied to the alternating current input terminals (no other power connected to terminals) without failure of the test specimen:

Amplitude: 1000 Volts (+/-5 percent), both positive and negative polarity.

Energy Source: Capacitor, oil filled, 15 microfarads (+/-10 percent), internal surge impedance less than 1 ohm.

Repetition: Applied to the Test Unit once every 2 seconds for a maximum of three applications for each polarity.

After the foregoing, the Test Unit must perform all defined functions upon the application of nominal alternating current power.

This test is considered to be a minimum test requirement for the Test Unit complying with ANSI/IEEE C62.41 (100 Kilohertz Ring Wave, the 1.2/50 microseconds – 8/20 Combination Wave and the EFT Burst) at voltages and currents specified at “Location Category B2” and at “Test Severity” level III (i.e. up to 4.0 Kilovolts, open-circuit). Regional conditions may warrant additional testing as described in ANSI/IEEE C62.41. (Authorized Engineering Information)

Transients, Input-Output Terminals.

The Test Unit (without protection in place or operational) must maintain all defined functions, when the test pulse occurs on the input-output terminals.

Amplitude: 300 Volts, both positive and negative polarity.

Pulse Source: 1000 ohms nominal impedance.

Repetition: 1 pulse per second, for a minimum of 5 pulses per selected terminal.

Pulse rise time: 1 microsecond.
Pulse width: 10 microseconds.

This test is considered to be a minimum test requirement for the Test Unit complying with ANSI/IEEE C62.41. Regional conditions may warrant additional testing as described in ANSI/IEEE C62.41. (Authorized Engineering Information)

Temperature and Humidity. The Test Unit must maintain all programmed functions when the temperature and humidity ambients are within the specified limits defined herein.

Ambient Temperature.

The operating ambient temperature range must be from -37 degrees C to +74 degrees C. The storage temperature range must be from -45 degrees C to +85 degrees C.

The rate of change in ambient temperature must not exceed 18 degrees C per hour, during which the relative humidity must not exceed 95 percent.

Humidity.

The relative humidity must not exceed 95 percent non-condensing over the temperature range of -37 degrees C to +74 degrees C.

Above +46 degrees C, constant absolute humidity must be maintained. This will result in the relative humidity shown in Exhibit 3-1 for dynamic testing.

Table 1

<table>
<thead>
<tr>
<th>Ambient Temperature/Dry Bulb (in degrees C)</th>
<th>Relative Humidity (in percent)</th>
<th>Ambient Temperature/Wet Bulb (in degrees C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-37.0 to 1.1</td>
<td>10</td>
<td>-17.2 to 42.7</td>
</tr>
<tr>
<td>1.1 to 46.0</td>
<td>95</td>
<td>42.7</td>
</tr>
<tr>
<td>48.8</td>
<td>70</td>
<td>42.7</td>
</tr>
<tr>
<td>54.4</td>
<td>50</td>
<td>42.7</td>
</tr>
<tr>
<td>Ambient Temperature/ Dry Bulb (in degrees C)</td>
<td>Relative Humidity (in percent)</td>
<td>Ambient Temperature/ Wet Bulb (in degrees C)</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>-------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>60.0</td>
<td>38</td>
<td>42.7</td>
</tr>
<tr>
<td>65.4</td>
<td>28</td>
<td>42.7</td>
</tr>
<tr>
<td>71.2</td>
<td>21</td>
<td>42.7</td>
</tr>
<tr>
<td>74.0</td>
<td>18</td>
<td>42.7</td>
</tr>
</tbody>
</table>

Test Facilities. All instrumentation required in the test procedures, such as voltmeters, ammeters, thermocouples, pulse timers, etc. must be selected in accordance with good engineering practice. In all cases where time limit tests are required, the allowance for any instrumentation errors must be included in the limit test.

Variable Voltage Source: A variable source capable of supplying 20 amperes from 100 VAC to 135 VAC.

Environmental Chamber: An environmental chamber capable of attaining temperatures of -37 degrees C to +74 degrees C and relative humidity given in Table 1.

Transient Generators: Transient generators capable of supplying the transients outlined above.

Test Procedure: Transients, Temperature, Voltage, and Humidity

Test A: Placement in Environmental Chamber and Check-Out of Hook-Up

Place the test unit in the environmental chamber. Connect the test unit AC input circuit to a variable voltage power transformer, voltmeter, and transient generator. The transient generator must be connected to the AC input circuit at a point at least 25 feet from the AC power source and not over 10 feet from the input to the test unit.

Connect test switches to the appropriate terminals to simulate the various features incorporated into the test unit. Place these switches in the proper position for desired operation.

Verify the test hook-up. Adjust the variable-voltage power transformer to 120 VAC and apply power to the test unit. Verify that the test unit goes through its prescribed startup sequence and cycles properly in accordance with the operation determined by the positioning of test switches in item b.
Upon the satisfactory completion and verification of the test hook-up, proceed with Test B.

Test B: Transient Tests (Power Service)

Program the test unit to dwell. Verify the input voltage is 120 VAC.

Set the transient generator to provide high-repetition noise transients as follows:

Amplitude: 300 Volts (+/-5 percent), both positive and negative polarity.

Peak Power: 2500 watts.

Repetition Rate: One pulse every other cycle moving uniformly over the full wave in order to sweep once every 3 seconds across 360 degrees of line cycle.

Pulse Rise Time: 1 microsecond.

Pulse Width: 10 microseconds.

Apply the transient generator output to the AC voltage input for at least 5 minutes. Repeat this test for at least two conditions of dwell for the test unit. The test unit must continue to dwell without malfunction.

Program the test unit to cycle through normal operations. Turn on the transient generator (output in accordance with item 2) for 10 minutes, during which time the test unit must continue to cycle without malfunction.

Set a transient generator to provide high-repetition noise transients as follows:

Amplitude: 300 Volts (+/-5 percent), both positive and negative polarity.

Source Impedance: Not less than 1000 ohms nominal impedance.

Repetition: One pulse per second for a minimum of five pulses per selected terminal.

Pulse Rise Time: 1 microsecond.

Pulse Width: 10 microseconds.

Program the test unit to dwell. Verify the input voltage is 120 VAC.

Apply the transient generator (output in accordance with item 5) between logic ground and the connecting cable termination of selected Field I/O input/output terminals of the test unit.
A representative sampling of selected input/output terminations must be tested. The test unit must continue to dwell without malfunction.

Program the test unit to cycle. Turn on the transient generator (output in accordance with item 5) and apply its output to the selected Field I/O input/output terminations. The test unit must continue to cycle without malfunction.

Reinstall protection and set a transient generator to provide low-repetition high-energy transients as follows:

- Amplitude: 600 Volts (+/-5 percent), both positive and negative polarity.
- Energy Discharge Source: Capacitor, oil-filled, 10 microfarads.
- Repetition Rate: One discharge each 10 seconds.
- Pulse Position: Random across 360 degrees of line cycle.

Program the test unit to dwell. Verify the input voltage is 120 VAC.

Discharge the oil-filled 10-microfarad capacitor ten times for each polarity across the AC voltage input. Repeat this test for at least two conditions of dwell. The test unit must continue to dwell without malfunction.

Program the test unit to cycle through normal operations. Discharge the capacitor ten times for each polarity while the test unit is cycling, during which time the test unit must continue to cycle without malfunction.

During the preceding transient tests, the test unit must continue its programmed functions.

The test unit must not skip normal program intervals/steps or portions thereof when in normal operation; place false inputs or produce false outputs while in dwell; disrupt normal sequences in any manner; or change parameters.

Nondestructive Transient Immunity:

Turn off the AC power input to the test unit from the variable-voltage power source.

Apply the following high-energy transient to the AC voltage input terminals of the test unit (no other power connected to terminals):

- Amplitude: 1000 V, both positive and negative polarity.
- Peak Power Discharge: Capacitor, oil-filled, 15 microfarads.
Maximum Repetition Rate: Applied to the Cabinet Assembly once every 2 seconds for a maximum of three applications for each polarity.

Upon completion of the foregoing, apply 120 VAC to the test unit and verify that the test unit goes through its prescribed startup sequence and cycles properly in accordance with the programmed functions. The first operation of the over-current protective device during this test is not considered a failure of the test unit.

NOTE—Test C through G follow the profile indicated in Figure 1 to demonstrate the ability of the test unit to function reliably under stated conditions of temperature, voltage, and humidity.

Figure 1
Test Profile

NOTES:
The rate of change in temperature must not exceed 18 degrees C per hour
Humidity controls must be set in conformance with the humidity given in Table 1 during the temperature change between Test D and Test E.

If a change in both voltage and temperature are required for the next test, the voltage must be selected prior to the temperature change.

Test C—Low-Temperature Low-Voltage Tests

Definition of Test Conditions

Environmental Chamber Door: Closed.

Temperature: -37 degrees C.

Low Voltage: 100 VAC.

Humidity Control: Off.

Test Procedure: While at room temperature, adjust the input voltage to 100 VAC and verify that the test unit is still operable.

With the test unit cycling through normal operations, lower the test chamber to -37 degrees C at a rate not exceeding 18 degrees C per hour. Allow the test unit to cycle for a minimum of 5 hours at -37 degrees C with the humidity controls in the off position. Then operate the test switches as necessary to determine that all functions are operable.

Remove power from the test unit for a minimum period of 5 hours. Upon restoration of power, the test unit must go through its prescribed startup sequence and then resume cycling.

With the test unit at -37 degrees C and the input voltage at 100 VAC, evaluate the following items against the respective standards:

Power Interruption Tests

On satisfactory completion of this test, proceed with Test D.

Test D—Low-Temperature High-Voltage Tests

Definition of Test Conditions

Environmental Chamber Door: closed.

Low Temperature: -37 degrees C.

High Voltage: 135 VAC.

Humidity Controls: Off.
Test Procedure: While at -37 degrees C and with humidity controls off, adjust the input voltage to 135 VAC and allow the test unit to cycle for 1 hour. Then operate the test switches as necessary to determine that all functions are operable.

With the test unit at -37 degrees C and the input voltage at 135 VAC (humidity controls off), evaluate the following items against the respective standards:

Power Interruption Tests

On satisfactory completion of this test, proceed to Test E.

Test E—High-Temperature High-Voltage Tests

Definition of Test Conditions

Environmental Chamber Door: Closed.

High Temperature: +74 degrees C.

High Voltage: 135 VAC.

Humidity Controls: In accordance with the humidity given in Table 1.

Test Procedure—With the test unit cycling, raise the test chamber to +74 degrees C at a rate not to exceed 18 degrees C per hour. Verify the input voltage is 135 VAC. Set the humidity controls to not exceed 95 percent relative humidity over the temperature range of +1.1 degrees C to +46 degrees C. When the temperature reaches +46 degrees C, readjust the humidity control to maintain constant absolute humidity; +42.7 degrees C wet bulb that results in the relative humidity shown in Table 1. Verify that the test unit continues to cycle satisfactory during the period of temperature increase and at established levels of relative humidity.

Allow the test unit to cycle for a minimum of 15 hours at +74 degrees C and 18 percent relative humidity. Then operate the test switches as necessary to determine that all functions are operable.

With the test unit at +74 degrees C and 18 percent relative humidity and the input voltage at 135 VAC, evaluate the following items against the respective standards:

Power Interruption Tests

On satisfactory completion of this test, proceed to Test F.
Test F—High-Temperature Low-Voltage Tests

Definition of Test Conditions

Environmental Chamber Door: Closed.
High Temperature: +74 degrees C.
Low Voltage: 100 VAC.

Humidity Controls: 18 percent relative humidity and +42.7 degrees C wet bulb.

Test Procedure: Adjust the input voltage to 100 VAC and proceed to operate the test switches to determine that all functions are operable. With the test unit at +74 degrees C and 18 percent relative humidity, +42.7 degrees C wet bulb, and the input voltage at 100 VAC, evaluate the following items against the respective standards:

Power Interruption Tests
On satisfactory completion of this test, proceed to Test G.

Test G—Test Termination

Program the test unit to cycle.
Adjust the input voltage to 120 VAC.

Set the controls on the environmental chamber to return to room temperature, +20 degrees C (+/-5 degrees C), with the humidity controls in the off position. The rate of temperature change must not exceed 18 degrees C per hour.

Verify the test unit continues to cycle through normal operations properly.

Allow the test unit to stabilize at room temperature for 1 hour. Proceed to operate the test switches to determine that all functions are operable.

Test H—Appraisal of Equipment under Test

A failure is defined as any occurrence that results in other than normal operation of the equipment. (See sub-section item b. below for details.) If a failure occurs, the test unit must be repaired or components replaced, and the test during which failure occurred must be restarted from its beginning.

The test unit is considered to have failed if any of the following occur:
If the test unit skips normal program intervals/steps or portions thereof when in normal operation, places false inputs, presents false outputs, exhibits disruption of normal sequence of operations, or produces changes in parameters beyond specified tolerances, or

If the test unit fails to satisfy the requirements of Tests A to G, inclusive.

An analysis of the failure must be performed and corrective action taken before the test unit is retested in accordance with this standard. The analysis must outline what action was taken to preclude additional failures during the tests.

When the number of failures exceeds two, it must be considered that the test unit fails to meet these standards. The test unit may be completely retested after analysis of the failure and necessary repairs have been made in accordance with item c.

Upon completion of the tests, visually inspect the test unit. If material changes are observed which will adversely affect the life of the test unit, the cause and conditions must be corrected before making further tests.

Upon satisfactory completion of all of the tests described, test the unit in accordance with Vibration Test.

Vibration Test.

Purpose of Test. This test is intended to duplicate vibrations encountered by the test unit (individual major components) when installed at its field location.

Fasten the test unit securely to the vibration test table prior to the start of the test.

Test Equipment Requirements.

Vibration table with adequate table surface area to permit placement of the test unit.

Vibration test consists of:

Vibration in each of three mutually perpendicular planes.

Adjustment of frequency of vibration over the range from 5 hertz to 30 hertz.

Adjustment of test table excursion (double amplitude displacement) to maintain a ‘g’ value, measured at the test table, of 0.5g; as determined by the following formula:

\[ g = 0.0511df^2 \]
Where:

\[ d = \text{excursion in inches} \]

\[ f = \text{frequency in hertz} \]

Resonant Search

With the test unit securely fastened to the test table, set the test table for a double amplitude displacement of 0.015 inch.

Cycle the test table over a search range from 5 hertz to 30 hertz and back within a period of 12.5 minutes.

Conduct the resonant frequency search in each of the three mutually perpendicular planes.

Note and record the resonant frequency determined from each plane.

In the event of more than one resonant frequency in a given plane, record the most severe resonance.

If resonant frequencies appear equally severe, record each resonant frequency.

If no resonant frequency occurs for a given plane within the prescribed range, 30 hertz must be recorded.

Endurance Test

Vibrate the test unit in each plane at its resonant frequency for a period of 1 hour at amplitude resulting in 0.5g acceleration.

When more than one resonant frequency has been recorded, the test period of 1 hour must be divided equally between the resonant frequencies.

The total time of the endurance test must be limited to 3 hours, 1 hour in each of three mutually perpendicular planes.

Disposition of Equipment under Test

Examine the test unit to determine that no physical damage has resulted from the vibration tests.

Check the test unit to determine that it is functionally operable in all modes of its prescribed operation.

The test unit may be removed from the test table. Upon satisfactory completion of the vibration test, proceed with the shock (impact) test.
Shock (Impact) Test.

Purpose of Test. The purpose of this test is to determine that the test unit is capable of withstanding the shock (impact) to which it may reasonably be subjected during handling and transportation in the process of installation, repair, and replacement. It is to be noted that the test unit is not, at this time, in its shipping carton.

Fasten the test unit firmly to the specimen table. In each of its three planes the test, drop the unit from a calibrated height to result in a shock force of 10g.

Test Equipment Requirements.

Shock (impact) test fixture equivalent to that suggested by the simplified sketch shown in Figure 2.

The test table must have a surface area sufficient to accommodate the test unit.

Calibrate the test table and the items tested as indicated. This shock test defines the test shock to be 10g (+/-1g).

Measure calibration of the test equipment for these shock tests by three accelerometers having fixed shock settings of 9g, 10g, and 11g. They must be Inertia Switch Incorporated ST-355, or the equivalent. Attach these devices rigidly to the test table.

Calibration of the fixture for each item to be tested is as follows:

Place a dummy load weighing within 10 percent of the test unit on the table.

Reset the three accelerometers and drop the test table from a measured height.

Observe that the accelerometers indicate the following:

Activate the 9g accelerometer.

The 10g unit may or may not be actuated.

The 11g unit must not be actuated.
Repeat calibration test (a) and (b) adjusting the height of the drop until, on ten successive drops, the following occurs:

The 9g unit is actuated ten times.

The 10g unit is actuated between four to eight times.

The 11g unit is not actuated on any of the ten drops.

Test Procedure.

The calibration height of the drop for the particular item under test as determined in Test Equipment Requirements must be used in this procedure.

Secure the test unit to the test table surface so that the test unit rests on one of its three mutually perpendicular planes.

Raise the test table to the calibrated height.

Release the test table from the calibrated height, allowing a free fall into the box of energy absorbing material below.
Repeat the drop test for each of the remaining two mutually perpendicular planes, using the same calibrated height for each drop test of the same test unit.

The observations of the accelerometer for the three tests of the test item are:

The 9g unit is actuated for all three tests. (Repeat the calibration if the unit is not actuated.)

The 10g unit may or may not be actuated in these tests.

The 11g unit is not actuated on any drop. (If the unit is actuated, repeat the calibration only if the test unit has suffered damage.)

Disposition of Test Unit.

Check the test unit for any physical damage resulting from the drop tests.

Check the test unit to determine that it is functionally operable in all modes of its prescribed operation.

Satisfactory completion of all environmental tests, including the shock (impact) is required.

Power Interruption Test Procedures. Conduct the following power interruption tests at low input voltage (100 VAC) and high input voltage (135 VAC) at -37 degrees C, and +74 degrees C.

Short Power Interruption. While the Test Unit is cycling through normal operations, remove the input voltage for a period of 475 milliseconds. Upon restoration of the input voltage, check to insure that the Test Unit continues normal operation as though no power interruption has occurred. Repeat this test three times.

Voltage Variation. All circuits of the Test Unit must be subjected to slowly varying line voltage during which the Test Unit must be subjected to line voltage that is slowly lowered from a nominal 120 VAC line voltage to 0 VAC at a rate of not greater than 2 Volts per second. The line voltage must then be slowly raised to 100 VAC at which point the Test Unit must resume normal operation without operator intervention. Perform this test at both -37 degrees C and +74 degrees C, at a nominal 120 VAC line voltage. Repeat this test three times.

Rapid Power Interruption. Subject the Test Unit to rapid power interruption testing of the form that the power is off for 350 milliseconds and on for 650 milliseconds for a period of 2 minutes. Perform power interruption through electromechanical contacts of an appropriate size for the load. During this testing, the controller must function normally and continue normal
sequencing (operation) at the conclusion of the test. This test must be performed at both -37 degrees C and +74 degrees C, at a nominal 120 VAC line voltage. Repeat this test three times.

Type 2070 Controller Unit.

2070.37 General.

Module Descriptions. The Controller Unit is composed of the Type 2070 Unit CHASSIS, along with other modules and assemblies. The following is a list of Type 2070 versions, their interface rolls and composition:

Unit Configuration. The Type 2070 Controller Unit Version defines the module composition to be delivered as follows:

MODEL 2070 CONTROLLER CONFIGURATIONS

<table>
<thead>
<tr>
<th>ASSOCIATED DEVICES</th>
<th>L</th>
<th>LS</th>
<th>LC</th>
<th>LCS</th>
<th>N1B</th>
<th>N2</th>
<th>N1C</th>
<th>N2C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Type 2070-1B CPU Module</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2 Type 2070-1C CPU Module</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3 Type 2070-2A Field I/O Module</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Type 2070-2B Field I/O Module</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5 Type 2070-3 Front Panel Assy.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6 Type 2070-4A Power Supply</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Type 2070-4AN Power Supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8 Type 2070-8 NEMA Base</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>9 Type 2070-2N Field I/O Module</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>10 Type 2070-7 Comm. Module</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2070 L is a basic configuration currently using the 1B and CPU Module.

2070 LS is the basic L version that replaces the 2A FIO with a 2B communication interface to drive the serial cabinet.

2070 LC and LCS are the same units using the 1C CPU Module.

2070N versions include 1B and 1C CPU Modules. The 2N Field I/O module is designed to replace the 2070-8 NEMA Base and use the TS2 serial interface.
The communications and option modules/assemblies must be called out separately from the unit version. The composition weight must not exceed 25 pounds.

2070.38 Metalwork. The CHASSIS Top and Bottom, Internal Structure Supports, Back Plane Mounting Surface, Module Plates, Power Supply Enclosure, and Front Panel must be made of 63 gauge minimum aluminum sheet. The CHASSIS Side panels must be 80 gauge minimum sheet.

2070.39 Power Fail and Power Restoration Operation. It is noted that the Power Failure Power Restoration operations of this unit are specific to the requirements of the user. All associated modules are to comply to said operations.

Power Limitations. 2070 UNIT module / assembly power limitations are as follows:

<table>
<thead>
<tr>
<th>Types</th>
<th>+5VDC</th>
<th>+12VDC ISO</th>
<th>+12VDC ser</th>
<th>-12 ser</th>
<th>VDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2070-1B CPU</td>
<td>1.0 amperes</td>
<td>250mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2070-1C CPU</td>
<td>2.0 amperes</td>
<td>250mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2070-2A FI/O</td>
<td>250 mA</td>
<td>750 mA</td>
<td>-----</td>
<td>-----</td>
<td></td>
</tr>
<tr>
<td>2070-2B FI/O</td>
<td>250 mA</td>
<td>500 mA</td>
<td>-----</td>
<td>-----</td>
<td></td>
</tr>
<tr>
<td>2070-3A&amp;B FPA</td>
<td>500 mA</td>
<td>-----</td>
<td>50 mA</td>
<td>50 mA</td>
<td></td>
</tr>
<tr>
<td>2070-3C FPA</td>
<td>500 mA</td>
<td>-----</td>
<td>50 mA</td>
<td>50 mA</td>
<td></td>
</tr>
<tr>
<td>2070-6 All Comm.</td>
<td>500 mA</td>
<td>-----</td>
<td>200 mA</td>
<td>200 mA</td>
<td></td>
</tr>
<tr>
<td>2070-7 All Comm.</td>
<td>250 mA</td>
<td>-----</td>
<td>50 mA</td>
<td>50 mA</td>
<td></td>
</tr>
</tbody>
</table>

Model 2070-6 and Others shall not exceed 6 Watts Max usage.

2070.40 EIA-485 Communications Circuitry. All circuitry associated with the EIA-485 Communications links must be capable of reliably passing a minimum of 1.0 megabits per second. Isolation circuitry must be by opto- or capacitive-coupled isolation technologies.

EIA-485 Line Drivers/Receivers. Through hole EIA-485 Line Drivers/Receivers, when used, must be socket mounted. Surface mounted drivers/receiver must be acceptable. EIA-485 Line Drivers/Receivers must not draw more than 35 mA in active state and 20 mA in inactive state per
A 100-Ohm Termination Resistor must be provided across each Differential Line Receiver Input. The Motherboard’s control signals (e.g., SP1-RTS) must be active, or asserted, when the positive terminal (e.g., SP1-RTS+) is a lower voltage than its corresponding negative terminal (e.g., SP1-RTS-). A control signal is inactive when its positive terminal voltage is higher than its negative terminal. Receive and transmit data signals must be read as a "1" when the positive terminal's (e.g., SP1-TXD+) voltage is higher than its corresponding negative terminal (e.g., SP1-TXD-). A data value is "0" when its positive terminal's (e.g., SP1-TXD+) voltage is lower than its negative terminal (e.g., SP1-TXD-).

2070.41 SDLC. SP5 and SP3 SDLC frame address assignments
(Command/Response) are as follows:

<table>
<thead>
<tr>
<th>SP5</th>
<th>SP3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU 2070-1</td>
<td>&quot;19&quot;</td>
</tr>
<tr>
<td>FI/O 2070-2A &amp; 8</td>
<td>&quot;20&quot;</td>
</tr>
<tr>
<td>CPU Broadcast to all</td>
<td>&quot;255&quot;</td>
</tr>
</tbody>
</table>

All other addresses are reserved by this standard. The SDLC response frame address must be the same address as the Command frame it receives.

2070.42 Type 2070-1B CPU Module.

Type 2070-1B Configuration. The TYPE 2070-1B CPU must be a single board module meeting the 2X WIDE board requirements. The module must be furnished normally resident in MOTHERBOARD Slot A5. The module must meet all the requirements listed under this section and Details except for the following:

A Dual SCC Device (async/synch) and associated circuitry must be furnished to provide two additional system serial ports. The Dual SCC1 must be assigned to the System Serial Port SP1 meeting all requirements called out for SP1. The Dual SCC2 must be assigned as System Serial Port SP8. The SP8 and associated circuitry must interface with the MC68360 address and data structure and serially be connected to the external world via the DB 25 Pin C13S Connector located on the module front panel. The SP8 must meet all SP2 Port requirements including EIA 485 Drivers / receivers and synchronous data rate of 614.4 kilobits per second.

The 68360 SCC1 must be reassigned to ETHERNET (ENET) Network meeting ETHERNET 10 MBPS IEEE 802.3 (TP) 10 BASE T Standard Requirements, both hardware and software. The four network lines must be used to route ETHERNET across the MOTHERBOARD to the “A” Connectors. DC Grounding plane around the network connectors and lines to
be provided. Network Lines must be assigned as: Network 1 = ENET TX+, Network 2 = ENET TX-, Network 3 = ENET RX+, and Network 4 = ENET RX-.

In addition, the conditioned ETHERNET must be brought out on RJ 45 C14S Connector mounted on the CPU-1B Front Panel. Four LEDs labeled “TX, RX, TX Collision and TX Status” must be mounted on the front panel signifying ETHERNET operational conditions.

The 2070-1B CPU must not draw more than 1.00 Amperes of +5VDC and 250 mA of ISO+12 VDC.

Main Controller Board (MCB)

CONTROLLER Device must be a Motorola MC68360 or equal, clocked at 24.576 MHz minimum. The Fast IRQ Service System is reserved for DEPARTMENT use only. The Interrupts must be configured as follows:

Level 7 - VMEbus IRQ7
Level 6 - VMEbus IRQ6 ACFAIL
Level 5 - VMEbus IRQ5 CPU Module Counters / Timers, LINESYNC (auto vectored), Serial Interface Interrupts
Level 4 - VMEbus IRQ4
Level 3 - VMEbus IRQ3
Level 2 - VMEbus IRQ2
Level 1 - VMEbus IRQ1

Memory Address Organization.

8000 0000 - 80FF FFFF STANDARD
9000 0000 - 9000 FFFF SHORT

16 megabytes of contiguous address space for each specified memory (DRAM, SRAM and FLASH) allocated on an even boundary. The SRAM and FLASH memories must be accessed through the OS-9 Operating System's File Manager, or approved equivalent. The address of each memory block must be specified by the manufacturer and provided with the documentation.

When the incoming +5 VDC falls below its operating level, the SRAM must drop to its standby state; and the SRAM and TOD Clock shift to the +5 VDC Standby Power. An on-board circuit will sense the +5 VDC Standby Power and shift to an On-board CPU Power Source. When the incoming +5 VDC
rises to within its operating level, the appropriate MCB Circuitry will shift from standby power to incoming +5 VDC.

RAM Memory. Provide a minimum of 8 megabytes of DRAM Memory, organized in 32-bit words. A minimum of 1 megabyte of SRAM is required, of which 512 KiloBytes minimum must be available for Department use as a RAM drive (R0). The time from the presentation of valid RAM address, select lines, and data lines to the RAM device to the acceptance of data by the RAM device must not exceed 80 nanoseconds and be less as required to fulfill zero wait state RAM device write access under all operational conditions.

FLASH Memory. Provide a minimum of 8 MB of FLASH memory, organized in 16- or 32- bit words. The MCB must be equipped with all necessary circuitry for writing to the FLASH memory under program control. No more than 2 MB of FLASH Memory to be used for the Boot Image (List) and a minimum of 6 MB be available for DEPARTMENT use. The 2 MB of FLASH Memory must be reserved for the Boot Image only. Flash memory must have a minimum rated capacity of 100,000 read/write cycles and be industrial grade or better.

Time-of-Day Clock. Provide a software settable hardware Time-of-Day (TOD) clock. It must maintain an accuracy of +/-1 minute per 30 days at 25 degrees C (77 degrees F) under on-board standby power. The clock must be aligned to a minimum fractional second resolution of 10 milliseconds and track seconds, minutes, hours, day of month, month, and year.

CPU Reset. Provide a software-driven CPU RESET signal (Active LOW) to reset other controller systems. The signal output must be driver capable of sinking 30 mA at 30 VDC. Execution of the program module “CPURESET” in the boot image must assert the CPU RESET signal once.

CPU Activity Indicator. Provide an open-collector output, capable of sinking 30 mA at 30 VDC, to drive the Front Panel Assembly CPU Activity LED INDICATOR.

Tick Timer. The OS-9 Operating System TICK Timer must be derived from each transition of LINESYNC with a tick rate of 120 ticks per second.

SRAM and TOD Holdup. The SRAM and TOD Clock Circuitry, under Standby mode, must draw no more than 8 microamperes at 2.5 VDC and 35 degrees C. Supply an On-board Capacitor to hold up SRAM and TOD or a minimum of 7 days.

Transition Board. Provide a TRANSITION Board (TB) to transfer serial communication and control signals between the MCB and the Interface Master-board. Said signal and communication lines must be driven/received off and on the module compliant to EIA- 485. The Transition Board must
provide a 1 KiloOhm pull-up resistor for the A2 & A3 installed lines. If the DC Ground is not present (slot not occupied) at the CPU EIA-485 line drivers/receivers, the drivers/receivers must be disabled (inactive).

Shielded Interface Harness. Provide a SHIELDED INTERFACE HARNESS that includes MCB and Transition Board connectors with strain relief, lock latch, mating connectors, and harness conductors. A minimum of 25 mm of slack must be provided. No power to be routed through the harness. The harness must be 100% covered by an aluminum mylar foil and an extruded black 0.8 mm PVC jacket or equal.

DataKey. Provide a DATAKEY Keyceptacle™ (KC4210, KC4210PCB or equal) mounted on the CPU module front panel (or the Transition Board of Type 1A). Power must not be applied to the receptacle if the key is not present.

The Manufacturer must supply a 2-megabyte Memory Size Datakey (SFK2Mb or equal) with each MODEL 1A TB (Transition Board) or 1B CPU module unless specified otherwise. The Datakey must be temperature rated for –40 to +80 degrees C operation, be black in color, and be initialized to the format and default values defined below.

When programmed, the memory on the key of header version 1 must be organized as follows:

<table>
<thead>
<tr>
<th>Bytes</th>
<th>Description</th>
<th>Default Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>16 bit Frame Check Sequence (FCS) calculated as defined in clause 4.6.2 of ISO/IEC 3309. This FCS is calculated across bytes 3-64</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Key Type</td>
<td>See table below</td>
</tr>
<tr>
<td>4</td>
<td>Header Version</td>
<td>1</td>
</tr>
<tr>
<td>5-8</td>
<td>Latitude</td>
<td>0.0</td>
</tr>
<tr>
<td>9-12</td>
<td>Longitude</td>
<td>0.0</td>
</tr>
<tr>
<td>13-14</td>
<td>Controller ID</td>
<td>0xFFFF</td>
</tr>
<tr>
<td>15-16</td>
<td>Communication drop number</td>
<td>0xFFFF</td>
</tr>
<tr>
<td>17-20</td>
<td>IP Address</td>
<td>10.20.70.51</td>
</tr>
<tr>
<td>Bytes</td>
<td>Description</td>
<td>Default Values</td>
</tr>
<tr>
<td>-------</td>
<td>------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>21-24</td>
<td>Subnet Mask</td>
<td>255.255.255.0</td>
</tr>
<tr>
<td>25-28</td>
<td>Default Gateway</td>
<td>10.20.70.254</td>
</tr>
<tr>
<td>29</td>
<td>Startup Override</td>
<td>0xFF</td>
</tr>
<tr>
<td>30-64</td>
<td>Reserved for Department use</td>
<td>All bytes set to 0xFF</td>
</tr>
<tr>
<td>65 to End</td>
<td>User Data</td>
<td>All bytes set to 0xFF</td>
</tr>
</tbody>
</table>

When programmed, Byte 3 of the header must contain the Key Type value as defined in the following table:

<table>
<thead>
<tr>
<th>Key Type</th>
<th>Model No.</th>
<th>Memory Size</th>
<th>Sector Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DK1000</td>
<td>1 KiloByte</td>
<td>1 Byte</td>
</tr>
<tr>
<td>2</td>
<td>LCK16000</td>
<td>16 KiloBytes</td>
<td>1 Byte</td>
</tr>
<tr>
<td>3</td>
<td>SFK2Mb</td>
<td>2 megabytes</td>
<td>64 KiloBytes</td>
</tr>
<tr>
<td>4</td>
<td>TBD</td>
<td>4 megabytes</td>
<td>64 KiloBytes</td>
</tr>
<tr>
<td>5</td>
<td>TBD</td>
<td>8 megabytes</td>
<td>64 KiloBytes</td>
</tr>
</tbody>
</table>

The data format in the CPU Datakey header for the Latitude and Longitude fields must comply with IEEE/ANSI 754-1985 STD. All the other fields follow a Big Endian Format as implemented by Motorola CPUs.

The Startup Override byte may be used to override the default controller startup procedure.

CPU Module Software. The following must be supplied:

Operating System

Drivers and Descriptors

Application Kernel

Deliverables

Error Handler
Operating System. The CPU Module must be supplied with Radisys/Microware OS-9 Version 3.2, or later, with kernel edition #372 or later. The following modules must be included:

Embedded OS-9 Real Time Kernel

Sequential Character File Manager (SCF)

Stacked Protocol File Manager (SPF)

Pipe File Manager (PIPEMAN)

Random Block File Manager (RBF)

C Shared Library (CSL)

Boot Image must include the following utility modules:

<table>
<thead>
<tr>
<th>Break</th>
<th>Date</th>
<th>Deiniz</th>
<th>Devs</th>
<th>Free</th>
<th>Copy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dir</td>
<td>Tmode</td>
<td>Edt</td>
<td>List</td>
<td>Load</td>
<td>Deldir</td>
</tr>
<tr>
<td>Dump</td>
<td>Del</td>
<td>Ident</td>
<td>Iniz</td>
<td>Irqs</td>
<td>Events</td>
</tr>
<tr>
<td>Echo</td>
<td>Format</td>
<td>Dcheck</td>
<td>Login</td>
<td>Link</td>
<td>Kermit</td>
</tr>
<tr>
<td>Tsmon</td>
<td>Mdir</td>
<td>Mfree</td>
<td>Pd</td>
<td>Makdir</td>
<td>Save</td>
</tr>
<tr>
<td>Attr</td>
<td>Rename</td>
<td>Procs</td>
<td>Unlink</td>
<td>Sleep</td>
<td>Xmode</td>
</tr>
<tr>
<td>Shell</td>
<td>Build</td>
<td>Setime</td>
<td>Merge</td>
<td>grep</td>
<td></td>
</tr>
</tbody>
</table>

Drivers and Descriptors.

Supplied modules must be re-entrant, address independent, and not contain self-modifying code.

Device drivers which require extensions to the standard OS-9 libraries must use the _os_getstat() and _os_setstat() functions.

#define SS_2070  0x2070

error_code _os_getstat(path_id path, SS_2070, PB2070 *pb);
error_code _os_setstat(path_id path, SS_2070, PB2070 *pb);
typedef struct
{
  u_int32 code;
  u_int32 param1;
union
{
  u_int32 param;
  void *pointer;
} param2;
} PB2070, *pb;

The following subcodes for use with PB2070.code are also defined:
#define GS2070_Status 0x1C
#define SS2070_SSig 0x1A
#define SS2070_IFC 0x22
#define SS2070_OFC 0x23
#define SS2070_Timer_Sig 0x1000
#define SS2070_Timer_Cyc 0x1001
#define SS2070_Timer_Start 0x1002
#define SS2070_Timer_Stop 0x1003
#define SS2070_Timer_Reset 0x1004

Note: When PB2070.param2.pointer is used, PB2070.param1 to be loaded with the size of what PB2070.param2.pointer is referencing. When calling _os_getstat() or _os_setstat(), all reserved or unused parameters and fields in PB2070 to be loaded with 0 (zero).

Drivers must be provided to access the FLASH, SRAM, and DRAM memories. The following descriptors must apply:
/f0     FLASH drive non-volatile, writeable
/dd    FLASH drive OS-9 default device for /f0
        /f0wp    FLASH Drive as /f0 but, write protection
        /f0fmt    FLASH Drive as /f0 except format enabled
/r0    SRAM Drive non-volatile ramdisk
        /r0fmt    SRAM Drive as /r0 but format enabled
/r2    DRAM Drive volatile 1 MB ramdisk, not automatically initialized

A driver to handle each of the four internal timers under the OS-9 Kernel must be provided. Provide access to the MC68360 internal timers through the following device descriptors:

Descriptor names for each timer:

timer1    = access to MC68360's internal timer #1
timer2    = access to MC68360's internal timer #2
timer3    = access to MC68360's internal timer #3
timer4    = access to MC68360's internal timer #4
timer12   = access to MC68360's internal timer #1 & #2 (cascaded)
timer34   = access to MC68360's internal timer #3 & #4 (cascaded)

Timer Standard OS-9 Function Calls:

error_code _os_open (char *timer_desc_name, path_id *path);
error_code _os_read (path_id path, void *timer_value, u_int32 *size);

Note: Prior to calling _os_read(), size must be loaded with the value 4 and timer value must be pointed to a u_int32. _os_read() must read the current timer value and load it into timer_value as μS x 100.

error_code _os_close (path_id path);

Timer Extension to Standard OS-9 Function Calls:

error_code _os_setstat(path_id path, SS_2070, PB2070 *pb);
The timer drivers must support the following modes using the SS_2070_os_setstat() option code and a custom parameter block structure:

Send signal after specified time interval. Sets timer to zero and schedules individual one-shot signal.

\[ pb\rightarrow code = SS2070\_Timer\_Sig\ (0x1000); \quad /* request for one-shot signal */ \]
\[ pb.param1 = signal; \quad /* signal code to send (0 = do not send a signal and cancel any pending signals) */' \]
\[ pb\rightarrow param2.param = period; \quad /* timer period in microseconds x 100 */ \]

Send recurring periodic signal. Sets timer to zero and schedules repeating periodic signal.

\[ pb\rightarrow code = SS2070\_Timer\_Cyc\ (0x1001); \quad /* request for periodic signal */ \]
\[ pb.param1 = signal; \quad /* signal code to send (0 = do not send a signal and cancel any pending signals) */' \]
\[ pb\rightarrow param2.param = period; \quad /* timer period in microseconds x 100 */ \]

Start timer. Start the timer if stopped. Timer will free run in a periodic mode, starting at the current timer value as its initial value and timer's maximum allowable time as its timer period (6.5535 seconds for timers 1-4 and 429496.7295 seconds for timers 12 and 34). Timer will not send a signal and any pending signals will be cancelled. Timer mode will be SS2070_Timer_Start. pb.code = SS2070_Timer_Start (0x1002); /* start timer if stopped */

Stop timer. Leaves current value in timer. Cancels any pending signals.

\[ pb\rightarrow code = SS2070\_Timer\_Stop\ (0x1003); \quad /* stop timer if running */ \]

Reset timer. Stops timer if running, resets timer value to zero, and cancels any pending signals.

\[ pb\rightarrow code = SS2070\_Timer\_Reset\ (0x1004); \quad /* reset timer (stop and zero) */' \]

Timer Extension to Standard OS-9 Function Calls:

\[ error\_code \_os\_getstat(path\_id\ path, SS\_2070, PB2070 \*pb); \]
The timer driver will support the following function using the SS_2070_os_getstat() option code and custom parameter block structure:

Retrieve current timer configuration.

```c
typedef struct
{
    u_int32 value;
    u_int32 mode;
    u_int32 signal;
    u_int32 period;
} Timer_status;
```

```
pb->code = GS2070_Status (0x1C) /* Request timer status data */

pb->param1 = sizeof(Timer_status)

pb->param2.pointer = Timer_status*
```

Status data must be returned in the structure pointed to by `pb->param2.pointer` as follows:

```
pb->param2.pointer->value /* current timer value in μS x 100 */

pb->param2.pointer->mode /* SS2070_Timer_Sig if one-shot signal pending, SS2070_Timer_Cyc if periodic signal pending, SS2070_Timer_Start if free running, SS2070_Timer_Stop if not active */

pb->param2.pointer->signal /* signal code pending if */
```
SS2070_Timer_Sig or
SS2070_Timer_Cyc, 0 otherwise */

pb→param2.pointer→period  /* timer period in microseconds x 100 if
SS2070_Timer_Sig or
SS2070_Timer_Cyc, 0 otherwise */

All timer periods are specified in units of hundreds of microseconds, i.e. a
timer period of 7 = 700 microseconds. The minimum allowed timer period
must be 500 microseconds. The maximum timer period for timers 1-4 must
be 6.5535 seconds (0xFFFF). The maximum timer period for timer12 and
timer34 must be 429496.7295 seconds (0xFFFFFFFF). The driver must
return error E$Param from _os_setstat() if the requested timer period is
outside the allowable range.

Access and control to the CPU Datakey must be provided through the
following descriptor name and OS-9 functions:

**Descriptor Name**
datakey = access to the CPU Datakey

**Function Calls**
error_code _os_open (char *datakey_desc_name, path_id *path);
error_code _os_close (path_id path);
error_code _os_read (path_id path, void *data_buffer, u_int32 *data_size);
error_code _os_write (path_id path, void *control, u_int32 *data_size);
error_code _os_seek(path_id path,u_int32 position);  sets read / write offset
error_code = _os_ss_erase(path_id path, u_int32 num_sec_erase); /*erases
sector(s) if pointer is on a block boundary, returns E$PARAM error if not on a
boundary */
error_code = _os_gs_pos(path_id path,u_int32 *position); /* gets current file
pointer position */
error_code = _os_gs_size(path_id path, u_int32 *size); /* gets current
datakey size */

Error Codes Returned by Function Calls

E$NotRdy if datakey is not inserted

E$Seek if Offset plus *data_size is beyond end of CPU Datakey.

E$EOF if upon read or write, the last byte of CPU Datakey has previously
been processed.”

Note: Use of SCF to implement the Datakey driver is not allowed.

The asynchronous serial communications device drivers must support the six
flow control modes (FCM#) described below:

FCM# Description

(0) No Flow Control Mode: The driver transmits data regardless of the state of
CTS. Upon a write command, the driver asserts RTS, and de-asserts RTS
when data transmission is completed. This is the default mode. When user
programs issue the first RTS related command, the driver switches to Manual
Flow Control Mode (FCM# 1).

(1) Manual Flow Control Mode: The driver transmits data regardless of the
state of CTS. The user program has absolute control of the RTS state. The
driver doesn't automatically assert or de-assert RTS.

(2) Auto-CTS Flow Control Mode: The driver transmits data only when CTS
is externally asserted. The user program has absolute control of the RTS
state. The driver doesn't automatically assert or de-assert RTS.

(3) Auto-RTS Flow Control Mode: The driver transmits data regardless of the
state of CTS. Upon a write command, the driver asserts RTS, and de-asserts
RTS when data transmission is completed and any configured RTS
extension is elapsed. If the user program asserts RTS, then RTS remains on
until the user program de-asserts RTS. If the user program de-asserts RTS
before the transmission buffer is empty, the driver holds RTS on until the
transmission buffer is empty and any configured RTS extension is elapsed.

(4) Fully Automatic Flow Control Mode: The driver transmits data only when
CTS is externally asserted. Upon a write command, the driver asserts RTS
and waits for CTS, starts data transmission when CTS is asserted, and de-
asserts RTS when data transmission is completed and any configured RTS
extension is elapsed. If user program asserts RTS, then RTS remains on
until the user program de-asserts RTS. If the user program de-asserts RTS
before the transmission buffer is empty, the driver holds RTS on until the transmission buffer is empty and any configured RTS extension is elapsed.

(5) Dynamic Flow Control Mode: The driver transmits data only when CTS is externally asserted. The driver controls RTS based on the status of its receiving buffer. The driver asserts RTS continuously as long as its receiving buffer has sufficient capacity to store incoming data. If the receiving buffer approaches full, the driver de-asserts RTS until enough data has been read from the buffer to create sufficient receive capacity.

The serial device driver must be able to set user options via _os_setstat() and return status via _os_getstat(). To support legacy application programs, the device driver must also be able to set user options via _os_ss_size() and to return status via _os_gs_size():

```c
error_code_os_setstat(path_id path, SS_2070, void *pb);
error_code_os_getstat(path_id path, SS_2070, void *pb);
error_code_os_ss_size(path_id path, u_int32 size);
error_code_os_gs_size(path_id path, u_int32 *size);
```

Note: The preferred method of accessing serial device drivers is through _os_setstat() and _os_getstat(). The _os_ss_size() and _os_gs_size() interface may not be required by future versions of this Item and is therefore not recommended for new development.

The option subcodes to be passed in pb->code and the data to be contained in pb->param1 are defined as follows. pb->param2 is unused here and should be set to 0 (zero). For _os_ss_size() and _os_gs_size(), the size argument is the same format as pb->param1.

The supported _os_setstat() / _os_ss_size() options must be as follows.

Subcode passed in pb->code is SS2070_OFC (0x23).

Data passed in pb->param1 is defined as follows:

<table>
<thead>
<tr>
<th>Bits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>31-24</td>
<td>Auto RTS turn-off extension in number of characters (range:0-255, 0=default).</td>
</tr>
<tr>
<td>23-14</td>
<td>Reserved for future use.</td>
</tr>
<tr>
<td>Bits</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>13</td>
<td>Inhibit return of error E$Write from _os_write() when transmit buffer full in FCM# 2, 4, 5 (default=0, 0=error, 1=block)</td>
</tr>
<tr>
<td>12</td>
<td>Inhibit variable SCC MRBLR (default =0; 0=NO; 1=inhibit).</td>
</tr>
<tr>
<td>11</td>
<td>Inhibit SCC TODR (default=0; 0=NO; 1=inhibit).</td>
</tr>
<tr>
<td>10-8</td>
<td>Flow Control Mode Number (FCM#) (range:0-5).</td>
</tr>
<tr>
<td>7-0</td>
<td>Subcode SS2070_OFC (0x23).</td>
</tr>
</tbody>
</table>

Variable MRBLR (68360 SCC)

To reduce the IRQ handler overhead, the 68360 SCC driver must use variable MRBLR as follows. If SS2070_OFC bit 12 is set to 1, the MRBLR must be fixed at 16 for all baud rates. Variable MRBLR is not required for SP1 or SP8 on the 2070-1B CPU Module.

<table>
<thead>
<tr>
<th>Baud Rate</th>
<th>MRBLR Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>1</td>
</tr>
<tr>
<td>2400</td>
<td>2</td>
</tr>
<tr>
<td>4800</td>
<td>4</td>
</tr>
<tr>
<td>9600</td>
<td>8</td>
</tr>
<tr>
<td>19200 &amp; Higher</td>
<td>16</td>
</tr>
</tbody>
</table>

TODR (68360 SCC only)

TODR requests processing a new TX buffer immediately. To reduce impact on other serial channel operations, SS2070_OFC bit 11 may be set to 1 to prevent assertion of TODR. TODR is not required for SP1 or SP8 on the 2070-1B CPU Module.

Subcode passed in pb→code is SS2070_IFC (0x22).

Data passed in pb→param1 is defined as follows:
### Description

<table>
<thead>
<tr>
<th>Bits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>31-11</td>
<td>Reserved for Future Use.</td>
</tr>
<tr>
<td>10</td>
<td>DCD must be asserted to receive data (default=0; 0=NO; 1=YES).</td>
</tr>
<tr>
<td>9-8</td>
<td>Reserved for Future Use.</td>
</tr>
<tr>
<td>7-0</td>
<td>Subcode = SS2070_IFC (0x22).</td>
</tr>
</tbody>
</table>

Subcode passed in `pb`→`code` is SS2070_SSig (0x1A).

If CTS is currently negated and bits 16 – 31 are not all 0:

Setting the SS2070_SSig parameter block bit 11 (send when CTS is asserted) will cause the controller to send a one-shot signal as soon as CTS is asserted.

Setting the SS2070_SSig parameter block bit 12 (send when CTS is negated) will cause the controller to send a one-shot signal immediately.

If CTS is currently asserted and bits 16 – 31 are not all 0:

Setting the SS2070_SSig parameter block bit 11 (send when CTS is asserted) will cause the controller to send a one-shot signal immediately.

Setting the SS2070_SSig parameter block bit 12 (send when CTS is negated) will cause the controller to send a signal one-shot as soon as CTS is negated.

If both bits 11 and 12 of the SS2070_SSig parameter block are set, and bits 16 – 31 are not all 0:

The controller will send a one-shot signal upon the next change of CTS state.

Data passed in `pb`→`param1` is defined as follows:

<table>
<thead>
<tr>
<th>Bits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>31-16</td>
<td>A signal number to be sent to calling process when the state of an input changes.</td>
</tr>
<tr>
<td>15-13</td>
<td>Reserved for Future Use.</td>
</tr>
<tr>
<td>12</td>
<td>Send signal when CTS is de-asserted.</td>
</tr>
<tr>
<td>Bits</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>11</td>
<td>Send signal when CTS is asserted.</td>
</tr>
<tr>
<td>10-8</td>
<td>Reserved for Future Use.</td>
</tr>
<tr>
<td>7-0</td>
<td>Subcode = SS2070_SSig (0x1A).</td>
</tr>
</tbody>
</table>

The supported _os_getstat() / _os_gs_size() options must be as follows.

Subcode passed in pb→code is GS2070_Status (0x1C).

Data returned in pb→param1 is defined as follows:

<table>
<thead>
<tr>
<th>Bits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>31-16</td>
<td>Current unfilled transmit buffer character count of the serial device driver.</td>
</tr>
<tr>
<td>15-11</td>
<td>Reserved for Future Use.</td>
</tr>
<tr>
<td>10-8</td>
<td>Current Flow Control Mode Number (FCM#).</td>
</tr>
<tr>
<td>7</td>
<td>Reserved for Future Use.</td>
</tr>
<tr>
<td>6</td>
<td>Overrun error –0=no error; 1=error has occur since last GS2070_Status call.</td>
</tr>
<tr>
<td>5</td>
<td>Frame error –0=no error; 1=error has occur since last GS2070_Status call.</td>
</tr>
<tr>
<td>4</td>
<td>Parity error –0=no error; 1=error has occur since last GS2070_Status call.</td>
</tr>
<tr>
<td>3-2</td>
<td>Reserved for Future Use.</td>
</tr>
<tr>
<td>1</td>
<td>DCD state –0=de-asserted; 1=asserted.</td>
</tr>
<tr>
<td>0</td>
<td>CTS state  –0=de-asserted; 1=asserted.</td>
</tr>
</tbody>
</table>

Device drivers compliant with the OS-9 SCFMAN must be provided for CPU Activity LED Indicator and Day Light Savings time correction features. The descriptor names must be as follows:

\[
\text{led} \quad = \quad \text{access to CPU Activity LED Indicator}
\]
dstclock  = access to Daylight Savings Time Clock correction

The standard OS-9 SCFMAN library calls and their functions are as follows:

error_code  _os_open (char *desc_name, path_id *path);   //open descriptor for command

error_code  _os_close (path_id path);    //close descriptor

error_code  _os_write (path_id path, void *value, u_int32 *data_size);    //set value of function

*value = 1, turn on LED or enable DST correction (default)

*value = 0, turn off LED or disable DST correction

set u_int32*data_size to 1

error_code  _os_read (path_id path, void *value, u_int32 *data_size );
   //get current state

set u_int32*data_size to 1

The Manufacturer must provide the following features to support the TOD operation and synchronization.

Leap Year and Daylight Savings Time (DST) Adjustments - The OS-9 System clock / calendar must automatically be adjusted to account for DST and leap years.

Setting Hardware Clock from OS-9 System Clock – Provide a device driver compatible with the OS-9 SCFMAN to allow the hardware TOD clock/calendar to be updated from the OS-9 system clock under application control. The descriptor name must be “ClockUpdate.” Opening the descriptor will cause the driver to synchronize the clock to a minimum of 10 milliseconds resolution. The driver must compensate for any time elapsed during the process of updating the hardware clock.

Setting OS-9 System Clock from Hardware Clock - At system power up, the OS-9 system TOD clock/calendar must automatically be updated from the hardware TOD clock. The clocks must be synchronized to a minimum of 10 milliseconds resolution.

The FLASH drive must be protected from corruption. It must be protected using the Write Protect (WP) bit of the Base Register. This bit must be set except when explicitly writing to flash. When writing to the FLASH drive the current sector of FLASH being written must first be backed up in SRAM. The backup sector copy must be invalidated when FLASH write operation is
completed. In case of power failure, the FLASH driver must detect the presence of the valid backup sector copy in SRAM and read sector data from the valid backup sector copy. A user write operation must restore the valid backup sector copy first. Execution of the program module, “FLRESTORE,” in the Boot Image must also restore the valid backup sector copy to FLASH drive after a specified delay. “FLRESTORE” must accept a delay parameter in seconds ranging from 0 to 600 seconds. The default delay factor is 30 seconds. No more that 150 KB of SRAM to be dedicated to this purpose.

Warning: Power loss or other interruption while writing to the FLASH drive may cause FLASH drive file and/or disk corruption. It is therefore strongly recommended that the FLASH drive be used to hold controller applications only.

MODEL 2070-1B CPU modules shall include the following set of standard OS-9 networking modules in the operating system boot image, sufficient to support network configuration, startup, and ftp and telnet servers:

spip, ip0, sptcp, tcp0 spudp, udp0, spraw, raw0, spenet, enet, netdb (dns version), ipstart, ifconfig, route, ndbmod, ftpd, ftdc, telnetd, telnetdc, pkman, pkdrv, pk, pks, ping, dhcp.

The boot image shall include a default inetdb module with a module revision of zero. It shall contain the following entries only.

**Hosts**

<table>
<thead>
<tr>
<th>Host</th>
<th>IP Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>localhost</td>
<td>127.0.0.1 me</td>
</tr>
</tbody>
</table>

**Protocols**

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Value</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ip</td>
<td>0</td>
<td>IP</td>
</tr>
<tr>
<td>icmp</td>
<td>1</td>
<td>ICMP</td>
</tr>
<tr>
<td>igmp</td>
<td>2</td>
<td>IGMP</td>
</tr>
<tr>
<td>tcp</td>
<td>6</td>
<td>TCP</td>
</tr>
<tr>
<td>udp</td>
<td>17</td>
<td>UDP</td>
</tr>
</tbody>
</table>

**Services**

<table>
<thead>
<tr>
<th>Service</th>
<th>Port</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ndp</td>
<td>13312/tcp</td>
<td>ndpd</td>
</tr>
<tr>
<td>npp</td>
<td>13568/tcp</td>
<td>nppd</td>
</tr>
</tbody>
</table>
The boot image shall include a default inetdb2 module with a module revision of zero. It shall contain the following entry only:

**Interfaces**

enet0  binding /spqe0/enet  (no address, netmask, or broadcast)

On the MODEL 2070-1B CPU module, an OS-9 SPF Ethernet hardware driver and descriptor for the 68360 (SCC1) must be provided in the operating system Boot Image. The descriptor must be named spqe0.

The following OS-9 modules to be included in the /f0/CMDS/BOOTOBJS flash disk directory to allow for standard TCP/IP network communications using Ethernet Protocol over Ethernet hardware and/or Serial Line Internet Protocol (SLIP) or Point-to-Point Protocol over serial links:

Drivers and Descriptors for PPP.

Drivers and Descriptors for SLIP.

LAN Comm Pak modules: spenet, enet, spip, ip0, sptcp, tcp0, spudp, udp0, spraw, raw0, sproute, route0, spipcp, ipcp0, splcp, lcp0, sphdlc, hdlc0, spslip, sps10

Network modules: pkman, pkdvr, pk, pks
Network Trap Handler: netdb_local, netdb_dns

NFS Modules: nfs, nfsnul and nfs_devices.

The following Network utilities must be included and must reside in the /f0/CMDS directory as identified in this Item:

arp, dhcp, ftp, ftpd, idbdump, idbgen, rpcdbgen, ifconfig, inetd, ipstart, ndbmod, netstat, ping, route, routed, telnet, telnetdc, hostname, nfsc, mount, rpcdump, nfsstat, exportfs, portmap, pppd, chat, pppauth, nfsd, mountd, and showmount.

Multi-user functionality:

The boot image init module must be configured with a “default directory name” as /f0wp. This will allow login and tsmon to provide the user with login prompt from the terminal port or from the network via a telnet session.

The following OS-9 modules to be included in the operating system boot image for the implementation of multi-user mode.

login, tsmon

Network Configuration at boot up:

The modules inetdb, inetdb2 and rpcdb must be generated by the make utility via the use of a makefile and the network configuration files residing the /f0/ETC directory. The generated inetdb, inetdb2 and rpcdb modules to be re-located to the /f0/CMDS/BOOTOBJ directory where they will be pick-up by the network configuration shell scripts located at /f0/SYS. Configure the modules with the network default values as defined in Section 10.B.6. (Data Key) via the interfaces.conf shell script. Provide a Utility Program named netcfg that reads the CPU Datakey for an IP Address, Subnet Mask and Default Gateway. If the Datakey is present and valid, netcfg will set the IP Address, Subnet Mask and Default Gateway of the Model 2070 Controller when executed by a user at the command line. The netcfg utility will create a new inetdb, inetdb2 and rpcdb database module based on the Datakey network parameters. The new inetdb, inetdb2 and rpcdb modules should be re-located to the /f0/CMDS/BOOTOBJ directory where they will be pick-up by the network configuration shell scripts located at /f0/SYS. The netcfg must also allow the user to read, write and display network parameters to and from the Datakey via the command line prompt.

If the Datakey is not present or invalid, netcfg must display an error and exit without altering the network configuration. The netcfg utility must reside in /f0/CMDS.

Standard Microware File System Configuration:
A user name “super” with password as “user” must be defined in the password file.

The PPP and SLIP descriptors must have baud rates and ports set as follows and be stored in the /f0/CMDS/BOOTOBJS directory,

hdlc0 and spsl0 configured to use /sp1 and 38400 bps
hdlc1 and spsl1 configured to use /sp2 and 115200 bps
hdlc2 and spsl2 configured to use /sp3 and 115200 bps
hdlc3 and spsl3 configured to use /sp4 and 38400 bps

Provide a set of example configuration files consistent with the above networking modules in the /f0/ETC directory. This directory must contain the following text files.

hosts, hosts.equiv, networks, protocols, services, inetd.conf, resolv.conf, hosts.conf, rpc, interfaces.conf, routes.conf.

Standard Microware File System Configuration.

The 2070 must follow Standard Microware File System Configuration. A /f0/CMDS, /f0/CMDS/BOOTOBJS, /f0/ETC and /f0/SYS directories implemented. Execute permission must be included in the attributes of files in the /f0/CMDS directory. Sysgo will set its execution directory to /f0wp/CMDS prior to spawning opexec or other processes. The /f0/CMDS/BOOTOBJS must contain the modules as identified above and other customizable descriptors and modules. The /f0/SYS must also contain the following four standard OS-9 network configuration shell script files: startspf, startnfs, loadspf and loadnfs.

The /f0/SYS must contain a "password" file. The password file will follow Microware’s password file format for the addition and configuration of multiuser functionality and password protection. A user name “super” with password as “user” must be defined in the password file.

The utilities tar, make, vi, fixmod and mshell must be included in the /f0/CMDS directory.

Application Kernel.

The provided software must boot OS-9 from SYSRESET. The entire program must be resident in FLASH Memory. Configure the serial port descriptors with the following defaults:

SP1 & 2 1.2 Kbps, 8-bit word, 1 stop, no parity, no pause, no echo
SP 3S 614.4 Kbps

SP4 9.6 Kbps, 8-bit word, 1 stop, no parity, no pause, x on and x off BOTH OFF

SP 5S 614.4 Kbps

SP 6 38.4 Kbps, 8-bit word, 1 stop and no parity

Hardware initialization, preliminary self-test, OS-9 initialization (except Extended Memory Test), and forking OPEXEC must be completed in less than 4 seconds. This startup time will be measured from the release of SYSRESET to the turn on of the CPU LED using a user level program named ONLED. The ONLED program must be the last module loaded into RAM and executed using opexec or a startup file.

Initialization. Configure the boot image init module with the default directory name as /f0wp and sysgo as the first executable module.

Sysgo must operate as follows:

Sysgo must set the execution directory to /f0wp/CMDS

Sysgo must check if the backspace key (0x08) is being received on /sp4 (c50s). If received, Sysgo must:

Fork a shell on /sp4 using the current directory.

Remain an active process and monitor the shell for termination. If the shell does terminate, Sysgo must fork another shell on /sp4. Unless Sysgo dies, a shell will always be provided on /sp4.

If the backspace key was not received, Sysgo must check for the presence of a Datakey. If present and valid, Sysgo will check the Startup Override byte in the Datakey header.

If Startup Override is 0x01, Sysgo must:

Fork a shell that executes a shell script stored on the Datakey in the following format. Immediately following the key header must be a 2-byte value indicating the length of the script. The script must immediately follow the length value, and be stored as ASCII text.

If there is any error reading or starting the script or if the shell terminates with an error, Sysgo must display an error message on /sp4 and fork another shell as described in step b. If there are no errors executing the script, Sysgo must exit without forking another shell.
If Startup Override is 0x02, Sysgo must:

Fork an executable module stored on the Datakey immediately following the header.

If there is any error loading or forking the module, Sysgo must display an error message on /sp4 and fork a shell as described in step b. If there are no errors forking the module, Sysgo must then exit without forking a shell.

If the backspace key was not received and Startup Override was not performed:

Sysgo must fork the module named /f0wp/OPEXEC if present at /f0wp.

If there is any error loading or forking OPEXEC, Sysgo must display an error message on /sp4 and fork a shell as described in step b. If there are no errors forking OPEXEC, Sysgo must then exit without forking a shell.

If the backspace key was not received, Startup Override was not performed, and there is no OPEXEC file:

Sysgo must fork a shell that executes a shell script named /f0wp/startup if present at /f0wp.

If there is any error reading or starting the script or if the shell terminates with an error, Sysgo must display an error message on /sp4 and fork another shell as described in step b. If there are no errors executing the script, Sysgo must exit without forking another shell.

If the backspace key was not received, Startup Override was not performed, and there is no OPEXEC and no startup file:

Sysgo must fork a shell as described in step b.

A Short Out is defined as the period of time between ACFAIL/POWER DOWN transition to LOW and back to HIGH without a SYSRESET transition to LOW. ACFAIL/POWER DOWN transitions must generate an interrupt. The interrupt updates an OS-9 event named "ACFAIL". The "ACFAIL" event sets a value 1 indicating an ACFAIL condition occurred for the DOWN transition and set 0 indicating non-ACFAIL condition for the HIGH transition. The IRQ7 and auto-vector 31(7) must not be used to update the "ACFAIL" event.

In addition, the ACFAIL condition must generate the OS-9 auto-vector 30(6) interrupt service. Each interrupt service installed must exit with the "Carry Bit" set allow OS9 to propagate the ACFAIL interrupt. The Manufacturer must supply an interrupt handler at priority 255 that acknowledges and clears the interrupt.
Reserve Priority 1 for the OS-9 system.

A Long Out is defined as ACFAIL transition to LOW follow by a SYSRESET going LOW. The SYSRESET going HIGH must be followed by an operating system reboot.

Error Handler.

A Manufacturer may include an error handling routine to save troubleshooting data regarding initialization, power-up test abnormalities and other error conditions. If used, the error report must be stored in the file /r0/ErrorReport and not exceed 11 kilobytes in size.

Diagnostic Acceptance Test (DAT).

A DAT Program must be provided resident in the 2070 Unit as the application program.

Re-Flash Utility. Provide a Utility Program that would allow the user to upgrade (re-flash) the Boot Image. This utility must provide the capabilities for upgrading the Operating System and drivers when available by the manufacturer. The Utility Program must provide the capability for the user to dynamically upgrade the Boot Image via the command prompt. The Manufacturer must also provide a copy in CD Memory of all files originally stored in the flash drive /f0 so that they can be reloaded as needed.

Deliverables.

The following items will be provided to the purchasing DEPARTMENT on a CD disk readable by a PC compatible computer.

Specific hardware memory addresses, including FLASH, SRAM, and DRAM starting addresses, must be specified and provided. Written documentation of addresses must be in PDF form and will have the file name of “Memory Map.pdf”

Copy of all provided written manuals in PDF form.

Copies of the vendor kernel, platform drivers and OS-9 utility executable modules

RE-FLASH Utility and the procedures for its use in PDF form. The PDF documentation of the procedures must have the file name of “Reflash Utility Procedures.pdf”.

Fully commented source code of Contractor developed drivers and utilities must be provided.
OS-9 compliant header files must be provided with all driver modules.

2070.43 Type 2070 – 1C Configuration. The TYPE 2070-1C CPU must be a single board module meeting the 2X WIDE board requirements. The module must be furnished normally resident in MOTHERBOARD Slot A5. The module must meet all the requirements listed under the 2070-1B section of this standard, with the following additions:

Engine Board. The TYPE 2070-1C CPU must use an Engine Board compliant to the AASHTO/ITE Next Generation ATC Standard. The Engine Board must be used for execution of the application software. No other microprocessor or memory of the 2070-1C CPU to be used for execution of the application software.

Ethernet Ports. The second ETHERNET port of the Engine Board must be brought out on an RJ 45 C15S Connector mounted on the 2070-1C front panel. The front panel LED indicators for the two Ethernet ports must conform to the AASHTO/ITE Next Generation ATC Standard.

Universal Serial Bus (USB). The TYPE 2070-1C CPU must include a USB port compliant to the AASHTO/ITE Next Generation ATC Standard, and brought out from the Engine Board to a USB C16S Connector mounted on the 2070-1C front panel.

Host Module Identification. The TYPE 2070-1C CPU must implement the host module identification using the Engine Board SPI serial port, compliant to the AASHTO/ITE Next Generation ATC Standard as follows:

SP2.2.5.HC1.Linux Special Provisions to the ATC 5.2 Standard Operating System & Board Support Package Requirements The ATC shall use a Linux operating system (O/S) and shall include standard POSIX libraries for application support including real-time extensions of POSIX 1003.1b. To facilitate application level access to the ATC hardware, a Board Support Package (BSP) and hardware tool chain shall be provided for access to hardware-specific drivers.

After boot-up the ATC Linux O/S shall make available to applications, access to the low level drivers (block, character and network) provided by the kernel (subject to current open source requirements) or through kernel modules.

Additionally, the ATC shall have the ability to boot as NFS.
b. SP2.2.5.HC2 Linux  Special Provisions to the ATC 5.2 Standard. Utility applications, modules, libraries and supporting data which include, but are not limited to, the following:

<table>
<thead>
<tr>
<th>Package</th>
<th>Version</th>
<th>Programs</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Busybox</td>
<td>1.00p8</td>
<td>[. addgroup, adduser, adjitimex, ar, ash, basename, busybox, cat, chgrp, chmod, chown, chroot, clear, cmp, cp, crond, crontab, cut, date, dd, delgroup, deluser, df, dimname, dmesg, dos2unix, du, echo, egrep, env, expr, false, fgrep, find, freeramdisk, getty, grep, gunzip, gzip, halt, head, hexdump, hostid, hostname, hwclock, id, ifconfig, ifdown, ifup, inetd, init, insmod, install, kill, killall, klogd, last, ln, logger, login, logname, logread, ls, lsmod, makedevs, md5sum, mesg, mkdir, mknod, mktemp, modprobe, more, mount, mv, netstat, nslookup, passwd, patch, pidof, ping, pivot_root, printf, ps, pwd, rdate, reboot, renice, reset, rm, rmdir, rmmod, route, run-parts, rx, sed, sh, sleep, sort, start-stop-daemon, stty, su, sulogin, sync, sysctl, syslogd, tail, tar, tee, telnet, telnetd, test, time, top, touch, tr, true, tty, umount, uname, uniq, unix2dos, unzip, uptime,</td>
<td>UNIX shell and commands collection <a href="http://www.busybox.net/">http://www.busybox.net/</a></td>
</tr>
<tr>
<td>UclibC</td>
<td>0.9.27</td>
<td><strong>Uclibc Equivalent</strong></td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>-----------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ld.so, libc, libcrypt.so, libdl.so</td>
<td><a href="http://www.uclibc.org/downloads">http://www.uclibc.org/downloads</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td>libm.so, libnsl.so, libnss_dns.so, libnss_files.so, libpthread.so, libresolv.so, libutil.so</td>
<td><strong>Uclibc Equivalent</strong></td>
<td></td>
</tr>
</tbody>
</table>

* Or higher

** Shall include Freescale toolchain with glibc 2.5, including C++ libraries as equivalent to Uclibc. Toolchain and libraries shall be built with software floating point implementation for those controller platforms which lack hardware floating point.

**c.** SP2.2.5.HC2 Linux File System Configuration

The Model 2070-1C CPU Module Linux File System Configuration shall meet the requirements and guidelines for files, directories, and utility commands as per the Filesystem Hierarchy Standard (FHS-2.3) dated January 28, 2004.

d. SP5.3.3.HC. Linux Special Provisions to the ATC 5.2 Standard

**FLASH Memory**

The engine board shall provide FLASH for the storage of O/S software and user application programs. A minimum of 32MB of FLASH, with a minimum of 24MB free, shall be provided exclusively for application program storage. FLASH devices shall use a segmented architecture allowing erasing, writing and reading of individual segments. Access to this memory shall be accomplished with wait states totaling no more than 100 ns and a data bus width of no less than 16 bits.

Application software shall be capable of reading from and writing to the FLASH without the FLASH being corrupted by the power fail conditions specified in Section 5.4.1.
(2) Dynamic RAM (DRAM)

The engine board shall contain a minimum of 64MB of DRAM, with a minimum of 40MB free, or equivalent volatile memory for application and O/S program execution. The preferred memory organization shall be in the native word length of the CPU for maximum performance and is preferred to operate with zero wait states. The minimum DRAM bus width shall be 16 bits. If the native bus width and zero wait states are not used in the engine board design, the engine board Manufacturer must publish DHRYSTONE test results to prove that the MIPS requirement is met.

(3) Static RAM (SRAM)

The engine board shall contain a minimum of 2MB of SRAM memory for non-volatile parameter storage. Access to this memory shall be accomplished with wait states totaling no more than 100 ns and a data bus width of no less than eight bits. In the absence of VPRIMARY the SRAM shall be supported and maintained by VSTANDBY_5.

d. SP11.1.3.HC. Linux Special Provisions to the ATC 5.2 Standard Manufacturers’ Quality Control Testing Certification

Guidance: If requested by the purchasing agency, quality control procedures shall be submitted prior to production. A compliant test report that is part of the quality control procedure shall be supplied with each delivered unit. Along with pass fail information this report shall include the quality control procedure, test report format and the name of the tester. It should be counter-signed by a corporate officer.

Quality control procedures shall be submitted by vendor prior to production, which includes verification test report of NextPhase version supplied by Harris County.

The quality control procedure shall include the following:

- Design acceptance testing of all supplied components
- Physical and functional testing of controller units
- Environmental testing report(s) and final acceptance
- Acceptance testing of all supplied components
- Physical and functional testing of all modules and items
- Verification of a minimum burn-in of all equipment
- Verification test report of NextPhase version supplied by Harris County
Annex A

Deliverables

The following items shall be provided with the 2070 Controller Unit

- Copies of the vendor kernel, platform drivers, and Linux utility executable modules
- Copies of the hardware toolchain
- Copies of all the files originally stored in the root directory /, so that they can be reloaded as needed
- Reflash utility and the procedures for its use in PDF Form

Annex B

Required Device Driver Interfaces (Normative)

This Annex specifies the device driver interfaces required by this standard. Where practical, standard Linux drivers are specified and no further detail is given. Otherwise, each driver interface is described in full detail.

B.1 ATC CPU_RESET

Overview

This section defines a generalized driver interface for generating a pulse on the CPU_RESET port pin defined on the ATC engine board. Although an underlying general purpose interface to the ATC engine board PIO pins exists, only the simplified interface of this section is exposed to the user applications for controlling the CPU_RESET pin.

The BSP shall provide an external function, void atc_cpu_reset (void), that generates a 125 ± 20 ms active-low pulse on the CPU_RESET signal. This function first sets the CPU_RESET signal low, and resets a timer to count 125 ms. When the timer expires, the CPU_RESET signal is raised HIGH again. This function is non-blocking and non-exclusive in nature and may be called repetitively to generate a longer active-low pulse if necessary. If the CPU_RESET pin is already low when called, then the pulse width timer is simply reset and begins timing 125 ms.

During boot-up, the CPURESET pin shall be asserted and unasserted, in order to set the front panel and field I/O to a known state. Assertion time requirements shall match that of the 2070 ATC.

Examples
extern void atc_cpu_reset (void)

    /* single 125 ms pulse on CPU_RESET */

    atc_cpu_reset();

        ...

    /* generate a 200 ms pulse on CPU_RESET */

    atc_cpu_reset ();

        pause ( 75 ms);  /* blocking delay of 75 ms */

    */

    atc_cpu_reset ();

    ...

f. SPB5.4.HC. Linux Special Provisions to the ATC 5.2 Standard (Corrects typo “uint8” with “uint32” as defined below)

B.5.4 ATC SPxs Data Structures

The defined structure member values are shown in parentheses. Structure members that are not applicable to a port’s selected protocol shall be ignored by the driver. Upon receipt of an invalid, as compared to not applicable, argument, the ioctl( ) function shall generate an EINVAL error.

The driver shall maintain one atc_spxs_config structure for each SPxs port.

typedef struct atc_spxs_config {
uint32 protocol;     // Set the port protocol (ATC_SDLC,

        // ATC_ SYNC, ATC_HDLC)

    Uint32 baud;       // Set the port baud rate (ATC_B1200,  

        // ATC_B4800, ATC_B9600, 

        // ATC_B19200, ATC_B38400, ATC_B57600, ATC_B76800,

        // ATC_B115200,,ATC_B153600, ATC_B614400)

    Uint32 transmit_clock_source;  //

        (ATC_CLK_INTERNAL,ATC_CLK_EXTERNAL)
Uint32 transmit_clock_mode;  // Sets whether the sync transmit clock is on continuously or bursts with the data frame
// (ATC_CONTINUOUS, ATC_BURST)

2070.44 Type 2070-2 Field I/O Module (FI/O).

Type 2070-2A Module. The TYPE 2070-2A MODULE consists of the Field Controller Unit; Parallel Input/Output Ports; other Module Circuit Functions (includes muzzle switch); Serial Communication Circuitry; Module Connectors C1S, C11S, and C12S mounted on the module front plate; VDC Power Supply (+12VDC to +5VDC); and required resident software.

Type 2070-2B Module. The TYPE 2070-2B MODULE consists of the Serial Communication Circuitry, VDC Power Supply, and Module Connector C12S mounted on the module front plate only.

Field Controller Unit (FCU). The FCU includes a programmable microprocessor/controller unit together with all required clocking and support circuitry. Provide operational software necessary to meet housekeeping and functional requirements resident in socketed firmware.

Parallel I/O Ports.

The I/O Ports must provide 64 bits of input using ground-true logic. Each input must be read logic “1” when the input voltage at its field connector input is less than 3.5 VDC, and be read logic “0” when either the input current is less than 100 microamperes or the input voltage exceeds 8.5 VDC. Each input must have an internal pull-up to the Isolated +12 VDC and not deliver greater than 20 mA to a short circuit to ground.

The I/O Ports must provide 64 bits of output.

Inputs must have the following characteristics:

A voltage between 0 and 4 volts will be considered the Low (True/Operate) state.

A voltage greater than 8 volts will be considered the High (False) state.
The transition from the Low state to High state (and vice versa) occurs between 4 and 8 volts.

Outputs must have the following characteristics:

The Low (True/Operate) voltage will be between 0 and 3 volts.

Current sinking capability in the Low state will be at least 100 mA.

With an external impedance of 100 kiloOhms or greater, the transition from 4 to 16 volts (and vice versa) and be accomplished within 0.1 millisecond.

The High state impedance must exceed 1 Megohms to 12 volts DC.

Each output must latch the data written and remain stable until either new data is written or the active-low reset signal. Upon an active-low reset signal, each output must latch a logic "0" and retain that state until a new writing. The state of all output circuits at the time of Power Up or in Power Down state must be open (logic 0). It must be possible to simultaneously assert all outputs within 100 microseconds of each other. An output circuit state not changed during a new writing will not glitch when other output circuits are updated.

Other Module Circuit Functions.

A maximum capacitive load of 100 picofarads must be presented to the LINESYNC input signal. The EIA-485 compliant differential LINESYNC signals must be derived from the LINESYNC signal.

Provide an External WDT “Muzzle” Jumper on the board. With the jumper in and NRESET transitions HIGH (FCU active), the FCU must output a state change on Output Port 5, bit 8 (Connector C1, pin 103 – Monitor Watchdog Timer Input) every 100 milliseconds for 10 seconds or due to CPU Command. When the jumper is missing (open), the feature will not apply. This feature is required to operate with the Type 210 Monitor Unit only.

Provide a WATCHDOG Circuit. The FIELD I/O software at Power Up with a value of 100 milliseconds must enable it. Its enabled state must be machine readable and reported in the FI/O status byte. Once enabled, the watchdog timer must not be disabled without resetting the FI/O. Failure of the FI/O to reset the watchdog timer within the prescribed timeout will result in a hardware reset.

One KHz Reference. Provide a synchronizable 1 kilohertz time reference. It must maintain a frequency accuracy of +/-0.01% (+/-0.1 counts per second).

Provide a 32-bit MILLISECOND COUNTER (MC) for “timestamping.” Each 1 KHz reference interrupt must increment the MC.
Provide a LOGIC Switch resident on the module board. The switch must function to disconnect Serial Port 3 (SP3) from the external world, Connector C12S. Its purpose is to prevent multiple use of SP3. Provide an LED on the module front panel labeled “SP3 ON”. If LED light ON, SP3 is active and available at C12S.

Serial Communications/Logic Circuitry.

System Serial Port 5 (SP5) EIA-485 signal lines must enter the I/O Module and be split into two multi-drop isolated ports. Route one to the FCU and the other converted to EIA-485, then routed to Connector C12S.

System Serial Port 3 (SP3) EIA-485 signal lines must enter the I/O module and be isolated, converted back to EIA-485 and then routed to connector C12S.

LINE SYNC and POWER DOWN lines must be split and isolated, one routed to the FCU for shut down functions and the other changed to EIA-485; then routed to connector C12S for external module use.

CPU RESET and POWER UP (SYSRESET) lines must be isolated and “OR’d” to form NRESET. NRESET must be used to reset FCU and other module devices. NRESET must also be converted to EIA-485 then routed to connector C12S.

If the Type 2070 module is a –2B, routing to FCU does not apply.

Isolation is between internal +5 VDC / Ground #1 and +12 VDC ISO / VDC Ground #2. +12 VDC ISO is for board power and external logic.

Buffers. Provide a Transition Buffer capable of holding a minimum of 1024 recorded entries. The Transition Buffer must default to empty. There must be two entry types: Transition and Rollover. The inputs must be monitored for state transition. At each transition (If the input has been configured to report transition), a transition entry must be added to the Transition Buffer. The MC must be monitored for rollover. At each rollover transition ($xxxx FFFF - $xxxx 0000), a rollover entry must be added to the Transition Buffer. For rollover entries, all bits of byte 1 are set to indicate that this is a rollover entry. Transition Buffer blocks are sent to the CPU module upon command. Upon confirmation of their reception, the blocks must be removed from the Transition Buffer. The entry types are depicted as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>Isb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition Entry Identifier</td>
<td>S</td>
<td>Input Number</td>
<td>1</td>
</tr>
</tbody>
</table>
Inputs. Input scanning must begin at I0 (bit 0) and proceed to the highest numbered input, ascending from LSB to MSB. Each complete input scan must finish within 100 microseconds. Once sampled, the logic state of an input must be held until the next input scan. Each input must be sampled 1,000 times per second. The time interval between samples must be 1 millisecond (+/-100 microseconds). If configured to report, each input that has transitioned since its last sampling must be identified by input number, transition state, and timestamp (at the time the input scan began) and be added as an entry to the Transition Buffer. If multiple inputs change state during one input sample, these transitions must be entered into the Input Transition Buffer by increasing input number. The Millisecond Counter must be sampled within 10 microseconds of the completion of the input scan.

Data Filtering. If configured, the inputs must be filtered by the FCU to remove signal bounce. The filtered input signals must then be monitored for changes as noted. The filtering parameters for each input must consist of Ignore Input Flag and the ON and OFF filter samples. If the Ignore Input flag is set, no input transitions will be recorded. The ON and OFF filter samples must determine the number of consecutive samples an input must be ON and OFF, respectively, before a change of state is recognized. If the change of state is shorter than the specified value, the change of state must be ignored. The ON and OFF filter values must be in the range of 0 to 255. A filter value of 0, for either or both values, must result in no filtering for this input. The default values for input signals after reset must be as follows:

<table>
<thead>
<tr>
<th>Input Signals</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtering</td>
<td>Enabled</td>
</tr>
</tbody>
</table>
On and off filter values must be set to 5

Transition monitoring Disabled (Timestamps are not logged)

Outputs. Simultaneous assertion of all outputs must occur within 100 microseconds. Each output must be capable of being individually configured in state to ON, OFF, or a state synchronized with either phase of LINESYNC. The condition of the outputs must only be "ON" if the FI/O continues to receive active communications from the CPU Module. If there is no valid communications with the CPU Module for 2.0 seconds, all outputs must revert to the OFF condition, and the FI/O status byte must be updated to reflect the loss of communication from the CPU Module. The data and control bits in the CPU Module-FI/O frame protocol must control each output as follows:

Output Bit Translation

<table>
<thead>
<tr>
<th>Case</th>
<th>Output Data Bit</th>
<th>Output Control Bit</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
<td>Output in the OFF state</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>1</td>
<td>Output is a square wave, synchronized to the LINESYNC signal. When LINESYNC is ON (1), the output is OFF, and when LINESYNC is OFF (0), the output is ON.</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>1</td>
<td>Output is a square wave, synchronized to the LINESYNC signal. When LINESYNC is ON (1), the output is ON, and when LINESYNC is OFF (0), the output is OFF</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>0</td>
<td>Output in the ON state.</td>
</tr>
</tbody>
</table>

In Case A above, the corresponding output must be turned OFF if previously ON and if previously OFF remain OFF until otherwise configured. For half-cycle switching (cases B and C), all outputs to be changed must be changed within 50 microseconds after the corresponding LINESYNC transition and must remain in the same state during the entire half cycle. In Case D above, the corresponding output must be turned ON if previously OFF and if previously ON remain ON until otherwise configured. All outputs never change state unless configured to do so.
Interrupts. All interrupts must be capable of asynchronous operation with respect to all processing and all other interrupts. MILLISECOND Interrupt must be activated by the 1 kilohertz reference once per milliseconds. An MC timestamp rollover flag set by MC rollover must be cleared only on command.

LINESYNC Interrupt - This interrupt must be generated by both the 0-1 and 1-0 transitions of the LINESYNC signal. The LINESYNC interrupt must monitor the MC interrupt and set the MC error flag if there has not been an interrupt from the 1 kilohertz source for 0.5 seconds (>=60 consecutive LINESYNC interrupts). The LINESYNC interrupt must synchronize the 1 kilohertz time reference with the 0-1 transition of the LINESYNC signal once a second. A LINESYNC error flag must be set if the LINESYNC interrupt has not successfully executed for 0.5 seconds or longer (>=500 consecutive millisecond interrupts).

Communication Service Routine. A low-level communication service routine must be provided to handle reception, transmission, and EIA-485 communication faults. The communication server must automatically:

For Transmission

Generate the opening and closing flags

Generate the CRC value

Generate the abort sequence (minimum of 8 consecutive '1' bits) when commanded by the FCU

Provide zero bit insertion

For Receiving

Detect the opening and closing flags

Provide address comparison, generating an interrupt for messages addressed to the I/O Module, and ignoring messages not addressed to the I/O Module

Strip out inserted zeros

Calculate the CRC value, compare it to the received value, and generate an interrupt on an error

Generate an interrupt if an abort sequence is received

Communication Processing. The task must be to process the command messages received from the CPU Module, prepare, and start response
transmission. The response message transmission must begin within 4 milliseconds of the receipt of the received message. The time from the receipt of message to the completion of the commanded task must not exceed 70 milliseconds.

Input Processing. This task must process the raw input data scanned in by the 1 ms interrupt routine, perform all filtering, and maintain the transition queue entries.

Data Communications Protocols.

Protocols - All communication with the CPU Module must be SDLC-compatible command-response protocol, support 0 bit stuffing, and operate at a data rate of 614.4 kilobits per second. The CPU Module must always initiate the communication and should the command frame be incomplete or in error, no I/O response will be transmitted. The amount of bytes of a command or response is dependent upon the I/O Module identification.

The frame type must be determined by the value of the first byte of the message. The command frames type values 112-127 and associated response frame type values 240-255 are allocated to the manufacturer diagnostics. All other frame types not called out are reserved. The command-response Frame Type values and message times must be as follows:

*Frame Types*

<table>
<thead>
<tr>
<th>Module Command</th>
<th>I/O Module Response</th>
<th>Description</th>
<th>Minimum Message Time</th>
<th>Maximum Message Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-43</td>
<td>128-171</td>
<td>Reserved for NEMA TS-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>177</td>
<td>Request Module Status</td>
<td>250 microseconds</td>
<td>275 microseconds</td>
</tr>
<tr>
<td>50</td>
<td>178</td>
<td>MILLISECOND CTR. Mgmt.</td>
<td>222.5 microseconds</td>
<td>237.5 microseconds</td>
</tr>
<tr>
<td>51</td>
<td>179</td>
<td>Configure Inputs</td>
<td>344.5 microseconds</td>
<td>6.8750 milliseconds</td>
</tr>
<tr>
<td>52</td>
<td>180</td>
<td>Poll Raw Input Data</td>
<td>317.5 microseconds</td>
<td>320 microseconds</td>
</tr>
<tr>
<td>Module Command</td>
<td>I/O Module Response</td>
<td>Description</td>
<td>Minimum Message Time</td>
<td>Maximum Message Time</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------------</td>
<td>-----------------------------------</td>
<td>----------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>53</td>
<td>181</td>
<td>Poll Filtered Input Data</td>
<td>317.5 microseconds</td>
<td>320 microseconds</td>
</tr>
<tr>
<td>54</td>
<td>182</td>
<td>Poll Input Transition Buffer</td>
<td>300 microseconds</td>
<td>10.25 microseconds</td>
</tr>
<tr>
<td>55</td>
<td>183</td>
<td>Command Outputs</td>
<td>405 microseconds</td>
<td>410 microseconds</td>
</tr>
<tr>
<td>56</td>
<td>184</td>
<td>Reserved</td>
<td>340 microseconds</td>
<td>10.25 milliseconds</td>
</tr>
<tr>
<td>57</td>
<td>185</td>
<td>Reserved</td>
<td>340 microseconds</td>
<td>6.875 milliseconds</td>
</tr>
<tr>
<td>58</td>
<td>186</td>
<td>Configure Watchdog</td>
<td>222.5 microseconds</td>
<td>222.5 microseconds</td>
</tr>
<tr>
<td>59</td>
<td>187</td>
<td>Controller Identification</td>
<td>222.5 microseconds</td>
<td>222.5 microseconds</td>
</tr>
<tr>
<td>60</td>
<td>188</td>
<td>I/O Module Identification</td>
<td>222.5 microseconds</td>
<td>222.5 microseconds</td>
</tr>
<tr>
<td>61-62</td>
<td>189-190</td>
<td>Reserved (note below)</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>63</td>
<td>191</td>
<td>Poll variable length raw input</td>
<td>317.5 microseconds</td>
<td>320 microseconds</td>
</tr>
<tr>
<td>64</td>
<td>192</td>
<td>Variable length command outputs</td>
<td>405 microseconds</td>
<td>410 microseconds</td>
</tr>
<tr>
<td>65</td>
<td>193</td>
<td>Reserved (note below)</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>67</td>
<td>195</td>
<td>Reserved (note below)</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

Messages 61 / 189, 62 / 190, 65 / 193, and 67 / 195 are reserved for ITS Cabinet Frame Types. Message 63 / Message 191 must be the same as Message 52 / 180 except Byte 2 of Message 180 response must denote the following number of input data bytes. Message 64 / 192 must be the same as Message 55 / 183 except Byte 2 of the Message 55 Command must denote the number of output data bytes, plus the following output control bytes.
Request Module Status. The Command must be used to request FI/O status information response. Command/response frames are as follows:

### Request Module Status Command

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 49)</td>
<td>0</td>
<td>1</td>
<td>1 0 0 1</td>
</tr>
<tr>
<td>Reset Status Bits</td>
<td>P</td>
<td>E</td>
<td>K R T M L W</td>
</tr>
</tbody>
</table>

### Request Module Status Response

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 177)</td>
<td>1</td>
<td>0</td>
<td>1 0 1 1</td>
</tr>
<tr>
<td>System Status</td>
<td>P</td>
<td>E</td>
<td>K R T M L W</td>
</tr>
<tr>
<td>SCC Receive Error Count</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCC Transmit Error Count</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC Timestamp MSB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC Timestamp NMSB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC Timestamp NLSB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC Timestamp LSB</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The response status bits are defined as follows:

- **P** Indicates FI/O hardware reset
- **E** Indicates a communications loss of greater than 2 seconds
- **K** Indicates the Datakey has failed or is not present
- **R** Indicates that the EIA-485 receive error count byte has rolled over
- **T** Indicates that the EIA-485 transmit error count byte has rolled over
M Indicates an error with the MC interrupt

L Indicates an error in the LINESYNC

W Indicates that the FI/O has been reset by the Watchdog

The FI/O status byte must be updated (set to '1') to reflect the faults noted in clause 12. Data Communications Protocols – a.(1). Each status bit must only be reset (set to '0') when the corresponding bit of the Request Module Status Command is a '1'. The Request Module Status Response must report the current status (subsequent to reset and sampling).

The FI/O must count the number of errored frames the FI/O Communications Processor reports. Separate counts must be maintained for transmit and received frames. When an individual count rolls over (255-0), the corresponding roll-over flag must be set.

FI/O modules with Datakey: On NRESET transition to High or immediately prior to any interrogation of the Datakey, the FI/O must test the presence of the Key. If absent, Status Bit "K" must be set to '1' and no interrogation take place. If an error occurs during the interrogation, Status Bit "K" must be set to '1'. FI/O modules without Datakey: Status Bit "K" must always be set to '1'

The MC timestamp value must be sampled just prior to the Request Module Status Response.

MC Management. MC MANAGEMENT frame must be used to set the value of the MC. The 'S' bit must return status '0' on completion. The 32-bit value must be loaded into the MC at the next 0-1 transition of the LINESYNC signal. The frames are as follows:

### Millisecond Counter Management Command

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 50)</td>
<td>0</td>
<td>0</td>
<td>1 1 0 0 1 0</td>
</tr>
<tr>
<td>New MC Timestamp MSB</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>New MC Timestamp NMSB</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>New MC Timestamp NLSB</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>New MC Timestamp LSB</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
</tbody>
</table>

Millisecond Counter Management Response
Configure Inputs. The Configure Inputs command frame must be used to change input configurations. The command-response frames are as follows:

### Configure Inputs Command

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 178)</td>
<td>1</td>
<td>0</td>
<td>1 1 0 0 1 0</td>
</tr>
<tr>
<td>Status</td>
<td>0</td>
<td>0</td>
<td>0 0 0 0 0 S</td>
</tr>
</tbody>
</table>

Number of Items (n)

Item # - Byte 1: E Input Number
Item # - Byte 2: Leading edge filter (e)
Item # - Byte 3: Trailing edge filter (r)

### Configure Inputs Response

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 179)</td>
<td>1</td>
<td>0</td>
<td>1 1 0 0 1 0</td>
</tr>
<tr>
<td>Status</td>
<td>0</td>
<td>0</td>
<td>0 0 0 0 0 S</td>
</tr>
</tbody>
</table>

Block field definitions must be as follows:

E  Ignore Input Flag.  "1" = do not report transitions for this input, "0" = report transitions for this input

e  A one-byte leading edge filter specifying the number of consecutive input samples which must be "0" before the input is considered to have entered to "0" state from "1" state (range 1 to 255, 0 = disabled)

r  A one-byte trailing edge filter specifying the number of consecutive input samples which must be "1" before the input is considered to have entered to "1" state from "0" state (range 1 to 255, 0 = disabled)
S return status $S = '0'$ on completion or $'1'$ on input error out of range

Poll Raw Input Data. The Poll Raw Input Data frame must be used to poll the FI/O for the current unfiltered status of all inputs. The response frame must contain 8 bytes (2A) or 15 bytes (2B) of information indicating the current input status. The frames are as follows:

Poll Raw Input Data Command

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 52)</td>
<td>0</td>
<td>0</td>
<td>1 1 0 0</td>
</tr>
</tbody>
</table>

Poll Raw Input Data Response (2070-2A)

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 180)</td>
<td>1</td>
<td>0</td>
<td>1 1 0 0</td>
</tr>
<tr>
<td>Inputs I0 (lsb) to I7 (msb)</td>
<td>x</td>
<td>x</td>
<td>x x x x</td>
</tr>
<tr>
<td>Inputs I8 to I63</td>
<td>x</td>
<td>x</td>
<td>x x x x</td>
</tr>
<tr>
<td>MC Timestamp MSB</td>
<td>x</td>
<td>x</td>
<td>x x x x</td>
</tr>
<tr>
<td>MC Timestamp NMSB</td>
<td>x</td>
<td>x</td>
<td>x x x x</td>
</tr>
<tr>
<td>MC Timestamp NLSB</td>
<td>x</td>
<td>x</td>
<td>x x x x</td>
</tr>
<tr>
<td>MC Timestamp LSB</td>
<td>x</td>
<td>x</td>
<td>x x x x</td>
</tr>
</tbody>
</table>

Poll Raw Input Data Response (2070-8)

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 180)</td>
<td>1</td>
<td>0</td>
<td>1 1 0 0</td>
</tr>
<tr>
<td>Inputs I0 (lsb) to I7 (msb)</td>
<td>x</td>
<td>x</td>
<td>x x x x</td>
</tr>
<tr>
<td>Inputs I8 to I119</td>
<td>x</td>
<td>x</td>
<td>x x x x</td>
</tr>
<tr>
<td>MC Timestamp MSB</td>
<td>x</td>
<td>x</td>
<td>x x x x</td>
</tr>
</tbody>
</table>
Poll Filtered Input Data. The Poll Filtered Input Data frame must be used to poll the FI/O for the current filtered status of all inputs. The response frame must contain 8 bytes (2A) or 15 bytes (2B) of information indicating the current filtered status of the inputs. Raw input data must be provided in the response for inputs that are not configured for filtering. The frames are as follows:

Poll Filter Input Data Command

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 53)</td>
<td>0</td>
<td>0</td>
<td>1 1 0 1 0 1 1 0</td>
</tr>
</tbody>
</table>

Poll Filter Input Data Response (2070-2A)

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 180)</td>
<td>1</td>
<td>0</td>
<td>1 1 0 1 0 0</td>
</tr>
<tr>
<td>Inputs I0 (lsb) to I7 (msb)</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>Inputs I8 to I63</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>MC Timestamp MSB</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>MC Timestamp NMSB</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>MC Timestamp NLSB</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
<tr>
<td>MC Timestamp LSB</td>
<td>x</td>
<td>x</td>
<td>x x x x x x</td>
</tr>
</tbody>
</table>

Poll Filter Input Data Response (2070-8)
<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 181)</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Inputs I0 (lsb) to I7 (msb)</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Inputs I8 to I119</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>MC Timestamp MSB</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>MC Timestamp NMSB</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>MC Timestamp NLSB</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>MC Timestamp LSB</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Poll Input Transition Buffer. The Poll Input Transition Buffer frame must poll the FI/O for the contents of the input transition buffer. The response frame must include a three-byte information field for each of the input changes that have occurred since the last interrogation. The frames are as follows:

### Poll Input Transition Buffer Command

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 54)</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Block Number</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

### Poll Input Transition Buffer Response

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 182)</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Block Number</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Number of Entries</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Item #</td>
<td>S</td>
<td>Input Number</td>
<td>Byte 3(I-1)+4</td>
</tr>
<tr>
<td>Item # MC Timestamp NLSB</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
Each detected state transition for each active input (see configuration data) is placed in the queue as it occurs. The FI/O must set the 'F' bit to '1' when attempting to record a transition and the Transition Buffer is full. While the Transition Buffer is full, all subsequent entries must be discarded. Bit definitions are as follows:

- **S**: Indicates the state of the input after the transition
- **C**: Indicates the 255 transition entries limit has been exceeded
- **F**: Indicates the transition buffer limit has been exceeded
- **G**: Indicates the requested block number is out of monotonic increment sequence
- **E**: Same block number requested, E is set in response

The Block Number byte is a monotonically increasing number incremented after each command issued by the CPU Module. When the FI/O Module receives this command, it must compare the associated Block Number with the Block Number of the previously received command. If it is the same, the previous buffer must be re-sent to the CPU Module and the 'E' flag set in the status response frame. If it is not equal to the previous Block Number, the old buffer must be purged and the next block of data sent. If the block number is not incremented by one, the status G bit must be set. The block number received becomes the current number (even if out of sequence). The Block Number byte sent in the response block must be the same as that received in the command block. Counter rollover must be considered as a normal increment.

The Timestamp must equal the MC value at the time the Poll Input Transition Buffer Response is generated.

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item # MC Timestamp LSB</td>
<td>x</td>
<td>x</td>
<td>Byte 3(I-1)+6</td>
</tr>
<tr>
<td>Status</td>
<td>0</td>
<td>0</td>
<td>Byte 3(I-1)+7</td>
</tr>
<tr>
<td>MC Timestamp MSB</td>
<td>x</td>
<td>x</td>
<td>Byte 3(I-1)+8</td>
</tr>
<tr>
<td>MC Timestamp NMSB</td>
<td>x</td>
<td>x</td>
<td>Byte 3(I-1)+9</td>
</tr>
<tr>
<td>MC Timestamp NLSB</td>
<td>x</td>
<td>x</td>
<td>Byte 3(I-1)+10</td>
</tr>
<tr>
<td>MC Timestamp LSB</td>
<td>x</td>
<td>x</td>
<td>Byte 3(I-1)+11</td>
</tr>
</tbody>
</table>
Set Outputs. The Set Outputs frame must be used to command the FI/O to set the Outputs according to the data in the frame. If there is any error configuring the outputs, the 'E' flag in the response frame must be set to '1'. If the LINESYNC reference has been lost, the 'L' bit in the response frame must be set. Loss of LINESYNC reference must also be indicated in system status information. The output bytes depend upon field I/O module. These command and response frames are as follows:

### Set Outputs Command

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 55)</td>
<td>0</td>
<td>0</td>
<td>1 1 0 1 1 1 1</td>
</tr>
<tr>
<td>Outputs O0 (lsb) to O7 (msb) Data</td>
<td>x</td>
<td>x</td>
<td>x x x x x x x</td>
</tr>
<tr>
<td>Outputs O8 to O103 Data</td>
<td>x</td>
<td>x</td>
<td>x x x x x x x</td>
</tr>
<tr>
<td>Outputs O0 (lsb) to O7 (msb) Control</td>
<td>x</td>
<td>x</td>
<td>x x x x x x x</td>
</tr>
<tr>
<td>Outputs O8 to O103 Control</td>
<td>x</td>
<td>x</td>
<td>x x x x x x x</td>
</tr>
</tbody>
</table>

### Set Outputs Response

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 183)</td>
<td>1</td>
<td>0</td>
<td>1 1 0 1 1 1</td>
</tr>
<tr>
<td>Status</td>
<td>0</td>
<td>0</td>
<td>0 0 0 0 0 L E</td>
</tr>
</tbody>
</table>

Configure Watchdog. The Configure Watchdog frames must be used to change the software watchdog timeout value. The Command and response frames are as follows:

### Configure Watchdog Command

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>msb</td>
<td>lsb</td>
<td>Byte Number</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----</td>
<td>-----</td>
<td>-------------</td>
</tr>
<tr>
<td>(Type Number = 58)</td>
<td>0</td>
<td>0</td>
<td>1 1 1 0 1 0</td>
</tr>
<tr>
<td>Timeout Value</td>
<td>x</td>
<td>x</td>
<td>x x x x x</td>
</tr>
</tbody>
</table>

Configure Watchdog Response

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 186)</td>
<td>1</td>
<td>0</td>
<td>1 1 1 0 1 0</td>
</tr>
<tr>
<td>Status</td>
<td>0</td>
<td>0</td>
<td>0 0 0 0 0 Y</td>
</tr>
</tbody>
</table>

The timeout value must be in the range between 10 to 100 milliseconds. If the value is lower than 10, 10 must be assumed. If the value is greater than 100, 100 must be assumed.

On receipt of this frame, the watchdog timeout value must be changed to the value in the message and the “Y” bit set. The response frame bit (Y) must indicate a '1' if the watchdog has been previously set and a '0' if not.

Controller Identification. This is a legacy message command / response for FI/O modules with Datakey resident. Upon command, a response frame containing the 128 bytes of the Datakey. See previous sections on Request Module Status for FI/O Status Bit 'K' definition. If “K” bit set, only the first two bytes must be returned. The Command and Response frames are as follows:

Controller Identification Command

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number= 59)</td>
<td>0</td>
<td>0</td>
<td>1 1 1 0 1 1</td>
</tr>
</tbody>
</table>

Controller Identification Response

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 187)</td>
<td>1</td>
<td>0</td>
<td>1 1 1 0 1 1</td>
</tr>
</tbody>
</table>
Module Identification. The I/O Module Identification Command frame must be used to request the FI/O Identification value. A response of "1" must be returned by 2070-2A, "2" by 2070-8, "3" is reserved for NEMA TS 2 Type 1 FI/O and "32 to 40" are reserved for ITS Cabinets. The command and response frames are shown as follows:

### I/O Module Identification Command

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 60)</td>
<td>0</td>
<td>0</td>
<td>1 1 1 1 0 0</td>
</tr>
</tbody>
</table>

### I/O Module Identification Response

<table>
<thead>
<tr>
<th>Description</th>
<th>msb</th>
<th>lsb</th>
<th>Byte Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Type Number = 188)</td>
<td>1</td>
<td>0</td>
<td>1 1 1 1 0 0</td>
</tr>
<tr>
<td>FI/O ID byte</td>
<td>x</td>
<td>x</td>
<td>x x x x x</td>
</tr>
</tbody>
</table>

2070.45 Type 2070-3 Front Panel Assembly.

General. The Type 2070-3 Front Panel Assembly (FPA) must be delivered with one of the three options as defined in this clause. All options must consist of a panel with Latch assembly and two TSD #1 hinge attaching devices, assembly PCB, external serial port connector(s), CPU active LED indicator, and FP Harness Interface. The options must include the additional features, as follows:

- **Option 3A** FPA controller, two keyboards, AUX switch, alarm bell and Display A
- **Option 3B** FPA controller, two keyboards, AUX switch, alarm bell and Display B - required for NEMA compliance (TS-1 & TS-2 type1) 8 x 40 display with 2 keypads
Option 3C System Serial Port 6 Lines, isolated and vectored to Connector C60S.

Keyboards. Provide two KEYBOARDS, one with sixteen keys for hexadecimal alphanumeric entry and the other with twelve keys to be used for cursor control and action symbol entry. Engrave or emboss each key with its function character. Each key must have an actuation force between 50 and 100 grams and provide a positive tactile indication of contact closure. Key contacts must be hermetically sealed, have a design life of over one million operations, be rated for the current and voltage levels used, and stabilize within 5 milliseconds following contact closure.

CPU Active Indicator. The cathode of the CPU ACTIVE LED INDICATOR must be electrically connected to the CPU Activity LED signal and be pulled up to +5 VDC.

Display. The DISPLAY must consist of a Liquid Crystal Display (LCD), a backlight, and a contrast potentiometer control. Display A must have 4 lines of 40 characters each with a minimum character dimensions of 0.20 inches wide by 0.41 inches high and an electro-luminescent (EL) backlight. Display B must have 8 lines of 40 characters each with minimum dimensions of 0.10 inches wide by 0.17 high and either LED or EL backlight.

Each character must be composed of a 5 x 7 dot matrix with an underline row or a 5 x 8 dot matrix. The viewing angle of the LCD must be optimized for direct (90 degrees) viewing, +/-35 degrees vertical, +/-45 degrees horizontal. The LCD must have variable contrast with a minimum ratio of 4:1. The LCD must be capable of displaying, at any position on the Display, any of the standard ASCII characters as well as user-defined characters.

The backlight must be turned on and off by the Controller Circuitry. The backlight and associated circuitry must consume no power when in off state. A potentiometer must control the LCD contrast with clockwise rotation increasing contrast. The contrast must depend on the angular position of the potentiometer, which must provide the entire contrast range of the LCD.

Cursor display must be turned ON and OFF by command. When ON, the cursor must be displayed at the current cursor position. When OFF, no cursor is to be displayed. All other cursor functions (positioning, etc.) must remain in effect.

FPA Controller. The FPA CONTROLLER must function as the Front Panel Device controller interfacing with the CPU Module.

Provide a FPA RESET Switch on the Assembly PCB. The momentary CONTROL switch must be logic OR’d with the CPU RESET Line, producing a FPA RESET Output. Upon FPA RESET being active or receipt of a valid Soft Reset display command, the following must occur:

82-127
Auto-repeat, blinking, auto-wrap, and auto-scroll must be set to OFF.

Each special character must be set to ASCII SPC (space).

The tab stops must be set to columns 9, 17, 25, and 33.

The backlight timeout value must be set to 6 (60 seconds).

The backlight must be extinguished.

The display must be cleared (all ASCII SPC).

The FPA module must transmit a power up string through /sp6 to the CPU once power is applied to the FPA, or the FPA hardware RESET BUTTON IS PUSHED. The string is “ESC [PU”, hex value “1B 5B 50 55”.

When a keypress is detected, the appropriate key code must be transmitted to SP6-RxD. If two or more keys are depressed simultaneously, no code is to be sent. If a key is depressed while another key is depressed, no additional code is to be sent.

Auto-repeat must be turned ON and OFF by command. When ON, the key code must be repeated at a rate of 5 times per second starting when the key has been depressed continuously for 0.5 second, and must terminate when the key is released or another key is pressed.

When the AUX Switch is toggled, the appropriate AUX Switch code must be transmitted to the CPU.

The controller circuitry must be capable of composing and storing eight special graphical characters on command, and displaying any number of these characters in combination with the standard ASCII characters. Undefined characters must be ignored. User-composed characters must be represented in the communication protocol on Page 9-7-12. P1 represents the special character number (1-8). Pn's represent columns of pixels from left to right. The most significant bit of each Pn represents the top pixel in a column and the least significant bit must represent the bottom pixel. A logic ‘1’ must turn the pixel ON. There must be a minimum of 5 Pn's for 5 columns of pixels in a command code sequence terminated by an "f." If the number of Pn's are more than the number of columns available on the LCD, the extra Pn's must be ignored. P1 and all Pn's must be in ASCII coded decimal characters without leading zero.

Character overwrite mode must be the only display mode supported. A displayable character received must always overwrite the current cursor position on the Display. The cursor must automatically move right one character position on the Display after each character write operation. When the rightmost character on a line (position 40) has been overwritten, the
cursor position must be determined based on the current settings of the auto-wrap mode.

Auto-wrap must be turned ON & OFF by command. When ON, a new line operation must be performed after writing to position 40. When OFF, upon reaching position 40, input characters must continue to overwrite position 40.

Cursor positioning must be non-destructive. Cursor movement must not affect the current display, other than blinking the cursor momentarily and periodically hiding the character at that cursor position.

Blinking characters must be supported, and be turned ON and OFF by command. When ON, all subsequently received displayable characters must blink at the rate of 1 Hertz with a 60% ON / 40% OFF duty cycle. It must be possible to display both blinking and non-blinking characters simultaneously.

Tab stops must be configurable at all columns. A tab stop must be set at the current cursor position when a SetTabStop command is received. Tab Stop(s) must be cleared on receipt of a ClearTabStop command. On receipt of the HT (tab) code, the cursor must move to the next tab stop to the right of the cursor position. If no tab stop is set to the right of the current cursor position, the cursor must not move.

Auto-scroll must be turned ON and OFF by command. When ON, a Line Feed or new line operation from the bottom line must result in the display moving up one line. When OFF, a Line Feed or new line from the bottom line must result in the top line clearing, and the cursor being positioned on the top line.

The display must have a buffer. The screen must be refreshed from the buffer at a rate of no less than 20 times per second.

The Display back light must illuminate when any key is pressed and illuminate or extinguish by command. The backlight must extinguish when no key is pressed for a specified time. This time must be program selected by command, by a number in the range 0 to 63 corresponding to that number of 10-second intervals. A value of 1 must correspond to a timeout interval of 10 seconds. A value of 0 must indicate no timeout.

The Command Codes must use the following conventions:

Parameters and Options: Parameters are depicted in both the ASCII and hexadecimal representations as the letter 'P' followed by a lower-case character or number. These are interpreted as follows:

Pn: Value parameter, to be replaced by a value, using one ASCII character per digit without leading zeros.
P1: Ordered and numbered parameter. One of a listed known parameters with a specified order and number (Continues with P2, P3, etc.)

Px: Display column number (1-40), using one ASCII character per digit without leading zero.

Py: Display line (1-4) one ASCII character

...: Continue the list in the same fashion

Values of 'h' (0x68) and 'l' (0x6C) are used to indicate binary operations. 'h' represents ON (high), 'l' represents OFF (low).

ASCII Representation: Individual characters are separated by spaces; these are not to be interpreted as the space character, which is depicted by SPC.

Hexadecimal Representation: Characters are shown as their hexadecimal values and will be in the range 0x00 to 0x7F (7 bits).

The Controller Circuit must communicate via a SP6 asynchronous serial interface. The interface must be configured for 38.4 kilobits per second, 8 data bits, 1 stop bit, and no parity.

C50 ENABLE function when grounded by pins 1 and 5, must be brought to Connectors A1, pin B21 for the purpose of disabling the module channel 2, (SP4).

Electronic Bell. The Front Panel must include an electronic bell to signal receipt of (0x07). The bell must sound at 2,000 Hertz, with a minimum output rating of 85 dB upon receipt of (0x07). Receipt of all other characters and ESC codes must continue during the time the bell sounds.

2070.46 Type 2070-4 Power Supply Module.

General. The Type 2070-4A Power Supply Module must be independent, self contained Module, vented, and cooled by convection only. The Module must slide into the unit’s power supply compartment from the back of the Chassis and be attached to the Backplane Mounting Surface by its four TSD #3 Devices.

The Type 2070-4B Module must meet the same requirements as the 2070-4A, except for 3.5 amperes of +5 VDC.

Module Front. An "On/Off" POWER Switch, four LED DC Power Indicators, PS Receptacle POWER Connectors, and the Incoming AC Fuse protection must be provided on the Module Front. The LED DC POWER Indicators
must indicate all required DC voltages meet the following conditions: the +5 VDC is within 5% and the 12 VDC is within 8% of their nominal levels.

Input Protection. Provide two 0.5-Ohm, 10-watt wire-wound power resistors with a 0.2 micro Henries inductance (one on the AC+ Line & on the AC-Line). Provide three 20 Joule surge arrestors between AC+ to AC-, AC+ to EG, and AC- to EG. A 0.68 µF capacitor must be placed between AC+ & AC- (between the resistor & arrestors).

+5VDC Standby Power. Provide +5 VDC STANDBY POWER to hold up specified circuitry during the power down period. It must consist of the monitor circuitry, hold up capacitors, and charging circuitry. Provide a charging circuit that under normal operation, fully charges and float the capacitors consistent with the manufacturers' recommendations. The Hold Up power requirements must be a minimum constant drain of 600 microamperes at a range of +5 VDC to +2 VDC for over 600 minutes.

Monitor Circuitry. Provide MONITOR CIRCUITRY to monitor incoming AC Power for Power Failure and Restoration and LINESYNC generation.

The ACFAIL/POWER DOWN Output Lines must go LOW (ground true) immediately upon Power Failure. The Lines must transition to HIGH at Power Restoration. The Lines must be driven separately. The SYSRESET/POWERUP Output Lines must transition to LOW 525 +/-25 milliseconds after ACFAIL/POWER DOWN transition to LOW. The Lines must transition to HIGH 225 +/-25 milliseconds after Power Restoration and the supply is fully recovered. The Lines must be driven separately.

The monitor circuitry must switch the +5 VDC Standby ON immediately upon Power Failure and isolate (OFF) the line at Power Up.

The 60 Hz Square Wave LINESYNC signal must be generated by a crystal oscillator, which must be synchronized to the 60-Hertz VAC incoming power line at 120 and 300 degrees. A continuous square wave signal must be +5 VDC amplitude, 8.333 milliseconds half-cycle pulse duration, and 50 +/-1% duty cycle. The output must have drive sink and source capability of 16 mA. A 2 K-Ohm pull-up resistor must be connected between the output and +5 VDC. The monitor circuit must compensate for missing pulses and line noise during normal operation.

The LINESYNC must continue until SYSRESET transitions LOW and begin when SYSRESET transitions HIGH.

Power Supply Requirements.
### Voltage Tolerances

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Tolerances</th>
<th>I Minimum</th>
<th>I Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>+5 VDC</td>
<td>+4.875 to +5.125 VDC</td>
<td>1.0 ampere</td>
<td>10.0 ampere- 2070-4A</td>
</tr>
<tr>
<td>+12 VDC</td>
<td>+11.4 to +12.6 VDC</td>
<td>0.1 ampere</td>
<td>0.5 ampere</td>
</tr>
<tr>
<td>-12 VDC</td>
<td>-11.4 to -12.6 VDC</td>
<td>0.1 ampere</td>
<td>0.5 ampere</td>
</tr>
<tr>
<td>+12 VDC</td>
<td>+11.4 to +12.6 VDC</td>
<td>0.1 ampere</td>
<td>1.0 ampere</td>
</tr>
</tbody>
</table>

Line/Load Regulation. Line / Load Regulation must meet the table tolerance values for voltage range of 90 to 135 VAC, the maximum and minimum loads called out in the table and including ripple noise.

Efficiency. 70% minimum.

Ripple and Noise. Less than 0.2% RMS, 1% peak to peak or 50 millivolts, whichever is greater.

Voltage Overshoot. No greater than 5%, all outputs.

Overvoltage Protection. 130% V out for all outputs.


Inrush Current. Cold Start Inrush must be less than 25 amperes at 115VAC.

Transient Response. Output voltage back to within 1% in less than 500 microseconds on a 50% Load change. Peak transient not to exceed 5%.

Holdup Time. The power supply must supply 30 watts minimum for 550 milliseconds after ACFAIL going LOW. The supply must be capable of holding up the Unit for two 500 milliseconds Power Loss periods occurring in a 1.5-second period.

Remote Sense. +5 VDC compensates 250 millivolts total line drop. Open sense load protection required.

### 2070.47 Unit Chassis Type 2070.

General.

The Chassis consists of the metal housing, Serial Motherboard, Back-plane Mounting Surface, Power Supply Module Supports, slot card guides, Wiring Harnesses, and Cover Plate(s).
All external screws must be countersunk and be Phillips flat head stainless steel type.

The housing must be treated with clear chromate and the slot designation labeled on the back-plane mounting surface above the upper slot card guide.

The Chassis must be cooled by convection only. The top and bottom pieces of the housing must be slotted for vertical ventilation.

Serial Motherboard. Serial Motherboard must function as support for its connectors, A1 to A5 and FP, and as the interface between the CPU and the dedicated modules/Front Panel carrying both serial communications, logic, and power circuits. The PCB must be multi-layered, with one layer plane assigned to DC Ground.

A wiring harness PS2 must be provided between the Type 2070-4 Power Supply and the Motherboard PCB (provide strain relief). Test points must be provided on the FPA side of the Motherboard for PS2 lines.

A wiring harness FP must be provided, linking the Motherboard with the FPA.

Details.

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<table>
<thead>
<tr>
<th>Type 2070-3</th>
<th>-</th>
<th>Front Panel Assembly, Key Codes</th>
<th>Figure 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 2070-4</td>
<td>-</td>
<td>Power Supply Module</td>
<td>Figure 15</td>
</tr>
<tr>
<td>Type 2070-5</td>
<td>-</td>
<td>VME Cage Assembly</td>
<td>Figure 16</td>
</tr>
</tbody>
</table>
Figure 3

Chassis Front View
Figure 4
Chassis Rear View

1. Four permanently attached 18' long Control Cables, Set 1002F
   (3), connected 30" from the backplane mounting surface.
2. CH - TRANSITION LOADING
   PCB - NETWORK CONTROLLER 10-16
3. Minimum length of harness shall be 47" and shall not
   protrude beyond the back of the 2070 units.
4. The VME Cage Assembly opening shall be delivered covered by
   a blank panel. Mounting for CEM hardware shall be provided on
   the backplane surface for panel mounting.
5. Power Supply will be marked with 2070-44 or 2070-45.
Figure 5

Chassis Top View
Figure 6

Chassis Motherboard
### Motherboard A Connector Pin Assignment

**Rev Date:** 2-11-94  
**FEBRUARY 20, 2004**  
9-7-5

#### Notes (1189 Detail):

1. Functions are referenced to the CPU.
2. EC ON H for EVF and EVFEE Server.
   EC ON B for HVPF and HVPFEE Server.
3. 42 Connector A: the rear-edge 4 connector to the left after viewed from the left.
   Back 4 & Connectors are pin assigned the same.
4. Connector A4 to A4, pins E1 and E2 shall read 'NA'.
   Connector A4, pins E3 shall read '23'
   Connector A4, pins E4 shall read '20'
   Connector A4, pins E5 shall read '19'
   Connector A4, pins E6 shall read '18'
   Connector A4, pins E7 shall read '17'
   Connector A4, pins E8 shall read '16'
5. The APE (IDS) #1 is reserved for network protection only, no Ethernet Shield.

#### Table:

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SP11A-C</td>
</tr>
<tr>
<td>2</td>
<td>SP11A-B</td>
</tr>
<tr>
<td>3</td>
<td>SP11A-A</td>
</tr>
<tr>
<td>4</td>
<td>SP11A-D</td>
</tr>
<tr>
<td>5</td>
<td>SP11A-E</td>
</tr>
<tr>
<td>6</td>
<td>SP11A-F</td>
</tr>
<tr>
<td>7</td>
<td>SP11A-G</td>
</tr>
<tr>
<td>8</td>
<td>SP11A-H</td>
</tr>
<tr>
<td>9</td>
<td>SP11A-I</td>
</tr>
<tr>
<td>10</td>
<td>SP11A-J</td>
</tr>
<tr>
<td>11</td>
<td>SP11A-K</td>
</tr>
<tr>
<td>12</td>
<td>SP11A-L</td>
</tr>
<tr>
<td>13</td>
<td>SP11A-M</td>
</tr>
<tr>
<td>14</td>
<td>SP11A-N</td>
</tr>
<tr>
<td>15</td>
<td>SP11A-O</td>
</tr>
<tr>
<td>16</td>
<td>SP11A-P</td>
</tr>
<tr>
<td>17</td>
<td>SP11A-Q</td>
</tr>
<tr>
<td>18</td>
<td>SP11A-R</td>
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<td>19</td>
<td>SP11A-S</td>
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<td>SP11A-T</td>
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<tr>
<td>21</td>
<td>SP11A-U</td>
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<td>SP11A-V</td>
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<td>23</td>
<td>SP11A-W</td>
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<tr>
<td>24</td>
<td>SP11A-X</td>
</tr>
<tr>
<td>25</td>
<td>SP11A-Y</td>
</tr>
<tr>
<td>26</td>
<td>SP11A-Z</td>
</tr>
<tr>
<td>27</td>
<td>SP11A-aa</td>
</tr>
<tr>
<td>28</td>
<td>SP11A-ab</td>
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<tr>
<td>29</td>
<td>SP11A-ac</td>
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<td>30</td>
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<td>33</td>
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<td>38</td>
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<tr>
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<td>SP11A-ao</td>
</tr>
<tr>
<td>42</td>
<td>SP11A-ap</td>
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</tbody>
</table>

**Figure 7**

Motherboard A Connector Pin Assignment
Figure 8
System PCB Modules General
Figure 9

2070-1A, 2070-1B and 2070-1C CPU Modules
### Field I/O Modules

**Figure 10**

Field I/O Modules

---

<table>
<thead>
<tr>
<th>Field I/O Modules</th>
<th>2070-2A</th>
<th>2070-2B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LED</strong></td>
<td>Active</td>
<td>Active</td>
</tr>
<tr>
<td><strong>CIGS</strong></td>
<td>Front View</td>
<td>Front View</td>
</tr>
</tbody>
</table>

### Notes (This Item):

1. **2070-2A** Connection shall be 4X wide, 2070-2B connection shall be 2X wide. **CODE SYSTEM PCB MODULE (CONSIDER DETAILS)**

2. Dark Circles in the CIGS Connector denote guide pin locations and open circles denote guide socket locations.

3. Dimension “A” shall be a minimum of 200.

4. CIGS = M5204 Type  
   CIGS = 27-Pin Circular Plastic Type  
   CIGS = 35-Pin 18 Socket Type

5. CIGS PIN 18 (45VDC) IS SERVICED from +12 VDC Power Supply

<table>
<thead>
<tr>
<th>CIGS Pin Assignment</th>
<th>PIN</th>
<th>FUNCTION</th>
<th>PIN</th>
<th>FUNCTION</th>
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<tr>
<td>1</td>
<td>RXD</td>
<td>14X5</td>
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<td>RXD</td>
</tr>
<tr>
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<td>TXD</td>
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<td>3</td>
<td>GND</td>
<td>14X5</td>
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<td>GND</td>
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<td>4</td>
<td>VCC</td>
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<td>VCC</td>
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<td>13</td>
<td>VCC</td>
<td>14X5</td>
<td>14</td>
<td>VCC</td>
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**EC MODEL 2070-2**  
FIELD I/O MODULES

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<th>9-7-8</th>
<th>FEBRUARY 20, 2004</th>
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Figure 11

Field I/O Module, C1 & C11 Connectors
Figure 12
Front Panel Assembly
### Model 2070-3 Aux Switch Codes

<table>
<thead>
<tr>
<th>Switch Position</th>
<th>ASCII Data (Text)</th>
<th>ASCII Data (HEX)</th>
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</thead>
<tbody>
<tr>
<td>ON</td>
<td>ESC o T</td>
<td>1B 4F 54</td>
</tr>
<tr>
<td>OFF</td>
<td>ESC o U</td>
<td>1B 4F 55</td>
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</table>

### Model 2070-3 Key Codes

<table>
<thead>
<tr>
<th>Key</th>
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<tr>
<td>C</td>
<td></td>
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<tr>
<td>F</td>
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<tr>
<td>(UP ARROW)</td>
<td>ESC ( A</td>
<td>1B 5B 41</td>
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<td>(DOWN ARROW)</td>
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<td>(RIGHT ARROW)</td>
<td>ESC ( C</td>
<td>1B 5B 43</td>
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<tr>
<td>(LEFT ARROW)</td>
<td>ESC ( D</td>
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<td>ESC</td>
<td>ESC o S</td>
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<td>NEXT</td>
<td>ESC o P</td>
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<td>YES</td>
<td>ESC o Q</td>
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<td>ESC o R</td>
<td>1B 4F 52</td>
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<td>-</td>
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<tr>
<td>ENTER</td>
<td>CR</td>
<td>0D</td>
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Figure 13

Front Panel Assembly Key Codes

100-127
Figure 14

Front Panel Assembly Key Codes
Figure 15

Power Supply Module
Figure 16

VME Cage Assembly
Type 2070 Peripheral Equipment.

General Notes.

The 2070-6x and 2070-7x modules must provide circuitry to disable its Channel 2 and EIA-232 control lines (TX, RX, RTS, CTS, and DCD) when a ground true state is present at Connector A1, Pin B21 (C50 Enable). The disable lines must be pulled up on this module.

Line drivers/receivers must be socket mounted or surface mounted.

Isolation circuitry must be opto- or capacitive-coupled isolation technologies. Each module’s circuit must be capable of reliably passing a minimum of 1.0 megabits per second.

The Comm modules must be “Hot” swappable without damage to circuitry or operations.

Type 2070-6 A & B Async/ Modem Serial Comm Modules

Power Requirements. A fused isolated +5 VDC with a minimum of 100 mA power supply must be provided for external use.

Option – Bourns MF – MSMD020 PTC (Positive Temperature Coefficient) Resettable Fuse, or approved equal, allowed.

Logic Switches. Two LOGIC switches per circuit must be provided (faceplate mounted).

One logic switch must be used to vertically switch between Half-Duplex (Down) and Full-Duplex (Up). In Half-Duplex mode, the Transmit connections must be used for both Receive and Transmit.

A MODEM Enable switch must be provided such that when in the UP Position must enable MODEM and disable MODEM in the DOWN Position.

Circuitry. Two circuits, designated CIRCUIT #1 and CIRCUIT #2, must be provided. Both circuit functions must be identical, except for their Serial Communications Port and external connector (CIRCUIT #1 to SP1 [or SP3] and C2S Connector and CIRCUIT #2 to SP2 [or SP4] and C20S Connector). The Circuits must convert the 2070 UNIT Motherboard SP EIA-485 signals to/from board TTL level signals, isolate and drive the converted EIA-232 Signals interfacing with their associated MODEM and external connector.

Modem Requirements. Each CIRCUIT must have a MODEM with the following requirements:
Data Rate: Baud modulation of 300 to 1200 for Module 2070-6A and 0 to 9600 for Module 2070-6B.

Modulation: Phase coherent frequency shift keying (FSK).

Data Format: Asynchronous, serial by bit.

Line & Signal Requirements: Type 3002 voice-grade, unconditioned Tone Carrier Frequencies (Transmit and Receive): 2070-6A - 1.2 KHz MARK and 2.2 KHz SPACE, +/-1% tolerance. 2070-6B - 11.2 KHz MARK and 17.6 KHz SPACE, +/-1% tolerance. The operating band must be (half power, -3 dB) between 1.0 KHz & 2.4 KHz for 2070-6A and 9.9 KHz & 18.9 KHz for 2070-6B.

Transmitting Output Signal Level: 0, -2, -4, -6, and -8 dB (at 1.7 KHz for 2070-6A & 14.7 KHz for 2070-6B) continuous or switch selectable.

Receiver Input Sensitivity: 0 to -40 dB.

Receiver Bandpass Filter: Must meet the error rate requirement specified below and provide 20 dB/octave, minimum active attenuation for all frequencies outside the operating band.

Clear-to-Send (CTS) Delay: 11 +/-3 milliseconds.

Receive Line Signal Detect Time: 8 +/-2 milliseconds mark frequency.

Receive Line Squelch: 6.5 (+/-1) milliseconds, 0 milliseconds (OUT).

Soft Carrier Turn Off Time: 10 +/-2 milliseconds (0.9 kilohertz for 2070-6A and 7.8 kilohertz for 2070-6B). When the RTS is unasserted, the carrier must turn off or go to soft carrier frequency.

Modem Recovery Time: Capable of receiving data within 22 milliseconds after completion of transmission.

Error Rate: Must not exceed 1 bit in 100 kilobits, with a signal-to-noise ratio of 16 dB measured with flat-weight over a 300 to 3,000 Hertz band.

Transmit Noise: Less than -50 dB across 600-ohms resistive load within the frequency spectrum of 300 to 3,000 Hertz at maximum output.

Modem interface: EIA-232 Standards.

Control Switch. A CONTROL switch must be provided on the module front panel to turn ON (Up) / OFF (Down) all module power.

Type 2070-7A & 7B Async Serial Comm Module
Circuitry. Two circuits, designated CIRCUIT #1 and CIRCUIT #2, must be provided. Their functions are identical, except for the CPU Serial Communications Port and external connector (CIRCUIT #1 to SP1 [or SP3] and Connector C21S and CIRCUIT #2 to SP2 [or SP4] and Connector C22S).

2070-7A. Each circuit must convert its EIA-485 signal lines (RX, TX, RTS, CTS and DCD) to / from board TTL Level Signals; isolate both signal and ground; and drive / receive external EIA-232 devices via C21 / C22 Connectors. Connectors must be DB-9S type.

2070-7B. Each circuit EIA -485 signal lines, (RX, TX, TXC (I), TXC (O) and RXC) and associated signal ground must be board terminated to matching drivers/receivers; isolated both signal and ground, and drive/receiver external EIA-485 devices via C21/C22 Connectors. Connectors must be DB-15S type.

Indicators. Each circuit signal TX and RX line must have an LED Indicator mounted on the front plate and labeled to function.

Details.

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Type 2070-6 - Async/Modem Serial Comm Module Figure17
Type 2070-7 - Serial Comm Module Figure18
Figure 17
Async/Modem Serial Comm Module
Figure 18

Serial Comm Module
2070.49 NEMA Module.

Type 2070N Controller Unit.

General. This section covers two versions of Type 2070 / NEMA Standard Controller Units. The versions associate with NEMA TS1 and NEMA TS2 Type 1 Standards as described in 3. General Requirements B.

Serial Port 5 Frame Address. The Serial Port 5 Frame Address for 2070-2N and 2070-8 must be “20”.

2070-2N Field I/O Module.

Interfaces. The 2070-2N Field I/O Module provides a TS2-1 compatible SDLC interface via 2070 Serial Port 3, AC Power to the 2070 Unit and Fault Monitor Logic Output via 2070 Serial Port 5 and Output Frame Byte 9 Bit 6 to the NEMA TS2 Cabinet Monitor Unit (CMU).

Type 2070-2N Module Requirements. The Module must meet the 2070–2A Module Requirements with the following exceptions:

No C1, C11 and C12 Connectors on the front panel of the module

No 64 inputs / 64 outputs requirements

Serial Port 5 routed to the FCU MPU Device only

Serial Port 3 must not have a disabling switch

Physical. The module must be a 4X type board / front panel with three connectors. The connectors are 10 Pin Connector A, a NEMA 5-15 Receptacle and a 15 Pin DB 15S C14 Connector.

Power. Incoming 2070 AC Power is derived from Connector A Pin C (AC+), Pin A (AC-), and Pin H (Equipment Ground). The power is directly routed to the NEMA 5-15 Receptacle. Connector A must intermate with a NEMA TS2 Type 1 (MS3106O-18-1S) cable.

Serial Port 3 Isolation. The module must isolate 2070 Serial Port 3 from the A3 Connector and reconver the lines to external EIA 485 drivers/receivers that must be terminated at C14 Connector. The Port must be clocked at 153.6 kilobits per second.

FCU Output. An FCU output must drive an open collector transistor whose output must be routed to Connector A Pin F for use as a FAULT MONITOR Output. The transistor must be capable of sinking 200 mA at 30 VDC.
Connector Pin Assignments. Connectors A and C14 pin out and functions are as follows:

### Connector A

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
<th>Pin</th>
<th>Function</th>
<th>Pin</th>
<th>Function</th>
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<tbody>
<tr>
<td>A</td>
<td>AC Neutral</td>
<td>E</td>
<td>NA</td>
<td>I</td>
<td>NA</td>
</tr>
<tr>
<td>B</td>
<td>NA</td>
<td>F</td>
<td>Fault Monitor J</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>AC Line</td>
<td>G</td>
<td>DC#2 Ground</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>NA</td>
<td>H</td>
<td>Equip Ground</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Connector C14S

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
<th>Pin</th>
<th>Function</th>
<th>Pin</th>
<th>Function</th>
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<tbody>
<tr>
<td>1</td>
<td>TX Data+</td>
<td>6</td>
<td>DC Ground</td>
<td>11</td>
<td>TX Clock -</td>
</tr>
<tr>
<td>2</td>
<td>DC Ground</td>
<td>7</td>
<td>RX Clock +</td>
<td>12</td>
<td>Equip Ground</td>
</tr>
<tr>
<td>3</td>
<td>TX Clock+</td>
<td>8</td>
<td>DC Ground</td>
<td>13</td>
<td>RX Data -</td>
</tr>
<tr>
<td>4</td>
<td>DC Ground</td>
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<td>TX Data -</td>
<td>14</td>
<td>NA</td>
</tr>
<tr>
<td>5</td>
<td>RX Data+</td>
<td>10</td>
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<td>15</td>
<td>RX Clock -</td>
</tr>
</tbody>
</table>

TS2 BIU Control. Serial Port 3 must control the TS2 BIU Units using SDLC Protocol that meets the NEMA TS2 Type 1 Frame Command / Response Standards.

### 2070-4N (A or B) POWER SUPPLY MODULE.

Requirements. The 2070-4N Power Supply Module supports the NEMA TS1 and TS2 Standards. The module is identical to the 2070-4N (A and B) Power Supply Requirements except for the following:

- The power cord must have a 15 in. +/- 1 in. length as measured from the panel to the plug tips.
- The AC Power Fail voltage must be 85VAC +/-2VAC.
- The AC Power Restore voltage must be 90VAC +/-2VAC.
The 2070-4N (A or B) power supply must have proper marking. Example: “2070 4N (A or B)”. A permanent sticker is an acceptable marking method.

Type 2070-8 Field I/O Module.

Type 2070-8 Field I/O Module. The Module consists of the Module Chassis, Module Power Supply, FCU Controller, Parallel Input/Output Ports, Serial Communications Circuits, and Module Connectors. The Module CHASSIS must be made of 0.06 inch minimum aluminum sheet and treated with clear chromate. All external screws, except where called out, to be countersunk and be Phillips flat head stainless steel. The matching nuts must be permanently captive on the mating surfaces.

Module Front Panel. The MODULE FRONT PANEL must be furnished with the following:

ON/OFF POWER Switch mounted vertically with ON in the UP position.
2. LED DC Power Indicator. The indicator must indicate that the required +5 VDC is within 5% and the +24 VDC is within 8%.

Incoming VAC fuse protection.

Two DB-25S COMM connectors labeled "EX1" & "EX2."

Four NEMA Connectors A, B, C, & D.

Label. A permanent LABEL must be affixed to the Front Panel. The label must display the unit's serial number. The number must be permanent and easy to read.

Module Power Supply. A MODULE POWER SUPPLY must be provided and located on the right side of the module as viewed from the front. The supply must provide the necessary module internal circuitry DC power plus 2.0 Amperes minimum of +24 VDC for external logic, detector inputs, and output load control. The supply must meet the following requirements:

Input Protection (See 10.E.3.).

Power Supply Requirements (See 10.E.6.).

DC Voltage Tolerances. DC Voltage tolerances must be +/-3%.

Incoming AC Power. The supplied INCOMING AC POWER must be derived from Connector A Pins "p" (AC+) and "U" (AC Neutral). External +24 VDC must be at Connector A, Pin "B" and Connector D Pin "NN." AC Power for
the 2070 receptacle must be tapped off from the secondary side of the ON Switch / Fuse configuration.

Module PC Boards. A MODULE PC Boards must be mounted vertically.

Power Down, NRESET, and LINESYNC. Power Down, NRESET, and LINESYNC must be routed to the module via C12 Connector. The state of the module output ports at the time of Power Down transition to LOW State and until NRESET goes HIGH must be an open circuit.

Compliance with Type 2070-2 Field I/O Requirements. The Module must meet all requirements under 10.C. with the following exceptions:

Parallel Ports. Parallel Ports, consisting of 118 Bits of Input and 102 bits of Output, must be provided. Specification for inputs applies except the voltage is +24 in lieu of +12 and Ground False, "0," exceeds 16.0 VDC. LINESYNC signal is incoming in differential logic.

Serial Communication Circuitry. The module must interface with the 2070-2B Field I/O module via HAR 1 Harness meeting EIA-485 Requirements. All signal lines must be isolated. HAR 1 Harness must be 17 lines minimum with a C12P Connector on one end and soldered with strain relief on the other. In addition to the Controller interface, the EIA-485 Signal lines must be routed to EX1 Connector. All necessary driver/receiver and isolation circuitry must be provided.

EIA-232 Serial Port. An EIA-232 Serial Port must be provided with rate selection by jumper of 0.3, 1.2, 2.4, 4.8, 9.6, 19.2, & 38.4 kilobits per second asynchronous and be connected at EX1 Connector.

HAR 2 Harness. A 22-line minimum HAR 2 Harness must be provided between EX2 Connector and Model 2070-6 Serial COMM Module in the Type 2070 UNIT. This provides two Modems or EIA-232 Interfaces with the 2070 UNIT and the outside world.

Fault and Voltage Monitor. FAULT and VOLTAGE MONITOR circuitry – NEMA TS1 Controller FAULT and VOLTAGE MONITOR functions (outputs to cabinet monitor) must be provided.

Two 3-input OR gates must be provided. The gate 1 output must be connected to Connector A, Pin A (FAULT MONITOR) and gate 2 output must be connected to Connector A, Pin C. Any FALSE state input must cause a gate output FALSE (+24VDC) state.

The FCU Port 10, Bit 7 output must normally change its state every 100 milliseconds. A MODULE Watchdog (WDT) circuit must monitor the output. No state change for 2 +/-0.1 seconds must cause the circuit output to generate a FALSE (+24 VDC) output (input to gates 1 and 2). Should the
FCU begin changing state, the WDT output must return to TRUE (0 VDC) state.

The module must have a +5 VDC monitoring circuit that monitors the module’s +5 VDC (+/-0.25). If the voltage exceeds the limits, the circuit output must generate a FALSE output (input to gates 1 and 2). Normal operation must return the output state to TRUE state.

The FCU microprocessor output must be assigned to FAULT Monitor (input to gate 1) and another output must be assigned to VOLTAGE Monitor (input to gate 2).

CPU Port 5 SET OUTPUT COMMAND Message OUTPUTs O78 and O79 must be assigned to FAULT (O78) and VOLTAGE (O79). The bit logic state “1” must be FCU output FALSE.

CPU / FCU operation at POWER UP must be as follows:

FCU Comm Loss Flag set. FAULT and VOLTAGE MONITOR outputs set to FALSE state.

CPU REQUEST MODULE STATUS COMMAND Message with “E” bit set is sent to FCU to clear Comm Loss Flag and responds to CPU with “E” bit reset.

Before the Comm Loss timer expires, the SET OUTPUT COMMAND data must be sent. In that data, the 078 and 079 logically set to “0” will cause the FCU microprocessor port pins assigned for FM and VM outputs to go to their TRUE state. At this point, the signal outputs defined in the message will be permitted at the output connectors. Any number of other messages may be sent between the MODULE STATUS COMMAND and SET OUTPUTS COMMAND.

If the above message sequence is not followed, Comm Loss Flag must be set (or remain) and VM & FM must retain the FALSE output state.

Performs items 2 & 3 above User Software.

A CPU / FCU Communications Loss during normal operation must cause all outputs to go blank (FALSE state) and must set the Comm Loss Flag. FM and VM outputs must be in FALSE state.

Details.

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MODEL 2070N1 - Side View Figure20
MODEL 2070N1 - Isometric View Figure21
MODEL 2070N1 - 2070-8 Field I/O Module, Connectors A & B Figure22
MODEL 2070N1 - 2070-8 Field I/O Module, Connectors C & D Figure23
MODEL 2070N1 - Connectors Figure24
NOTES (THIS DETAIL)

1. The Model 2070 Controller Unit is shown only for reference.

2. The bottom supports shall be double flanged.

3. A = Connector A (MS-3112-22-5SP Type)
   B = Connector B (MS-3112-22-3SS Type)
   C = Connector C (MS-3112-24-6IS Type)
   D = Connector D (MS-3112-24-6IP Type)
   EX1 = Connector EX1 (II-25S Type)
   EX2 = Connector EX2 (II-25S Type)

4. 2.286 mm wide spacers shall be provided between the inside wall of the 2070-8 Module and the 2070 unit (each side).
Figure 20

Side View
Figure 21
Isometric View

NOTES (THIS DETAIL)
1. The module housing bottom shall be slot vented. The top shall be open.
### Configuration Command Codes

<table>
<thead>
<tr>
<th>Command</th>
<th>Value</th>
<th>Function</th>
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**NOTE:** Values are in decimal format. Values of 00000000 to 11111111.

Reverse Video & Underline - ON required for front panel assembly Option 34 & 36.

Command shall be evaluated for option 32 (ESD).

### Inquiry Command-Response Codes

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**NOTE:** Values are in decimal format. Values of 00000000 to 11111111.

Reverse Video & Underline - ON required for front panel assembly Option 34 & 36.

Command shall be evaluated for option 32 (ESD).

---

Figure 22

2070-8 Field I/O Module, Connectors A & B
Figure 23

2070-8 Field I/O Module, Connectors C & D
## Figure 24

2070-8 Field I/O Module, EX1 & EX2 Connectors

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**2070-8 FIELD I/O MODULE**

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| FEBRUARY 20, 2004     | 11-5-6
2070.50 Glossary.

Terms and Abbreviations. Wherever the following terms or abbreviations are used, the intent and meaning is interpreted as follows:

A Ampere

AC Alternating Current

AC+ 120 Volts AC, 60 hertz ungrounded power source

AC- 120 Volts AC, 60 hertz grounded return to the power source

DEPARTMENT The DEPARTMENT director, acting either directly or through properly authorized agents, such agents acting within the scope of the particular duties delegated to them.

ANSI American National Standard Institute

ASCII American Standard Code for Information Interchange

Assembly A complete machine, structure or unit of a machine that was manufactured by fitting together parts and/or modules

ASTM American Society for Testing and Materials

AWG American Wire Gage

C Celsius

C Language The ANSI C Programming Language

Cabinet An outdoor enclosure generally housing the controller unit and associated equipment

Certificate of Compliance A certificate signed by the manufacturer of the material or the manufacturer of assembled materials stating that the materials involved comply in all respects with the requirements of the specifications

Channel An information path from a discrete input to a discrete output.

Component Any electrical or electronic device
Contractor  The person or persons, Manufacturer, firm, partnership, corporation, vendor or combination thereof, who have entered into a contract with the DEPARTMENT, as party of the second part or legal representative

Controller Unit  That portion of the controller assembly devoted to the operational control of the logic decisions programmed into the assembly

CPU  Central Processing Unit

CTS  Clear To Send

DAT Program  The DEPARTMENT’s Diagnostic and Acceptance Test Program

dB  Decibel

dBa  Decibels above reference noise, adjusted

DC  Direct Current

DCD  Data Carrier Detect (Receive Line Signal Detector)

DIN  Deutsche Industrie Norm

DRAM  Dynamic random access memory. Random access means that the processor can access any part of the memory or data storage space directly rather than having to proceed sequentially from some starting place. DRAM is dynamic in that it needs to have its storage cells refreshed or given a new electronic charge every few milliseconds.

EG  Equipment Ground

EIA  Electronic Industries Association

EMI  Electro Magnetic Interference

EPROM  Ultraviolet Erasable, Programmable, Read Only Memory Device

EEPROM  Electrically Erasable, Programmable, Read Only Memory Device

Equal  Connectors: comply with physical dimensions, contact material, plating and method of connection. Devices: comply to function, pin out, electrical and operating parameter requirements, access times and interface parameters of the specified device

ETL  Electrical Testing Laboratories, Inc.
Firmware  A computer program or software stored permanently in PROM, EPROM, ROM or semi-permanently in EEPROM

FLASH  A +5 VDC powered IC Memory Device with nonvolatile, electrically erasable, programmable, 100K read/write minimum cycles and fast access time features

FPA  Front Panel Assembly

HEX  Hexadecimal

Hz  Hertz

IC  Integrated Circuit

I.D.  Identification

IEEE  Institute of Electrical and Electronics Engineers

ISO  Isolated

Jumper  A means of connecting/disconnecting two or more conductive by soldering/desoldering a conductive wire or by PCB post jumper

KB  Kilobytes

Keyed  Means by which like connectors can be physically altered to prevent improper insertion.

Laboratory  The established laboratory of the DEPARTMENT or other laboratories authorized by the DEPARTMENT to test materials involved in the contract

LCD  Liquid Crystal Display

LED  Light Emitting Diode

LOGIC  Negative Logic Convention (Ground True) State

LSB  Least Significant Byte

lsb  Least Significant Bit

MB  megabyte
MSB       Most Significant Byte
msb       Most Significant Bit
m         Milli
MCU/ MPU/ IMP Micro Controller Unit, Microprocessor Unit, or Integrated Multiprotocol Processor
MIL       Military Specifications
MODEM     Modulation/Demodulation Unit
Module     A functional unit that plugs into an assembly
Motherboard A printed circuit connector interface board with no active or passive components
MOS       Metal-Oxide Semiconductor
MOV       Metal-Oxide Varistor
MS        Military Standards
N          Newton: SI unit of force
N.C.      Normally closed contact
N.O.      Normally open contact
NA        Presently Not Assigned. Cannot be used by the Manufacturer for other purposes
NEMA      National Electrical Manufacturer's Association
NETA      National Electrical Testing Association, Inc.
n         nano
NLSB      Next Least Significant Byte
nlsb      Next Least Significant Bit
NMSB      Next Most Significant Byte
nmsb      Next Most Significant Bit
PCB       Printed Circuit Board
PDA       Power Distribution Assembly
PLA/PAL   Programmable Array Logic Device

Power Failure  A Power Failure is said to have occurred when the incoming line voltage falls below 92 +/- 2 VAC for 50 milliseconds. See Power Conditions.

Power Restoration  Power is said to be restored when the incoming line voltage equals or exceeds 97 +/- 2 VAC for 50 milliseconds. See Power Conditions.

Power Conditions  16.7 ms (one 60 Hertz cycle) reaction period is allowed to be included in the 50 milliseconds timing or added to (67 milliseconds duration). The hysteresis between power failure and power restoration voltage settings must be a min. of 5 VAC with a threshold drift of no more than 0.2 VAC.

ppm       Parts per million
PWM       Pulse Width Modulation
RAM       Random Access Memory
RF        Radio Frequency
RMS       Root-Mean-Square
ROM       Read Only Memory Device
RTS       Request to Send
R/W       Controller Unit Read/Write Control Line
RxD       Received Data
SCI       Serial Communications Interface
SDLC      Synchronous Data Link Control
S         Logic State
s         second

Second Sourced  Produced by more than one Manufacturer
SRAM      Static Random Access Memory Device
SW    Switch
TB    Terminal Block
TOD    Time Of Day Clock
Triac    Silicon-Controlled Rectifier which controls power bilaterally in an AC switching circuit
TTL    Transistor-Transistor Logic
Thumb Screw Device (TSD) A retractable screw fastener with projecting stainless steel screw, spring and natural aluminum knob finish. (TSD No.2 must be flat black.)

TSD No.1 - 8-32 SOUTHCO #47-62-301-20 or equal.
TSD No.2 - 8-32 SOUTHCO #47-62-301-60 or equal.
TSD No.3 - M3 SOUTHCO #47-82-101-10 or equal.

TxD    Transmitted Data
u    Micro
UL    Underwriter's Laboratories, Inc.
VAC    Voltage Alternating Current (root mean square)
VDC    Voltage Direct Current
VME    Versa Module Eurocard, VMEbus Standard IEEE P1014/D1.2

x    Number Value
XX    Manufacturer's Option

WDT    Watchdog Timer: A monitoring circuit, external to the device watched, which senses an Output Line from the device and reacts

2070.51 Warranty. The controller unit assembly and all components shall have a full warranty against all manufacturers’ defects, including parts and labor, for a minimum of three (3) years from the date of delivery. Vandal damage and damage due to automobile accidents or acts of nature will not be included under Contractor’s guarantee.

The Supplier shall bear all expenses with return of any material Harris County deems necessary to return for adjustment during warranty period.
Harris County, or its agent, reserves the right to withhold payments which or claims of bidder.

Harris County will determine the supplier’s responsibility for any controller unit assembly failure if failure occurs within the warranty period. Harris County will contact the supplier with instructions on the pick-up and delivery of defective controller assembly component. The supplier shall be responsible for all shipping and related handling charges.

2070.52 Compliance. The Supplier shall guarantee that the 2070 Controller Unit is fully integrated and fully compatible with the local controller operation software, currently in used by Harris County, and assure as such by providing a letter of compliance.

“Burn-in” each controller unit and provide a Quality Control report as described in this Item. The certification report shall be furnished by the supplier and attached to each controller unit. The report shall indicate the dates of the “burn-in” period, number of hours, and “burn-in” temperature, and other pertinent test information in the previously approved by Harris County.

2070.53 Measurement and Payment. The work performed, materials furnished, equipment, labor, tools, and incidentals will not be measured or paid for directly, but will be subsidiary to pertinent Items.

END OF ITEM 2070