730K

TDOT STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION
January 1, 2015

SPECIAL PROVISION REGARDING SECTION 730K - TRAFFIC SIGNALS CITY OF KNOXVILLE
730 GENERAL REQUIREMENTS
Effective July 1, 1992
Revised November 5, 2015

DESCRIPTION

730.01 Description of Work – This work consists of furnishing and installing all necessary materials and equipment to complete in-place traffic signal systems, modify existing systems, or both, all as shown on the Plans or the Standard Drawings or Special Details, and as specified in these Specifications. Unless otherwise shown on the Plans or specified in the Special Provisions, all materials shall be new. Any deviation from these specifications shall be at the discretion and approval of the City of Knoxville, Traffic Engineering Department.

Where existing systems are to be modified, incorporate the existing material into the revised system, salvage it, or abandon it as specified or as directed by the Engineer.

Furnish and install all incidental parts that are not shown on the Plans or specified herein, but that are necessary to complete the traffic signal or other electrical systems, or that are required for modifying existing systems, as though such parts were shown on the Plans or specified herein. Include the costs of such incidentals in bid price for other items. All systems shall be complete and in operation to the Engineer's satisfaction at the time of completion of the work this is to include but not limited to the traffic signal system work, traffic signal communications, traffic signs, traffic markings and any other work required to insure that the traffic signal system can function as per the final plans.

It is the responsibility of the signal contractor to notify the City of Knoxville in writing through the Tennessee Department of Transportation, TDOT Construction Office when the work is complete in order that the final inspection can be scheduled and performed by the City of Knoxville.

The traffic signal system shall be the sole responsibility of the traffic signal contractor until such time a final inspection is performed, all discrepancies found in the inspection are corrected to the satisfaction of the City of Knoxville and the City assumes maintenance responsibilities in writing.

The traffic signal contractor will be notified in writing through the TDOT Construction Office of all discrepancies noted in the final inspection. The contractor will notify the City through the TDOT Construction Office when all discrepancies discovered through the final inspection process have been corrected in the event that re-inspection of the traffic signal system is required.

GENERAL REQUIREMENTS

730.02 Regulations and Code - Ensure that all equipment provided conforms to NEMA Standards Publication, Traffic Control Systems, latest revision, or the Radio Manufacturers Association, whichever is applicable. In addition to the requirements of these Specifications, the Plans, and the Special Provisions, all material and work shall conform to the requirements of the NEC; the Standards of AASHTO, ASTM, ANSI, ITE, and IMSA; the MUTCD; and other applicable local ordinances. Wherever reference is made to the NEC, or the Standards mentioned above, consider the reference to mean the code or standard that is in effect on the date of advertising the bids or authorization for force account.

730.03 Submittal Data Requirements - Within 30 days after the issuance of the work order, submit to the Engineer, the Division of Materials and Tests, and the local entity (city or county engineer), one collated set of the manufacturer's

descriptive literature and technical data that fully describes the types of signal equipment proposed for use. In the descriptive literature, identify the manufacturer and models and include sufficient information for the Engineer to determine if the equipment or material meets the requirements of the Plans and these Specifications. Include with these sets of submittal data a list of the materials submitted along with descriptive material for, but not limited to, the following items:

1. Controller
2. Cabinet and Exhaust Fan
3. Detectors
4. Signal Heads including Lamp Information and Mounting Hardware
5. Loop Wire and Loop Sealant
6. Shielded Detector Cable
7. Signal Cable
8. Cable for Span Wire, Guys, and similar features
9. Pull Boxes
10. Conduit
11. Coordination Equipment
12. Communications Cable
13. Communications Equipment

Also include in the submittal sets detailed scale drawings of all non-standard or special equipment and of all proposed deviations from the Plans. Upon request, submit for approval sample articles of materials proposed for use. The Department will not be liable for any materials purchased; labor performed, or delays to the Work prior to such approval.

In addition to the above, the contractor will submit to the Engineer a notarized letter certifying that all traffic signal materials listed in the submittal conform to the Plans and Specifications along with a copy of a statement from the maintaining agency that the system is acceptable to the agency.

Submit six prints of “Design” or “Shop” drawings, indicating the proposed dimensions and material specification for each of the supports and mast arms involved, to the Division of Structures for approval purposes within 30 days after the work order is issued. The Department will review these drawings at the earliest possible date, and will return two prints marked “Approved for Fabrication,” or “Returned for Revisions as Noted.” Respond by taking appropriate action to ensure the earliest possible correction of these items so as not to delay the installation.

730.04 Mill Test Reports and Certification - Provide Mill Test Reports (MTR) or Certifications of Conformance to the Specifications for Materials and Design for all materials incorporated into the Work. Supply the following prior to acceptance of the structures:

1. MTR’s for MAJOR structural items only, as identified in Table 730.04-1, shall include both physical and chemical descriptions of the material as supplied to the fabricator. When physical properties are altered during the fabrication, supplement the MTR covering chemical composition with certified test reports indicating the physical properties of this material after fabrication.

2. Certifications of Conformance to the Specifications for all remaining material not covered by MTR as identified in Table 730.04-1.

3. Certification that all welding was performed by operators qualified as follows: Steel welders to AWS and aluminum welders to ASME.

4. Certification of Conformance to the Specification for the Design of all components not completely dimensioned and detailed on the Standard Drawing.

Table 730.04-1: Required Mill Test Reports and Certifications

Component Materials	M.T.R.	Certification
Tubes for arms and poles	X	
Base Castings	X	
Anchor Bolts	X	
Pole tops, misc. fittings and hardware		X
Fabricated or cast-type arm connections		X
Galvanizing		X

730.05 Working Drawings - Provide within the controller cabinet and to the local maintaining agency an electrical schematic diagram of the cabinet and system wiring. Submit manufacturer's instructions for installation, maintenance, and operation of all equipment to the local maintaining agency and also place a copy within the controller cabinet. Place all such materials inside a plastic envelope mounted in the cabinet.

730.06 Guarantee - Guarantee the Traffic Signal System(s) installed under these Specifications, including all equipment, parts, and appurtenances in connection therewith, to the City or County and State against defective workmanship and materials for a period of not less than 1 year following the date the signal system is made operational, except in no case shall this guarantee expire prior to 3 months after the final acceptance of the Project. Upon completion of the Project, turn over to the government agency responsible for maintaining the signal installation all warranties or guarantees on equipment and materials that are offered by the manufacturers as normal trade practice and that have not expired.

730.07 Training - Provide to the maintaining agency a training session on the controller and associated cabinet equipment to be supplied on the Project. The training session shall last for a minimum 4 hours unless the maintaining agency determines a lesser time is adequate. Train the user in the complete operation and programming features of all controllers. Provide this training prior to the acceptance of the Project at a facility agreed upon by the maintaining agency.

After the required training, certify to the Engineer that training has been completed.

This training requirement shall not apply if a training program meeting these criteria has been provided to the maintaining agency by this vendor and/or manufacturer on the equipment being bid within 18 months prior to the date of the invitation to bid. This requirement shall apply if the bidder is proposing new, upgraded, or modified equipment not covered in the previous training program.

MATERIALS AND INSTALLATION

730.08 Excavating and Backfilling - Perform excavation needed to install conduit, foundations, and other equipment, so as to cause the least possible damage to the streets, sidewalks, and other improvements. Excavate trenches no wider than necessary to properly install the electrical equipment and foundations. Do not begin excavating until immediately before installing conduit and other equipment. Place the material from the excavation where it will cause the least disruption and obstruction to vehicular and pedestrian traffic and the least interference with the surface drainage.

Backfill the excavations and compact to at least the density of the surrounding material. Remove all surplus excavation material and dispose of outside the highway right-of-way, in accordance with 203.07, or as directed by the Engineer.

After backfilling, keep excavations well-filled, and maintain in a smooth and well-drained condition until permanent repairs can be made.

At the end of each day's work, and at all other times when construction operations are suspended, remove all equipment and other obstructions from that portion of the roadway used by public traffic, and park a minimum of 30 feet from the edge of pavement unless otherwise protected by guardrail, bridge rail, or barriers installed for other purposes.

Perform excavation in the street or highway so as to restrict no more than one traffic lane in either direction at any time. Do not obstruct traffic during hours of peak flow unless otherwise approved by the Engineer. Incorporate construction signing in accordance with the MUTCD.

730.09 Removing and Replacing Improvements - Replace or reconstruct, with the same kind of materials as found on the Work, improvements, such as sidewalks, curbs, gutters, Portland cement concrete and asphalt concrete pavement, bituminous surfacing, base material, and all other improvements removed, broken, or damaged by the Contractor.

Before removing the sidewalk and pavement material, use an abrasive type saw to cut, to a minimum depth of 2 inches, the outline of all areas to be removed in Portland cement concrete sidewalks and in all pavements. Use any method satisfactory to the Engineer to cut the remainder of the required depth. Make cuts neat and true with no shatter outside the removal area.

Whenever a part of a square or slab of existing concrete sidewalk or driveway is broken or damaged, remove the entire square or slab and reconstruct the concrete as specified above.

Perform all work in accordance with these Specifications, or the applicable local ordinance, whichever is of a higher standard. Consider this removal and replacement work to be incidental to other items.

730.10 Foundations - Construct foundations for posts, standards, and cabinets of Class A Portland cement concrete. Please contact the City of Knoxville for current dimensions for cabinet foundations.

Pour foundations for posts, standards, and pedestals after the post, standard, pedestal, or anchor bolts or reinforcing steel is in proper position. Form the exposed portions to present a neat appearance. Rest the bottom of concrete foundations on firm undisturbed ground.

Construct forms to be true to line and grade. Finish tops of footings for posts and standards, except special foundations, to curb or sidewalk grade or as ordered by the Engineer. Use rigid forms, securely braced in place. Place conduit ends and anchor bolts by means of a template until the concrete sets. Moisten both the forms and the ground that will be in contact with the concrete before placing concrete. Do not remove forms until the concrete has cured for at least twelve (12) hours and hardened sufficiently to allow form removal without causing damage to the concrete.

Apply an ordinary surface finish to exposed surfaces of concrete. Wherever the edge of a concrete foundation or sidewalk section is within 18 inches of any existing concrete improvement, extend the sidewalk section to meet the existing improvement.

Where obstructions prevent the construction of planned foundations, construct a foundation satisfactory to the Engineer.

730.11 Anchor Bolts - Furnish, with anchor-base type poles, anchor bolts meeting the requirements of ASTM F1554, Grade 55 or other high strength steel anchor bolts having minimum yield strength of 55,000 pounds per square inch and a minimum ultimate strength of 90,000 pounds per square inch. Fit each anchor bolt with two heavy hex nuts. Hot-dip galvanized nuts and not less than 10 inches of the threaded ends of anchor bolts according to ASTM A153. The anchor bolts shall be capable of resisting at yield strength stress the bending moment of the shaft at its yield strength stress.

Set standards, posts, and pedestals plumb by adjusting the nuts before the foundation is finished to final grade. Do not use shims or similar devices for plumbing or raking. After plumbing or raking has been completed, cut off anchor bolts 1/4inch above the top nut, and paint the exposed surface with rust protective paint.

Furnish all anchor bolts and nuts required for relocating existing standards and posts.

730.12 Pull Boxes – The pull boxes described in this section are industry standards. Please refer to the plans and drawings for what type of pull box to use. Please contact the City of Knoxville for current design standards. Traffic pull boxes shall have a minimum dimensions: 23” x 17” x 18” and be constructed and installed as shown on the Plans and standard drawings or as directed by the Engineer. Additional pull boxes may be required where conduit runs are more than 100 ft. (30.5 m) long. Pull boxes shall be installed wherever practicable out of the line of traffic. Covers shall be level with the pavement, or with the curb or sidewalk grade, or with the surrounding ground as required. Each pull box shall include one extra 2 in. (50 mm) conduit.

Electrical conductors shall be placed within pull boxes in such a manner as to be clear of the metal frame and cover. All pull boxes shall be in compliance with Figure 4.39 in the Tennessee Department of Transportation (TDOT) Traffic Design Manual. The bottom of the pull box shall rest firmly on a bed of crushed stone with a minimum depth of 12 in. (300 mm) below the bottom, and extending 6 in. (150 mm) beyond the outside edge of the pull box, unless otherwise specified by the Engineer. Fiber optic pull boxes must be properly grounded according to NEC, EIA/TIA and Bellcor (Telcordia) standards.

All splice points must contain sufficient slack (50 foot minimum or as direct by Plans) to allow for future addition of communication devices, cable and splice repairs, or additional runs of “drop" cable. Sizes for fiber optic pull boxes will be determined based upon the number of cables in the system. Pull boxes will be required on each side of a street or railroad crossing. The frame shall have a minimum weight of 42 lbs. (19 kgs). The cover shall be of the "Extra Heavy" type with a minimum weight of 54 lbs. (24.5 kgs).

Pull boxes other than concrete shall be composed of reinforced plastic or epoxy mortar and be designed and tested to temperatures of -50° F (-45° C), and meet the requirements of the following: ASTM D 756, ASTM D 543, ASTM D 570, ASTM D 790, and ASTM D 635 and shall be based on 30,000 lbs. (13,610 kgs) single axle load over 10 x 20 in. (250 x 500 mm) area. The word "TRAFFIC" or the words "TRAFFIC SIGNALS" shall be inscribed on top of the covers.

A. Fiber Optic Pull Boxes - Type A Pull Box with Cover. The pull box shall meet the following requirements:

1. Minimum dimensions: 36” x 26” x 32” exterior, Pull Box and cover shall be precast composite polymer concrete product. Pull boxes with a polymer cover but other material for the box will NOT be accepted.

2. Pull Boxes and covers shall be single-stack open-bottom assemblies configured as shown in the Plans.

3. Vertical Design / Test Load - 22,500lbs/33,750lbs. Loadings shall comply with ANSI 77 2002 and shall exceed Tier 15 test provisions for both the cover and sidewall.

4. Pull Box shall meet NEC 2014 for handhole enclosures.

5. Pull Box cover shall be labeled (FIBER OPTICS) with 3 inch letters.

6. Installation shall be as per guidelines of the TDOT Standard Specifications for Road and Bridge Construction, latest version. Pull boxes and covers shall be installed per the design details.

7. Pull Box will be measured in units of each and paid for at the contract price per each after the complete installation. The price bid shall include furnishing and installing the pull box and cover including excavation, gravel, restoration, and miscellaneous materials necessary for a complete and accepted installation. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

B. Type B Pull Box with Cover - The pull box shall meet the following requirements:

1. Minimum dimensions: 49”W x 32” Lx 36”D exterior

2. Pull Box and cover shall be precast composite polymer concrete product. Pull boxes with a polymer cover but other material for the box will NOT be accepted. Note this is a different pull box than shown in TDOT Standard Drawings.

3. Pull Boxes and covers shall be single-stack open-bottom assemblies configured as shown in Plans.

4. Vertical Design / Test Load - 22,500lbs/33,750lbs. Loadings shall comply with ANSI 77 2002 and shall exceed Tier 15 test provisions for both the cover and sidewall.

5. Pull Box shall meet NEC 2005 for hand hole enclosures.

6. Pull Box cover shall be labeled (FIBER OPTICS) with 3 inch letters.

7. Each Pull Box shall come equipped with four Cable Racks and twelve Rack Hooks. The Cable Racks shall be a minimum of twenty-four (24) inches and Rack Hooks shall be a minimum of seven (7) inches in length. The Cable Racks and Rack Hooks shall be hot dipped Galvanized Steel.

8. Installation shall be as per guidelines of the TDOT Standard Specifications for Road and Bridge Construction, latest version. Pull boxes and covers shall be installed per the design details.

9. Cable racks and rack hooks shall be installed per the Manufacturer’s recommendations.

10. Ducts shall enter the side of the pull box using a terminator and shall extend into the box no more than four (4) inches and no less than two (2) inches.

11. Pull Box will be measured in units of each and paid for at the contract price per each after the complete installation. The price bid shall include furnishing and installing the pull box and cover including excavation, gravel, restoration, cable rack rails and hooks, terminator rings, and miscellaneous materials necessary for a complete and accepted installation. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

C. Type C Pull Box with Cover - Type C pull boxes shall only be used for electrical power conduit/wiring and shall meet TDOT Standard Specifications for Road and Bridge Construction. Installation shall be per guidelines of the TDOT Standard Specifications for Road and Bridge Construction, latest version. Pull boxes and covers shall be installed per the design details. Pull Box will be measured in units of each and paid for at the contract price per each after the complete installation. The price bid shall include furnishing and installing the pull box and cover including excavation, gravel, restoration, cable rack rails and hooks, terminator rings, and miscellaneous materials necessary for a complete and accepted installation. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

730.13 Transformer Base – Fabricate the transformer base from steel plate and sheet, and design it to harmonize with the shaft. Provide each transformer base with:

1. One 7-1/2 x 9 inch minimum hand-hole, with a cover secured with stainless steel fastening screws;

2. Four galvanized steel bearing plates to fasten the base to the anchor bolts;

3. Four galvanized steel bolts, nuts, and washers to fasten base and standard; and

4. One 1/2-inch, 13 UNC grounding nut welded to the inside of the base opposite the hand hole opening.

Ensure that the strength of the transformer base is comparable with that of the shaft.

When a transformer base is required, no hand-hole will be required in the shaft.

730.14 Conduit - Furnish and install plastic and steel conduit in accordance with these Specifications and close conformity with the lines shown on the Plans or as established by the Engineer.

Threads shall be clean cut, straight, and true and of sufficient length to allow proper coupling. Do not use long running threads on any part of the Work. Protect threads in transit and during installation, and provide conduit with proper supports and protection during construction to prevent damage. Properly thread, ream, and cap all ends of pipe installed for future connections to prevent water and foreign matter from entering the conduit system. Provide threaded ends with approved conduit bushings.

Signal conduit shall be 2 inches in diameter, and detector conduit 1 inches in diameter, unless otherwise specified or directed. Conduit for service connections shall be 1-1/4 inches in diameter. Do not use conduits smaller than 1inch in diameter unless otherwise specified, except grounding conductors at service points shall be enclosed in 1/2-inch diameter conduit. The Contractor may, at no additional cost to the Department, use larger size conduit, in which case it shall be for the entire length of the run with no reducing couplings allowed.

A. Materials - Provide conduits and fittings as follows:

1. **Steel Conduit**

   a. Rigid conduit and fittings shall be heavy - wall, hot dipped galvanized steel conforming to Federal Specification WW-C-581-d(3) and ANSI C80.1. It shall be galvanized inside and out and shall meet the requirements of ASTM A53. Each length shall bear the label of Underwriters Laboratories, Inc.

   b. Flexible conduit shall be galvanized flexible steel meeting Federal Specification WW-C-581-d(3), ANSI C80.1 and UL Standard 6 with a minimum 40-mil thickness of polyvinyl chloride (PVC) coating conforming to ASTM D746.

2. **Plastic Conduit -** For plastic conduit, provide high impact PVC, Schedule 40.

3. **Continuous Flexible Conduit (Conduit Duct Bank)**

   1. Continuous Flexible Conduit shall be manufactured from virgin high-density polyethylene (HDPE) resin compound with a minimum cell classification of PE 345434C for PE 3408 materials in accordance with ASTM D-3350.

      a. Physical and Mechanical Properties and Test Methods

Tensile Strength @ yield - 3,000 PSI min.	ASTM D-638
Density – 0.941 g/cc min	ASTM D-4883/1505

   2. Conduit shall be extruded from colored material for uniform full-thickness coloring.

   3. All Continuous Flexible Conduit shall be labeled with durable identification giving the name of the manufacturer, conduit size (inner diameter trade size and wall thickness/rating), manufacturer/date codes, the legend “TENN DOT”, and sequential foot marking. Labeling shall occur a maximum of every 2 ft.

4. Conduit to be used in bends and sweeps shall have a minimum burn through time of 30 minutes when tested in accordance with Generic Requirement GR-356-CORE, Issue 1, October 1995.

5. The conduit manufacturer shall have a documented Quality Control/Assurance System.

6. All buried conduit used on this project shall conform to the color scheme and use described below:

   a. Conduit Bank Type 1

      - Green Drop Fiber and/or RDS Cable

   b. Conduit Bank Type 2

      - Green Drop Fiber and/or RDS Cable
      - White RDS Cable, Second Drop Fiber or Spare

   c. Conduit Bank Type 3
      - Green Drop Fiber and/or RDS Cable
      - Blue RDS Cable or Second Drop Fiber
      - White Second RDS Cable or Spare

   d. Conduit Bank Type 4

      - Orange Trunk Fiber Cable
      - Blue RDS Cable or Drop Fiber
      - White Spare or Second RDS Cable
      - Brown Spare

   e. 2”, 3”, and 4” Electrical Conduit

      - Grey Electrical wire

7. 1¼ in. conduit shall conform to ASTM D-3035 and meet the following requirements:

      - Smoothwall SDR 11
      - Nominal outer diameter: 1.660 in
      - Minimum inner diameter: 1.313 in
      - Minimum wall thickness: 0.151 in

8. 2 in. conduit shall conform to ASTM D-3035 and meet the following requirements:

      - Smoothwall SDR 11
      - Nominal outer diameter 2.375 in
      - Minimum inner diameter 1.885 in
      - Minimum wall thickness 0.216 in

9. Coupling

   a. Make every effort to minimize coupling. Couplings are permitted only with the Engineer’s prior approval.

b. Couplings shall be airtight and watertight. All couplings shall be installed in accordance with the conduit and the coupling manufacturer's recommendations. Only couplings of the type specified below and approved by the conduit manufacturer are permitted.

c. Couplings shall be accomplished only by hydraulic press-on or electro-fusion coupling methods.

   i. Use hydraulic press-on couplings of seamless tool-grade tubular aluminum with sealing ring barbs and center stop.

   ii. Use hydraulic compression duct coupling tools and follow all manufacturer's installation procedures, fully inserting both conduit sections to the coupling center stop.

   iii. Use pre-fabricated electro-fusion couplings that are field-installed using the coupling manufacturer's recommended automatic self-monitoring fusing machine and installation procedures.

Do not use any other coupling methods.

4. Multi-cell "Factory Installed Bullet Resistant" Fiberglass Conduit

a. The multi-cell conduit system shall be a pre-assembled conduit manufactured from a minimum of a 4 inch round outerduct containing 4 factory installed round 1-1/4 inch innerducts.

   i. The innerducts shall be held together in a square (4 conduit system) configuration by a system of spacers or equivalent mechanism.

   ii. The coupling system shall be resistant to water infiltration, air loss during cable installation and shall be capable of locking the system tightly together in order to not allow free twisting of the innerducts.

b. The multi-cell conduit system manufacturer shall have a documented Quality Control/Assurance System.

c. Outerduct:

   i. All outerduct shall be a minimum of 4 in. trade size and shall have a nominal 20 ft lay length. Types to be used shall be designated on the Plans.

   ii. The spigot end of the duct shall have a circumferential insertion depth mark to insure that proper insertion depth is achieved.

   iii. Bullet resistant fiberglass conduit shall have a minimum wall thickness of 0.250 inches. The conduit shall prevent the penetration of a .45 caliber slug fired from a distance of 20 feet. The conduit shall conform to the following requirements when tested in accordance with this TSP. All accessories and fittings, including outerduct couplings, expansion joints, anchor and stop rings, etc., shall meet all the same "bullet resistant" requirements as the conduit. All conduit and fittings shall be grey.

   iv. Outerduct shall be labeled with durable identification giving the name of the manufacturer, manufacturer/date codes and the legend "TENN DOT". Labeling shall occur a maximum of every 2 ft.

   v. Physical and Mechanical Properties and Test Methods:

Ultimate Tensile Strength - 11,000 PSI Min.	ASTM D-2105
Dielectric Strength - >= 500 Volts/Mil.	ASTM D-149
Water Absorption - 1% Max.	ASTM D-570
Specific Gravity - 1.9 - 2.0	ASTM D-792
Glass Content - 68 + - 2%	API SPEC 15 LR
Barcol Hardness - 58 – 52	ASTM D-2583

vi. Where Structure Conduit Bank Type 1 and 2" Structure Conduit w/bank is shown in the plans, the conduit shall be 2" fiberglass conduit and shall meet the same applicable characteristics as the outerduct described above.

d. Innerduct:

i. Innerducts shall be manufactured from polyvinyl chloride (PVC) or high density polyethylene (HDPE). Innerducts shall be factory treated with an atomized silicone or manufactured in a manner to reduce friction during pulling of fiber optic cable. Innerduct to be used in bends and sweeps shall have a minimum burn through time of 30 minutes when tested in accordance with Generic Requirement GR-356-CORE, Issue 1, October 1995. The dimensions of innerduct shall meet the requirements of the manufacturer's catalog cuts approved by the Department.

ii. HDPE innerduct shall have a permanent dry lubricant extruded within the inner wall and shall incorporate longitudinal ribs within the inner wall.

iii. HDPE innerduct shall conform to the following requirements:

1. Color of innerducts - 4-way (orange, blue, brown, white)

2. Nominal Inner Size - 1 1/4"

e. Coupling Body:

i. Each multi-cell system shall offer a complete line of factory-made fixed bends and sweeps. No flexible bends or field-made bends will be permitted. Bullet resistant fiberglass bends and sweeps shall have compatible bell and spigot ends. In no case shall bends and sweeps exceed a 90-degree direction change.

1. Water tightness - 6 PSI Minimum

2. Air tightness - no leakage at 100 PSI

f. Bends and Sweeps

i. Each multi-cell system shall offer a complete line of factory-made fixed bends and sweeps. No flexible bends or field-made bends will be permitted. Bullet resistant fiberglass bends and sweeps shall have compatible bell and spigot ends. In no case shall bends and sweeps exceed a 90-degree direction change.

ii. Fixed bends for bullet resistant fiberglass multicell conduit shall be available in radii no less than the following:

1. 4 ft. radius: 11 ¼ degrees

2. 6 ft. radius: 22 ½ degrees

g. 9 ft. radius: 45 and 90 degrees

B. Installation

All bends shall be in strict compliance with the NEC.

Lay conduits to a depth of 6 inches below sub grade but not less than 24 inches below pavement grade except when approved by the Engineer; conduit may be laid at a depth of not less than 24 inches below top of curb when placed in back of the curb. Place conduit runs for detectors parallel to existing or proposed curbs and not more than 18 inches behind the curb face unless other specified. Place steel conduit or Schedule 80 PVC conduit under existing pavements by approved jacking or drilling methods. Do not disturb pavements without the Engineer's approval. Where trenching is allowed in a traffic bearing area, use PVC conduit (Schedule 40) encased in concrete.

After completing the installation of the conduit, test all conduits installed under the Contract with a mandrel having a diameter 1/4-inch smaller than the conduit and a length of 2 inches. Repair, to the Engineer's satisfaction, all conduits that will not allow passage of the mandrel; if repairs cannot be accomplished, remove and replace the conduit at no additional cost to the Department. After the mandrel test, scour all conduits with a stiff wire brush slightly larger in diameter than the conduit. Clear all conduits in the Engineer's presence.

Extend conduits terminating in anchor base standards and pedestals approximately 2 inches above the foundation and slope them toward the hand-hole opening. Conduits shall enter concrete pull boxes from the bottom and shall terminate not less than 2 inches not more than 4 inches above the bottom of the box and near the box walls to leave the major portion of the box clear.

Clean existing underground conduit to be incorporated into a new system by blowing with compressed air, or by other means approved by the Engineer.

730.15 Conductors - Traffic Control Conductors shall be rated at 600 volts. Run all conductors, except loop conductors and cables run along messengers, in conduit, except where run inside poles. Where signal conductors are run in lighting standards containing high voltage street lighting conductors, encase the signal conductors in flexible or rigid metal conduit. Where telephone circuits are introduced into controller foundations, encase the telephone conductors in flexible metal conduit and in conformance with the NEC.

Conductors for traffic loops shall be continuous AWG No. 14 XLP stranded wire to the detector terminals or spliced with shielded detector cable within a pull box, conduit, or pole base.

Detector cable shall be two conductor twisted pair shielded AWG No. 14 stranded meeting IMSA Specification No. 19-2. **(See 730.29.A)**

730.16 Cable - All signal cable shall conform to applicable IMSA Specification No. 19 or 20. Use stranded cable color coded AWG No. 14 for all signal and accessory circuits. Retain the same color identification for the entire length of a circuit run.

730.17 Wiring

1. Terminate all wiring to screw terminals using lugs.

2. Make all splices with solder-less connectors, and insulate splices with weatherproof tape applied to a thickness equal to the original insulation.

3. Attach cables to messenger with non-corrosive lashing rods or stainless steel wire lashings.

4. All wiring within enclosed cabinets shall be neatly formed and harnessed and shall have sufficient length for access and servicing.

730.18 Service Connection - Coordinate service connection details and metering with the local utility as directed by the Engineer and in conformance with the City and County requirements. Obtain the necessary service for each installation.

730.19 Sealant - Provide sealant material selected from the Qualified Products List maintained by the Department's Material and Test Division for sealing saw-cuts. The sealant material shall resist the upward movement of loop and lead-in and shall exhibit stable dielectric characteristics, including a low permitivity and high dielectric strength. It shall bond to the roadway paving material, preventing entry of moisture, and shall remain flexible without melting through the anticipated temperature and weather conditions. **(See 730.29.A)**

730.20 Strand Cable - Span cable for suspending signal heads between pole supports shall be 7-strand, Class A, copper-covered steel wire strand or greater, meeting the requirements of ASTM A460, with a minimum breaking strength as noted on the Plans. An acceptable alternate is 7-strand steel wire with a Class A zinc coating meeting the requirements of ASTM A475, with a minimum breaking strength as shown on the Plans.

Strand cable for messenger wire (other than span wire as specified above) and pole guy cable use shall be of the diameter(s) shown on the Plans and shall meet the requirements of ASTM A475 for zinc-coated steel wire strand, 7-strand Siemens-Martin Grade with a Class A zinc coating or greater.

Figure 8 cable combining the messenger cable and conductor cable in an insulated jacket is an acceptable alternate to conductor cable lashed to a messenger cable.

730.21 Bonding and Grounding - Make metallic cable sheaths, conduits, cabinets, anchor bolts, metal poles and pedestals mechanically and electrically secure to form a continuous system, and ensure they are effectively grounded. Bonding and grounding jumpers shall be copper wire or copper strap of not less than the same cross-sectional area as No. 6 AWG. Install in accordance to NEC article 250 and 410 section IV Luminaire Supports.

Furnish and install a ground electrode at each service point. Ground electrodes shall be one-piece lengths of copper-weld ground rod not less than 8 feet in length and 1/2 inch in diameter, installed in accordance with the NEC. Install all ground rods in pull boxes. All traffic signal supports shall have a separate ground rod attached to each structure. They are considered auxiliary grounding electrode and will be installed in accordance with section 250.54 of the NEC. Pull box installation must conform to 730.12. Ground the conduit and neutral as required under the NEC, except that grounding conductors shall be No. 6 AWG or approved equal, as a minimum. Enclose exposed ground conductors in 1/2-inch diameter conduit, and bond to the electrode with a copper-weld ground clamp.

730.22 Field Test - Prior to completing the work, conduct the following tests on all traffic signal and lighting circuits in the Engineer's presence:

1. Test for ground at service point in circuit. Per NEC 2014 **250.53 Grounding Electrode System Installation**
   a. Rod, Pipe, and Plate Electrodes Rod, pipe, and plate electrodes shall meet the requirements of 250.53(A)(1) through (A)(3).
      (1) Below Permanent Moisture Level.
      If practicable, rod, pipe, and plate electrodes shall be embedded below permanent moisture level. Rod, pipe, and plate electrodes shall be free from nonconductive coatings such as paint or enamel.

(2) Supplemental Electrode Required.
A single rod, pipe, or plate electrode shall be supplemented by an additional electrode of a type specified in 250.52(A)(2) through (A)(8). The supplemental electrode shall be permitted to be bonded to one of the following:

i. Rod, pipe, or plate electrode
ii. Grounding electrode conductor
iii. Grounded service-entrance conductor
iv. Nonflexible grounded service raceway
vi. Any grounded service enclosure

Exception: If a single rod, pipe, or plate grounding electrode has a resistance to earth of 25 ohms or less, the supplemental electrode shall not be required.

(3) Supplemental Electrode.
If multiple rod, pipe, or plate electrodes are installed to meet the requirements of this section, they shall not be less than 1.8 m (6 ft) apart.

Informational Note: The paralleling efficiency of rods is increased by spacing them twice the length of the longest rod.

~~2. Conduct a megger test on each circuit between the circuit and ground. The insulation resistance shall be not less than the values specified in Section 119 of the NEC.~~

3. Conduct a functional test to demonstrate that each part of the system functions as specified or intended herein.

4. Test all detector loops and leads before and after they are sealed in the pavement to ensure there are no shorts to ground in the system and to ensure that the loop plus lead-in inductance is within the operating range of the detector. Replace or repair, in a manner approved by the Engineer, all faults in material or in the installation revealed by these tests. Repeat the applicable testing until no fault appears. **(See 730.29.A)**

Replace or repair, in a manner approved by the Engineer, all faults in material or in the installation revealed by these tests. Repeat the applicable testing until no fault appears.

730.23 Inspection - After completion of the installation and before final acceptance of the Project, conduct a full operational check of the system under actual traffic conditions in the presence of the Engineer. The operational check shall cover a minimum time period of 30 calendar days. During this period, perform all necessary adjustments and replace all malfunctioning parts of the equipment required to place the system in an acceptable operational condition at no additional cost to the Department. Perform all work and furnish all materials required under these Specifications subject to the direct supervision, inspection, and approval of the Engineer. Provide the Engineer and authorized representatives free access to the work, and to all plants, yards, shops, mills, and factories where, or in which, articles or materials to be used or furnished in connection with such work are being prepared, fabricated, or manufactured. Provide full and sufficient information to determine that the performance of the work, the character of materials, and the quality of workmanship and materials meets the intent of these Specifications.

Only perform work in the presence of the Engineer or the Inspector appointed by the Engineer, unless permission to do otherwise has first been obtained. The Engineer may reject any work that is performed or constructed in the absence of the Engineer or Inspector, without such permission having been granted, either expressly or by implication.

The inspection of the work shall not relieve the Contractor of its obligation to properly fulfill the Contract as specified. If the Engineer finds a part of the work, or the materials used in the work, to be defective or unsuitable at any time prior to final acceptance, repair or replace such defective or unsuitable work or material.

Request the presence of an Engineer or Inspector in connection with the work under these Specifications at least 24 hours before such services will be required.

SIGNAL HEADS

730.24 Signal Heads – Each vehicle signal head shall:

1. Be of the adjustable, colored lens, vertical type with the number and type of lights detailed as specified herein and as shown on the Plans;

2. Provide a light indicator in one direction only;

3. Capable of adjustment (without attachments) through 360 degrees about a vertical axis; and

4. Signals (3,4, or 5 section) suspended on span wire will have a top metal (aluminum) section. Any signal mounted on mast arms with "Astro-Brac" type hardware or approved equivalent can be plastic signal housings.

4. Be mounted as shown on the Plans or as directed by the Engineer.

Arrange the lenses in the signal faces in accordance with Section 4B-9 of the MUTCD. All circular indications shall use 12-inch Light Emitting Diodes (LED) module unless otherwise shown on the Plans. All arrow indications shall use 12-inch LED modules. All new vehicle signal heads installed at any one intersection shall be of the same style and from the same manufacturer. Apply one or more coats of primer to all signal heads, signal head mountings, and outside of hoods, followed by two coats of high quality synthetic resin enamel of Traffic Signal Black meeting or exceeding Federal Specifications TT-C-595 Gloss Black.

Apply one or more coats of primer to louvers as specified, signal hood interiors, and back plates, followed by two coats of Lusterless Black Enamel meeting or exceeding Master Painters Institute (MPI) Reference 94. Examine all factory enameled equipment and materials for damaged paint after installation, and repair such damaged surfaces to the Engineer's satisfaction. Factory applied enamel finish in good condition and of appropriate color will be acceptable.

Suspensions for span wire mounting of multi-faced signal heads and signal head clusters (such as a 5-section signal head) shall include an approved swivel type balance adjuster for proper vertical alignment.

Fabricate signal heads from die-cast bodies. Sand castings will not be acceptable.

Ensure that all signal heads meet the minimum Contract requirements for adjustable face vehicle traffic control signal heads.
In addition to these requirements, comply with the following:

A. Optical Units - Signal indications shall be L.E.D. type and meet standards set forth by the I.T.E. for light output. All LED lenses shall have a minimum five-year warranty.

B. Signal Head Mounting and Mounting Brackets - Furnish signal heads that either have integral serrations or are equipped with positive lock rings and fittings designed to prevent heads from turning due to external forces. Lock ring and connecting fittings shall have serrated contacts. Provide signals with water-tight fittings using neoprene washers.

Support bracket-mounted signal heads, as shown on the Plans, by mounting brackets consisting of assemblies of 1-1/2 inch standard pipe size. Ensure that all members are either plumb, level, symmetrically arranged, and securely assembled. Conceal all conductors within poles and mounting assembly. Secure each slip fitter to the pole.

C. Directional Louvers - Where shown on the Plans, furnish and install louvers in the hoods of the signal head sections designated.

Directional louvers shall have a snug fit in the signal hoods. Construct the outside cylinder and vanes from a non-ferrous metal or galvanized sheet steel. Paint louvers with two coats of black enamel as specified in 730.24.F.

D. Back Plates - Where shown on the Plans, furnish and attach back plates to the signal heads. All back plates shall be louvered and constructed of 3,003, half-hard, 0.051-inch minimum thickness aluminum sheet. All back plates shall have a reflective border around each back plate. Other materials such as plastic or fiberglass may be used where approved. In fabricating back plates, bend back the inside vertical edges, adjacent to the signal head, to form mounting brackets for attaching to the signal. Form back plates in two or more sections and bolt together, thus allowing for installation after signal heads are in place. Back plates shall have a dull black appearance.

E. Wiring - Signal head leads shall be No. 18 AWG stranded with 221°F thermoplastic insulation. Wire a separate white (common) lead to each socket shell; and wire a colored lead, corresponding to the color code shown on the Plans, to each socket terminal. Provide leads of sufficient length to allow connection to the terminal block specified. Provide each complete signal head with a minimum 4-point terminal block, properly mounted in a signal section. Stud type terminal blocks shall have not less than 1/4-inch edge clearance to any portion of the stud. Exterior wiring shall have a 360-degree drip loop in advance of entering the head.

F. Pedestrian Signals - When shown on the Plans, provide pedestrian signals conforming to the following:

1. Pedestrian indications should attract the attention of and be readable to the pedestrian both day and night and at all distances from 10 feet to the full width of the area to be crossed.

The housing door, door latch, and hinges shall be of aluminum, or approved equal. Hinge pins shall be stainless steel. Provide the door with a neoprene gasket capable of making a weather resistant, dust-proof seal when closed.

All pedestrian signal heads, mountings, outside of hoods, and pedestrian push button housings shall have one or more coats of primer followed by two coats of high quality synthetic resin enamel of Traffic Signal Black, meeting or exceeding Federal Specifications TT-C-595 Gloss Black. The interior of signal hoods shall have one or more coats of primer followed by two coats of Lusterless Black Enamel meeting or exceeding MPI Reference 94. Examine all factory enameled equipment and materials for damaged paint after installation, and repaint such damaged surfaces to the Engineer's satisfaction. Factory applied enamel finish in good condition and of appropriate color will be acceptable. Pedestrian pushbutton housings may be yellow following the same guidelines as above.

G. Countdown Pedestrian Signals - When shown on the Plans, countdown pedestrian signals shall conform to the following:

1. The requirements of the **MUTCD**.

2. Applicable provisions of the current specification of the Institute of Transportation Engineers standard titled Vehicle Traffic Control Signal Heads – Part 2: L.E.D. Vehicle Traffic Signal Modules (VTCSH Part 2).

3. Current specification of the Institute of Transportation Engineers standard titled Pedestrian Traffic Control Signal Indications (PTCSI).

4. FCC Title 47, Subpart B, Section 15 on Emission of Electronic Noise.

5. Current NEMA Standard TS-1 for operational compatibility.

The manufacturer must supply certification, which includes a copy of the test report by an independent technical laboratory as to the module compliance with ITE specifications (where it applies). The report shall also indicate that the tests were performed only after the modules received a thirty (30) minute operational warm-up period immediately preceding the tests.

H. Signal Head Installation - Install signal heads with the faces completely covered until the entire installation is ready for operation.

CONTROLLERS – GENERAL

730.25 Controllers - A controller shall consist of the complete electrical mechanism for controlling the operations of traffic control signals, including the timing mechanism and necessary auxiliary equipment, mounted in a cabinet.

A. Interval Sequence - The color sequence of signal indications shall be green, yellow, and red. Overlaps, such as green and yellow indications showing at the same time, will not be permitted. During any interval there shall be no visual flicker of signal indications. Under no conditions shall controllers allow conflicting green signal indications to be displayed.

B. Flashing Operations - Equip controllers to allow any combination of flashing red or yellow lights. However, set the flashing operation for flashing yellow lights on the main street or highway unless otherwise specified in the Special Provisions, shown on the Plans, or directed by the Engineer. The flashing mechanism shall produce between 50 and 60 flashes per minute through two 120-volt, 15-ampere circuits. One illuminated period at each flash shall not be less than 1/2 and not more than 2/3 of the total cycle. Pedestrian signals shall be dark during flashing operations. During normal operation, pedestrian signals shall flash DON'T WALK during the pedestrian clearance interval.

Use two circuit solid state flashers unless otherwise specified.

C. Wiring Diagrams - Submit a schematic wiring diagram of the controllers and auxiliary equipment at the time the controllers are delivered, or prior to ordering if requested by the Engineer. This diagram shall show in detail all circuits and parts. Identify such parts on the diagram by name or number and in such a manner as to be readily interpreted.

D. Operating Line Voltage - Provide equipment designed to operate from a 120-volt, 60-cycle AC supply. Operation shall be satisfactory at voltages from 105 to 130. All operating voltages into and out of the controller shall be NEMA level DC voltages, except for AC power (connector A, pin p and U)

E. Lightning Protectors and Interference Suppressors - Furnish ample lightning protectors to provide effective defense against high transient voltages caused by lightning discharges or other sources. Furnish each controller cabinet with the following surge protection devices:

1. Provide main power suppressor, for all but flasher or remote detector cabinets, having the following characteristics:
    - a. Peak Surge Current: 20,000 amperes
    - b. Clamp Voltage: 250 volts
    - c. Response Time: Voltage NEVER exceeds 250 volts
    - d. Continuous Current: 10 amperes at 120 volts AC

2. For controller flasher, flashing beacon, and remote detector cabinets, provide a power protector having the following characteristics:
    - a. Peak Current: 15,000 amperes
    - b. Power Dissipation: 15 watts
    - c. Peak Voltage: 212 volts

3. Provide loop detector input terminals with the following:

a. Peak Surge Current:	400 amps Differential Mode 1,000 amps Common Mode
b. Response Time:	40 nanoseconds
c. Input Capacitance:	35 picofarads typical
d. Clamp Voltage:	30 volts max (either mode)

4. Provide auxiliary relays and fan with a resistor/capacitor circuit to suppress generated noise.

5. Provide an RF Filter in controller cabinets capable of filtering of RF noise over the range of 60 hertz through 20 Megahertz. The RF filter may be incorporated as part of the Main Power Suppressor

F. Controller Cabinets - Controller cabinet shall be housed in a rigid, weatherproof cabinet, constructed, finished and equipped as detailed throughout this document. All cabinets shall be wired to TS 2 Type 2 standards. Unless specifically specified differently in the drawings and specifications for a particular project, all the following shall be included when a Knoxville cabinet is provided.

1. Material, Workmanship, Dimensions and Layout

a. All cabinets shall be of weather tight construction fabricated from aluminum sheet minimum 0.125 in. (3 mm) thickness or cast aluminum alloy minimum 0.25 in. (6 mm) thickness.

b. The interior of each cabinet shall be powder coated white to reduce overall cabinet temperature, reduce glare, and increase ambient light during night time troubleshooting in the cabinet.

c. All pad mounted cabinets should be 72” high X 40” wide X 26” deep unless a different size is specified in the plans. Due to many size differences between manufactures we will accept cabinet height sizes from 70” to 75”.

d. All pole mounted cabinets shall be 60” high X 36” wide X16.5 deep at a minimum, unless a different size is specified in the plans. The pole mounted cabinet will be determined on a per job basis.

e. All pole mount cabinets shall be equipped with a removable bottom panel to facilitate optional pad mounting.

f. All cabinets shall have a name plate riveted to main door 16.5”W x 4”H with two lines of one inch text that displays “CITY OF KNOXVILLE” on first line and “TRAFFIC CONTROL” on second line. Inside each letter shall be clearly identified with black paint that will bond to the surface of plate. Please contact the City of Knoxville for current design standards. Please contact the City of Knoxville for current design specs.

g. All base mounted cabinets shall have cabinet flanges welded to the cabinet base to accommodate standard Knoxville base and anchor bolt pattern. There shall be 4 anchor bolt holes that center the cabinet over anchor bolts located 30” apart center to center in width and 18” center to center front to back. Each mounting hole shall be one inch by 2 inches oblong (front to back) to accommodate anchor bolts.

h. All shelves and panels shall mount on C-Channel type rails and be fully adjustable by loosening panel bolts.

i. No less than three shelves shall be provided to support controller and auxiliary equipment. Shelves shall be a minimum of 10 inches deep. Shelves shall be the entire inside width of cabinet minus mounting rails. The shelves shall have slots aligned with the cabinet mounting rails. All shelves shall be secured with spring mounted nuts and hex head bolts. "Drop in" shelves secured with Nylon cable ties are not allowed. The front edge of the shelf shall be punched every 6 inches to accommodate tie-wrapping of cables/harnesses.

j. Cabinet Main Back panel shall have a hinged type mount at the bottom of the panel to facilitate rotating the panel forward for inspection of the rear wiring.

k. All feed through terminals shall be soldered. The use of crimp on style connectors on the rear of the panel will not be accepted.

2. Doors

a. Cabinets shall have a hinged front opening door which shall include substantially the full area of the front of the cabinet and be hinged on the right side facing the outside of the cabinet. There shall also be a rear door the same dimensions as the front door and hinged on the right side facing back of cabinet.

b. Both front and back doors shall be equipped with a positive hold fast device to secure the door in at least two open positions; one position at approximately 90 degrees and the other at 120 degrees or more.

c. The holdfast device shall be easily secured and released without the use of tools.

d. The top of the cabinet shall incorporate a 1-inch slope toward the rear to prevent rain accumulation.

e. Cabinets shall also be equipped with a switch compartment and the manual switches specified in this section and shall have a hinged front opening auxiliary door. Each door shall have a gasket to provide a weatherproof seal when closed.

f. All surfaces shall be free from weld flash. Welds shall be smooth, neatly formed, free from cracks, blowholes and other irregularities. All sharp edges shall be ground smooth.

g. A rain channel shall be incorporated into the design of the main door opening to prevent liquids from entering the enclosure.

h. The main door shall have No. 2 pin-tumbler cylinder lock.

i. The auxiliary front door shall have a standard police sub-treasury lock.

j. Two keys for each lock shall be provided.

3. Ventilation - Unless otherwise specified, ventilation shall be provided as follows:

a. All cabinets shall be ventilated through internal baffles located in the top front and rear of the cabinet.

b. Inlet ventilation openings shall be filtered on the front and rear door. Inlet ventilation openings shall be filtered using size 14” X 20” X 1” filter.

c. Cabinets shall be provided with two independently controlled "Exhaust Fans".

d. Exhaust fans shall consist of an electric fan with ball or roller bearings and a capacity of at least 100 ft^3 (3 m^3) per minute.

e. The fans shall be mounted in a rain tight housing attached to the plenums inside the top front and rear of the cabinet.

f. Each fan shall be controlled by thermostats having a temperature differential between turn-on and turn-off of 15° F (0, +5° F) (8° C (0, + 3° C)), adjustable for turn-on through a minimum calibrated range of from 100° to 150° F (38 to 65° C).

4. **All cabinets shall include a cabinet sliding storage drawer mounted under lower shelf in accordance with the following:**

a. Approximate exterior dimensions 1.75 inches (H) x 16 inches (W) x 14 inches (D).

b. Telescoping drawer guides to allow full extension from beneath the shelf using ball bearings.

c. Opening storage compartment lid to access storage space for cabinet documentation and other items.

d. Supports a weight of 25 Lb. when extended.

e. Non-slip plastic laminate surface attached to the compartment lid which covers a minimum of 90% of the surface area of the drawer lid.

f. The drawer shall be installed in accordance to 5.D.

5. Auxiliary Equipment - Except cabinets used in special applications, all cabinets shall be fitted with the following:

a. All terminal panels shall be arranged for adequate electrical clearance.

b. One 8-position outlet strip located on the right side of the cabinet, mounted so as not to interfere with shelf space. The outlet strip should be mounted either on a 45 degree angle or a 90 degree angle so large power supplies for devices may be accommodated.

c. L.E.D type lighting mounted on the plenum, under the front of each shelf, and over the rear of the back-panel. All L.E.D lights shall be controlled by a door switch.

d. A form fitting enclosure with two (2) cavities measuring 10" X 17" X 3"shall be mounted to the bottom shelve to secure BBS batteries, the document drawer shall attach to the bottom of the enclosure.

e. Back-panel shall include module "plug-in" type load capacitors for signal output and incorporate MOV (Metal Oxide Varistors) for surge providing capacitive loading and MOV protection. MOV protection shall be provided for each output. Capacitive loading shall be available for each output or for green and yellow outputs only. Capacitive loading shall provide an AC impedance equivalent to the DC resistance provided by a 1.5 K-ohm resistor. Modules shall be accessible from the front of the load bay and replaceable within a few seconds.

f. A main Power Distribution Assembly (PDA) on the right cabinet wall shall contain the following:

(1) The top, front, and sides of the panel shall be protected by a clear plastic cover and with openings to allow access to the circuit breakers. The rear and bottom shall be open for ventilation.

(2) GFI outlet in the front panel

(3) A removable/serviceable multi-stage surge suppressor equivalent to Hesco HE1750

(4) Circuit Breakers minimum requirements for:

i. Main power Input to provide all power associated with normal operation. (30 Amp)

ii. Equipment Power to provide power to all associated cabinet equipment. (10 Amp)

iii. Service entrance Power to provide Power for the lamp and duplex receptacle. (10 Amp)

iv. Sign Power (15 Amp) to provide power to street name signs (if required by plans)

(5) Radio Interference Filter (RFI) which meets the requirements set forth in Section 5.4.2.5 of the NEMA Standards Publication No. TS 2-2003 or later revision.

(6) A normally-open, 50-amp, Solid State Relay (SSR) signal contactor.

(7) Bus bars:

i. One 6-Position alloy for PDA Chassis Ground (Earth) connections.

ii. One 6-Position alloy for PDA AC- (Neutral) connections. This Busbar shall be isolated from the panel and cabinet.

g. Bus bar panel located directly under the PDA on the right cabinet wall with:

(1) Minimum of one 17 position bar for Chassis Ground (Earth)

(2) Minimum of two 17 position bars for AC- Common Return (Neutral). This Busbar shall be isolated from the panel and cabinet.

h. The MMU channel inputs shall be terminated at the closest tie point to the field termination of the signal displays.

i. Where required to perform specified functions general purpose relays shall be provided.

j. Common Ground System: AC – return (Neutral) and Chassis (Earth) must be referenced to a single ground point at the electric service.

k. Logic ground may be connected to AC- or Chassis at the detector power terminal panel.

l. Provide a plug in Pedestrian Push Button Isolation device to completely isolate Pedestrian push buttons from AC-, Chassis, and Logic Ground.

m. Individual phase pedestrian test switches to be toggle type of the On-Off-Momentary type located at the top of the loop panel to place:

(1) Up- “CALL” – locked detector call

i. Center - “AUTO” – no call – Call provided by detectors.

ii. Down - “TEST” – momentary detector call

n. A Police Switch Panel behind the auxiliary door to contain the following switches:

(1) A Signals on/off switch.

(2) An Auto/Flash switch, which shall be wired when in the Flash position, shall cause the cabinet to provide Flash Operation and Stop Time shall be applied to the controller.

(3) Auto/Manual switch to activate Manual Control Enable.

(4) Manual control pushbutton switch with self-coiling cord. Cord shall attach to a 2 position terminal strip via fork type connectors

o. A Technician Switch Panel inside the main door to contain the following switches:

(1) Equipment Power On/Off switch for Controller and Monitor.

(2) A Stop-Time switch to apply Stop Time to both controller rings.

(3) A Signal On/Off switch which will remove the AC power applied to the signal heads for normal operation while the controller continues to operate.

(4) A Signal Auto/Flash switch to enable intersection flash when in the Flash position.

(5) Switch terminals on back of main cabinet door shall be insulated or shielded so that no live parts are exposed for safety.

(6) All switches protected from accidental actuation by hinged clear plastic cover.

p. Leads to the auxiliary door and technician switch panel switches shall be stranded and no less than:

(1) # 8 AWG for Signal On/Off Switch

(2) # 18 AWG for all other AC switches.

(3) # 20 AWG for all DC switches.

q. A TS2 Port-3 FSK Communications Panel shall be provided with:

(1) Aluminum panel mounted on left cabinet wall.

(2) Two 5-position terminal blocks for Transmit pair, receive Pair, and ground in and out of surge suppresser.

i. EDCO PC642-008D surge suppresser or approved equivalent and base.

ii. TS2 9-Position FSK communications harness.

r. Each cabinet shall include on the left side wall a Loop Panel which includes:

s. Terminal blocks to accommodate the termination of loop lead in wires and pedestrian push button wires.

t. EDCO surge bases and accompanying EDCO PC-642C-030 surge suppressors or equivalent to terminate incoming vehicle call input wires, pedestrian push button wires and loop lead in wires.

u. All termination and function locations shall be clearly identified with permanent style labels.

v. A ground bar of at least 17 positions at the lower edge of the panel.

w. Each cabinet shall include on the left side wall a Preemption Panel compatible with Trafficware controllers:

(1) Terminal blocks to accommodate the termination of incoming preemption wires.

(2) A bank of relays for conveying preemption calls to the controller.

(3) All termination and function locations shall be clearly identified with permanent style labels.

x. All cabinets to include sixteen I/O load switches, one flasher, six flash transfer relays, one BIU and four detector cards (two channel variety).

y. Wiring - The cabinet shall be wired according to the following:

6. Back-panel

a. Shall be wired for 8 vehicle movements, 4 pedestrian phases and 4 overlaps (sixteen channels).

b. Sixteen NEMA input and output indicating load switches and bases shall be provided.

c. Shall be wired for 8 flash relay bases to allow any loadswitch (phase) outputs to flash Yellow, Red, or no-flash.

d. Cabinet Main Back Panel signal outputs shall use both color coded red, yellow and green wires and red, yellow and green labels for easy identification.

e. All pedestrian and overlap signal wires shall feed to their back-panel positions from below the terminal strips and not travel over the face of the back-panel and other signal wires.

f. Provide 4 terminal screw downs per channel, one each for red, yellow, green and flash.

g. Color coded labels shall be placed on the inside of the front cabinet door to illustrate the procedure for changing the signal output flash colors.

h. Detector rack (eight 2-Channel Slots) shall be included and shall be wired and clearly labeled:

(1) Slot-1 PH-1/6

(2) Slot-2 PH-2/5

(3) Slot-3 PH-3/8
(4) Slot-4 PH-4/7

(5) Slot-5 PH-1/6

(6) Slot-6 PH-2/5
(7) Slot-7 Pre-3/4

(8) Slot-8 Pre-1/2

7. Individual phase vehicle detector test switches shall be included and shall be toggle type of the On-Off-Momentary type located at the top of the loop panel to place:

a. Up- "CALL" – locked detector call

b. Center - "AUTO" – no call – Call provided by detectors.

c. Down - "TEST" – momentary detector call

8. Wire type:

a. All wiring, 14 AWG and smaller, shall conform to MIL-W-16878/17, Type B/N. The wire shall have a minimum of 0.010 inches thick PVC insulation with clear nylon jacket.

b. All wiring larger than 14 AWG shall have UL listed THHN/THWN 90 degrees Celsius. 600V, 0.020 inches thick PVC insulation with clear nylon jacket.

9. Power Supply - The cabinet shall include a cabinet power supply meeting the requirements of NEMA specification TS2. The power supply shall be completely enclosed in an aluminum housing, shall be shelf mounted, and shall provide the following voltage and current outputs:

a. +12 VDC +/- 1 VDC, 2.0 A

b. +24 VDC +/- 1 VDC, 2.0 A

c. 12 VAC, 0.25 A

d. Outputs shall be fused with slow blow fuses of the ratings indicated.

e. AC power input shall be protected against over current with a 2 Amp slow blow fuse.

f. L.E.D. indicators on the front panel shall denote the presence of 12 VAC, 24 VDC and 12 VDC and the 60 Hz reference signal Test points for logic common and +24 VDC shall also be provided on the front panel.

g. The power supply harness shall be connected to a terminal block at the top of the cabinet detector panel.

h. The panel shall have a decal that is color coded to indicate all voltage and ground bus connections for safety reasons. A clear plastic cover shall be placed over the terminal bloc to prevent accidental contact with line voltage terminals.

10. Bus Interface Unit (BIU) - The cabinet shall include:

a. A detector rack with provision for a BIU as defined in Section 8 of NEMA Standards Publication No. TS 2, 2003 or later revision.

b. One BIU that shall be a NEMA designated BIU2 as listed in Table 8-1 of NEMA Standards Publication No. TS 2-2003 or later revision.

c. One SDLC distribution panel with connectors for 10 SDLC cables.

d. Three SDLC cables one each for MMU, Controller, and detector rack BIU.

e. The cabinet assembly shall have provision for supporting detection inputs by means of NEMA TS1 interface method or by NEMA TS2 BIU method. The cabinet assembly shall be easily converted from one interface method to the other. Converting from one method to the other shall not require replacement of the detection rack. When utilizing the TS1 method, detector calls shall be routed via a modular harness from the detector rack to the back-panel assembly and the vehicle call inputs to the controller. A BIU shall not be employed. When using the TS2 BIU method, the detector rack shall use a standard BIU to route detector calls to the controller via the SDLC Port 1 bus and the modular TS1 harness shall be removed. It shall not be necessary to reconfigure numerous jumpers to make the switch from TS1 to TS2 detection.

11. Lightning Protectors and Interference Suppressors **-** Ample lightning protectors to provide effective defense against high transient voltages caused by lightning discharges or other sources shall be provided. Each controller cabinet must be furnished with the following surge protection devices:

a. Main power suppressor shall be EDCO SHP-300-10 or approved equivalent for all but flasher or remote detector cabinets and shall have the following characteristics:

(1) Peak surge current: 20,000 Amperes

(2) Clamp Voltage: 340 Volts

(3) Response Time: Voltage NEVER exceeds 340 Volts

(4) Continuous Current: 10 AMPS at 120 VOLTS AC

b. Power Protector for Controller Flasher, Flashing Beacon, and Remote Detector Cabinets:

(1) Peak Current: 15,000 Amperes

(2) Power Dissipation: 15 Watts

(3) Peak Voltage: 650 Volts

c. Controller detector input terminals (vehicle and pedestrian) shall be terminated at a plug-in surge suppressor, EDCO PC-642C-030 or approved equivalent, and have the following characteristics:

(1) Peak Surge Current: 400 Amps Differential Mode

(2) Response Time: 40 Nanoseconds

(3) Input Capacitance: 35 pf typical

(4) Clamp Voltage: 30 Volts Max (either mode)

12. Flash Relays, Auxiliary Relays, and Fan shall be provided with a resistor/capacitor circuit to suppress generated noise.

TRAFFIC ACTUATED CONTROLLERS

730.26 Traffic Actuated Controllers – The City of Knoxville currently uses the TS2 Type 2 Trafficware 980ATC or approved equivalent. **T**he controller mechanism shall meet or exceed the current NEMA Traffic Signal Systems Standard. Provide Standard A, B, and C Connectors. Submit private laboratory certification that the proposed unit is in complete compliance with the most current NEMA standards.

The NEMA TS2 Type 2 980ATC controller and Malfunction Management Unit (MMU) shall transfer data via RS232 Port for tracking phase output, status, and logging data back to the controller. MMU must be accessible via through the traffic controller Ethernet/RS232.

The controller shall have all timing values entered via a front panel mounted keyboard. This keyboard shall be an integral part of the controller unit. Each controller shall have all operating timing parameters as specified in NEMA on a per phase basis, including all Volume/Density features. Each phase shall have a defeat-able Last Car Passage feature wherein the last vehicle receiving the Phase Green shall receive at least one full Passage Time increment. The controller shall have all of the following keyboard entered values or parameters:

1. Start on condition of the controller where the user can select via the keyboard the following:

a. Phases to start in

b. Phase display to be on

c. Overlap display start-on condition

d. Normal start-up display shall be mainstreet green phase(s), with concurrent overlaps green

2. Phase recall functions:
   a. Non-lock detector

   b. Lock detector call

   c. Minimum recall

   d. Maximum recall

   e. Pedestrian recall

   f. Non-actuated phase

   g. Phase not active, phase omitted

   h. Pedestrian phase omitted

3. All phase interval timing values except the Phase Yellow Clearance shall be as per NEMA. Each controller phase Yellow Clearance Interval is 3 seconds as a minimum.

The controller shall have a back-lit liquid crystal display for each ring of the controller to provide an English language menu for programming with displays for programming or reading all controller features. The dynamic displays for real-time operation shall be able to display the following values for each ring or phase(s) concurrently:

1. Per Phase Display:
   a. Phase Vehicle Call

   b. Phase Pedestrian Call

   c. Phase is Next In Service

   d. Phase is In Service

   e. Phase Pedestrian Intervals in Service

2. Per Ring Display:
   a. Ring Gapped Out

   b. Ring Maximum Green Termination

   c. Ring was Force Off Terminated

   d. Ring Maximum Green II in effect

   e. Ring Phase in Service Operating:
      (1) Lock Call

      (2) Non-Lock Call

(3) Minimum Recall

(4) Maximum Recall

(5) Pedestrian Recall

(6) Non-Actuated Mode

3. Per Ring Display of Timing Values (Real Time). The following values shall be selectively displayed and shall display the current value in a real time mode.

a. Minimum Green Interval

b. Passage Timer

c. Pedestrian Interval Timing

d. Maximum Green Timer

e. Time Before Reduction Timer

f. Time to Reduce Timer

It shall be possible to inspect and alter any currently programmed value while the controller is in operation without affecting the field operation. The controller shall continue to operate the intersection as values are inspected or altered.

The controller shall store all operator entered data in EEPROM devices that require no battery to support value storage. No internal components of circuitry shall require battery support.

The timer shall have a front-panel mounted RS-232 connector to allow the user to print a hard copy of all programmed data to a standard serial printer. The printer shall use a standard RS-232 connecting cable.

730.27 Auxiliary Equipment for Traffic Actuated Controllers - Furnish and install the following auxiliary equipment in each cabinet for traffic actuated controllers.

A. Load Switches and Flash Transfer Relays

Provide each cabinet complete, with the necessary number of NEMA load switches and Flash Transfer relays necessary to affect the specified signal sequence and phasing. Load switches and flash transfer relays shall:

1. Meet NEMA standards.

2. Load switches front-face mounted LED indicators to indicate the “On” condition of both the Input and Output circuits. Flash transfer relays will have front-face mounted LED indication to indicate the “On” condition.

3. Use replaceable “cube” type circuitry or encapsulated discrete component construction. No un-encapsulated discrete component constructions are acceptable.

B. Time Clock Switches

Where shown on the Plans, provide time clock switches of solid state circuitry, continuous duty, with a 7-day cycle clock operating from the 120-volt AC service line. Provide switching for a minimum of one independent output and ensure the

time of day selection is adjustable to within 1 minute of the desired time. Provide a battery backup system that can maintain time keeping and memory a minimum of 24 hours after power interruption.

Furnish an omitting device as an integral part of the time switch to allow the switching operation to be skipped for any preselected day or days of the week. The time clock shall automatically compensate for daylight savings time changes. When the time clock is supplied as an internal component of the controller, supply the clock feature to provide for the selection of Maximum Green II on time of day, day of week, week of year basis. Time clocks shall meet NEMA environmental specifications.

C. Malfunction Management Unit (MMU)

Model MMU 516L-E Malfunction Management Unit or approved equivalent is an enhanced MMU that monitors up to 16 traffic signal indications (channels) for conflict, improper sequencing, incorrect timing, and improper signal voltage levels. The MMU 516L-E is fully compliant with NEMA Standard TS2-2003. The MMU 516L-E is also capable of operating in older TS1 type cabinets, and is compatible with 12-channel Conflict Monitor Units conforming to the NEMA Standard TS1-1989.

All connectors, indicators, and operator controls are located on the front panel of the MMU 516L-E. Channel and control input signals and relay output connections are made through two MIL-C-26482 connectors, and the SDLC Port is an A-size,15 contact, D shell connector. The MMU 516L-E is equipped with a 10/100 Ethernet Port and a RS232 Port, which are excellent for tracking important phase output, status, and logging data back to the controller or to a PC for logging. The programming card and the AC line fuse are easily accessed from the front panel. The MMU 516L-E provides a Reset Timeout feature to prevent a broken switch or accidental wiring fault from holding the unit in the reset state for an extended period of time.

LED indicators, in addition to the TS2 specified indicators, include Dual Indication Fault, Yellow+Red Clearance Fault, Programming Card Ajar, Field Check (active channels do not match SDLC message from controller) Fault, and LEDs for two +24VDC input faults and CVM input faults. Status indicators provided include: AC Line Power, Type 12 Indicator, SDLC Transmitter Active, and SDLC Message Received. For added safety, the MMU516L-E performs continuous diagnostic tests during all operating modes. All memory elements, the microprocessor, operating voltages, and critical circuitry are checked.

D. Spread Spectrum Wireless Radio

Microhard Nano IPn920T wireless radio or approved equivalent. This radio offers full Ethernet/Serial/USB bridge and routing functionality. With the LAN out interface radio is ready to wire directly to CAT5 cable OEMs can integrate this unit quickly and efficient. The Nano IP Series also features flexible maintenance utilities, secure firewall features and network management facilities.

E. Battery Back-Up System

The Battery Backup System (BBS) shall power the Traffic cabinet in the event of a power failure or other user selectable event such as time of day. The BBS system will supply 120VAC ±3% at 60 Hz ±0.1% to the cabinet.

A front panel switch will allow the user to bypass the internal inverter and force the cabinet to run on the AC Power line. In the normal position, the BBS Controller will monitor the AC Line Voltage and in the event of a power failure will switch the cabinet power to the Inverter output in less than 8 milliseconds. Two relays will be used to switch the power and isolate the Inverter power from the AC line Voltage.

The BBS Inverter will be powered by battery panels that are sized such that the panels can be mounted underneath or on top of the existing NEMA internal cabinet shelves and shall be installed by cabinet supplier. The battery panels will incorporate smart battery chargers that are controlled by the main Controller/Inverter. Communication between the Controller/Inverter and the battery panel chargers is through a serial bus contained in the interconnect cable. The Main Controller/Inverter will be able to turn any battery Panel or individual battery string ON or OFF.

Battery Panel size and capacity will be based on the cabinet size and load requirements. 1000 Watt system with 4 hour battery uptime will be standard in 16 phase cabinet. Up to 16 panels can be attached to one Controller/Inverter. The temperature of the battery cells will be continuously monitored and charge current modified based on temperature. The number of battery panels in a system will NOT affect battery charge time. Charging or discharging of the battery panel will not add a significant amount of heat to the cabinet.

The Battery Panels shall use cells based on Nickel Zinc Chemistry. The cells will not have any environmental restrictions and will be able to be disposed of or recycled easily. There will be no transportation restrictions on the batteries.
The Main Controller/Inverter will have a 4 line by 20-character LCD display with a white LED back light. A keypad will control the curser on the display and allow the user to select different operational parameters as well as check the status of the system. The LCD display will be able to display the current line Voltage, the cabinet load current, and battery status including calculated backup time.

Eight relays will be available on the rear or front panel with uncommitted Com, NO, and NC contacts. The control of the relay is set up on the front panel with the keypad and display or through a PC connected to the USB port. The relays can be controlled by the following events:

1. Power Failure
2. Low Battery
3. Time following Power Failure
4. Time of Day
5. Temperature
6. Inverter shut down

The relays will use individual 3 pin Phoenix type connectors that plug into the front panel for easy removal of the BBS Controller.

The BBS will be able to exercise and determine the status and capacity of all battery strings on a continuing basis. An accurate backup time can then be calculated. The depth of discharge value can be adjusted if more backup time is required versus battery life. The Voltage at which the BBS switches to battery power and then back to the AC line is settable by the user. An over-voltage point can also be set where the BBS switches to battery power if too high of a voltage are sensed on the AC power line. The BBS will also monitor the current consumption of the cabinet, which can be used as a diagnostic tool by the traffic technicians. The Main Controller/Inverter will be a NEMA internal shelve mount unit.

Battery backup system shall have a quick disconnect panel that will allow a hot swap operation. Shall have a bypass and normal operation switch.

F. Environmentally Hardened Managed Ethernet Switch

The ComNet CNGE5MS or approved equivalent managed Ethernet switch has three 10/100/1000Base-TX and two Gigabit combo ports that utilize SFP modules for fiber and twisted pair copper communication mediums. The switch shall offer centralized and convenient management through a windows-based utility. The module shall support transmission utilizing Category 5 cable or better, multimode, or single-mode fiber. The module shall support the Ethernet data IEEE 802.3 protocol using Auto-negotiating and Auto-MDI/MDI-X features.

The switch shall be capable of using a MSA Compliant Small Form-Factor Pluggable (SFP) modules allows for an optical or electrical interface when using a managed switch, unmanaged switch or media converter. These interchangeable SFP modules are available for use with copper media, multimode optical fiber, or single mode optical fiber. The optical fiber SFP modules are available in Fast Ethernet one and two fiber versions and Gigabit Ethernet one and two fiber versions. They also are available with LC or SC optical connectors. The SFP modules offer different wavelengths and optical power budget to allow distances from 300 meters to 120 kilometers. These SFP modules are industrially rated to perform in the most difficult operating environments.

The managed switch shall include no less than 3 (three) 10/100/1000T(X) RJ-45 ports and 2 (two) combo SFP 10/100/1000T(X) RJ-45 ports / 100/1000FX ports. Use of an SFP port disables the corresponding 10/100/1000TX RJ-45 port. Similarly, use of a 10/100/1000TX RJ-45 port disables the corresponding SFP port. The module shall require no in-field electrical or optical adjustments or in-line attenuators to ease installation. The module shall provide power, link speed, and fiber port status indicating LED's for monitoring proper system operation. The modules shall provide automatic re-settable solid-state current limiters on each module to reduce the chance of a single point failure of the system. The module shall provide a serial connection for local management of the device.

G. Preemption Systems

Currently, the City uses Sonem 2000 preemption by Traffic Systems LLC. Any other type of preemption will be used at the City's discretion.

Controller/MMU

Traffic controller and Malfunction Management Unit (MMU) shall transfer data via RS232 Port for purposes of data logging when requested by ATMS, logs will provide at a minimum date and time stamp of all AC power line disturbances, MMU faults, program card and front panel programming, intersection station ID and text description of the location at the top of each report through the traffic controller Ethernet/RS232.

PROGRAMMING

Minimum flash; 0-16 seconds, Short yellow per channel, Programmable sequence monitor, Latch selectable options

INDICATIONS

Conflict LED, Red Fail LED, 24 V-1 and V-2 Controller Voltage Monitor, Red+Yel Clearance, Clearance Diagnostics, Port 1 Fault, Tx, Rx; Program Card Ajar Indication Fail LED, Field Check, Power LED, Type 12 Mode

ENVIRONMENTAL

Operating Temperature: -34C to +74C
Storage Temperature: -45C to +85C
Humidity: Less than 95% non-condensing to +43C

NEMA + FEATURES

Meets and exceeds TS2-1992 Specifications, Operates in TS1 Cabinets, EPROM Memory, No batteries, Menu Driven LCD Display, Machine tooled socket I.C.'s, Programmable Minimum Flash Time, Latch 24 V failures, Latch CVM Failure, Enhanced Monitoring, Flashing Yellow Protected/Permissive, 10/100 Ethernet

FLASHING BEACONS

730.28 – Beacons

Flashing School Signals **-** When shown on the Plans, provide flashing school signals that conform to the following:

1. The signal shall produce two alternate flashing lights within the marginal limits of a school speed limit sign. Details of the sign construction shall be as shown on the Plans. Sign colors shall conform to the MUTCD and be constructed of materials complying with these specifications.

2. The two lenses shall be yellow in color and a minimum of 8 inches in diameter. Mount the lenses in the sign using a molded endless rubber gasket with the sign being mounted to the signal case. The reflector for the round lens shall be glass and firmly mounted between the lens assembly and the case so as to produce a weatherproof and water-tight optical unit.

3. Provide a two circuit type flasher unit to provide alternating equal on-off operation. The flashing mechanism shall produce between 50 and 60 flashes per minute through two 120-volt, 60-cycle AC, 15-ampere circuits. The flasher shall be of solid state construction.

4. Wire the unit for external circuits.

5. The signal shall be actuated by time switch meeting **730.27**.B. Locate the timing device in a remote mounted control cabinet.

6. Where an illuminated speed limit indication is shown on the Plans, the numeral message shall be illuminated in Portland Orange in a rectangular lens and illuminated only during the period when the signal produces two alternately flashing amber lights.

Flashing Beacons - Can be AC or solar/ battery powered type. Where applicable flashing beacons will be specified in the plans.

DETECTORS

730.29 Detectors - Provide detectors, of the type shown on the Plans, to actuate signal phases of traffic actuated controllers. Provide ample lightning protection to provide effective defense against high transient voltages caused by lightning discharges or from other sources. The lightning protection shall conform to 730.25.F.11 EDCO-642C-030 or approved equivalent.

A. Inductive Loop Detectors

Loop amplifiers shall be of the single-channel, totally self-contained type, using a standard 10-pin MS connector (MS3102A-18P) and designed to operate within the NEMA environmental standards. All loop amplifiers shall be of the type to provide both "Extended" and "Delayed" outputs. The loop detector amplifier shall be full automatic, requiring no adjustments to effect operational ability other than setting of the operating frequency and sensitivity. The amplifier shall:

1. Sense any legal motor vehicle traveling at speeds up to 65 miles per hour.

2. Have both a "Pulse" and "Presence" Output:
   a. Pulse output shall generate an output of 125 ±25 millisecond output for each vehicle entry.
   b. Presence output shall provide a continuous output for up to 60 minutes as long as a vehicle is within the detection zone.

3. Provide at least four user selectable sensitivity ranges.

4. Be supplied with at least three frequency ranges for crosstalk minimization.

5. Have a front-face mounted indicator to indicate active output of the internal relay. This indicator shall indicate the presence of:
   a. Normal Output

   b. Delayed Output

   c. Extended Output

6. Have a front-panel mounted "Reset" switch that when pressed shall cause the unit to completely re-tune itself.

7. Have Delayed or Extended timing features with the following ranges:
   a. Delayed output of 0 to 30 seconds in 1-second increments.

b. Extended output of 0 to 10 seconds in 1/4-second increments.

8. Have internal diagnostics to determine the operational ability of the loop. These diagnostics shall determine if a loop is opened or shorted, and shall provide a visible indication of such condition. Additionally, if such a condition occurs, the amplifier unit shall default to a "constant" output.

9. Provide output by a mechanical relay, which shall be "off" to provide an output.

10. Have all delay functions wired to the associated plan phase green to inhibit that function during controller phase green.

11. Able to operate with loop lead-in lengths of at least 2,000 feet. Comply with the details of the detector loop installation as shown on the Plans or Standard Drawings.

B. Installation Requirements

1. Wire Routing

a. Contractor shall install detector loops in accordance with TDOT Standard Drawing T-SG-3, Standard Notes and Details of Detector Loops. All other loop configurations can be obtained from the Institute of Transportation Engineers, Traffic Detector Handbook and/or contacting the City of Knoxville.

2. Types of Loops include:

a. 6' x 45' vehicle power head detector loop

b. 6' x 20' vehicle power head detector loop

c. Type and Size to be detailed in the Notice to Proceed.

3. Loop Termination Location

a. This is the location that loop homerun needs to be taken back to in order to reconnect to the detection system.

4. Termination Description

a. Type of wire connection

b. Pull box attachments location

c. Phase association for labeling

C. Saw Slot

1. Loop Layout. The general loop layout will be placed as per City of Knoxville requirements to meet the needs of the particular approach. For example, in sweeping right turn lanes, the loop layout will conform to the movement of the vehicle inside the lanes.

2. Roadway. Saw slot in the roadway will be 3 inches deep and 3/8" in width when completed prior to installing backer rod, wire and loop sealant. The saw slot requirements will be confirmed by the City inspector on the inspection form for that particular loop prior to installing the loop elements.

The homerun saw slot will take the shortest and most direct route to the location of terminations to avoid undue increase in overall cost of the loop.

3. Curb / Sidewalk. Saw slot into the curb and across the sidewalk will utilize construction joints in an effort to provide the most esthetically pleasing appearance and avoid damaging individual sidewalk panels.

4. Cleaning. All saw cuts must be thoroughly cleaned of dirt and saw cut tailings with high pressure compressed air and/or water until clean. The saw cut must be completely dry before installing wires.

D. Backer Rod

1. Backer rod will be installed the full length along bottom of saw slot to provide a smooth protective surface for the loop wire to rest.

2. Short six inch section of backer rod will be placed on top of the loop wire every two feet to insure that the wire does not become exposed at the surface of the saw slot prior to sealant placement.

E. Wire

1. All detector loop wire used shall be I.M.S.A. Specification No. 51-3 1997 XHHW detector wire, 14 AWG, single conductor stranded.

2. The detector loop wire home runs shall be installed with 3 turns per foot. This will be done from the point the wire exits the head of the loop until the homerun is terminated at controller cabinet or spliced to the existing homerun.

3. All loop head and homerun wire to be continuous with no splices within the roadway.

4. Special caution must be taken when placing the loop wire into the saw cut to avoid scraping, cutting, or breaking the insulation. Sharp objects that could damage the insulation should be removed from the saw slot. Wire should not be forced into the saw cut with a screw driver or other sharp instrument.

5. At all pavement joints or cracks, slack should be provided in the wiring to prevent future insulation breaks.

F. Wire Labeling - Pull box and Cabinet wiring shall be heat shrink labeled and meet all ANSI and TIA/EIA-606-B industry labeling standards.

G. Sealant - Once the wire has been place in the slot with the backer rod, the slot will be filled with a TDOT acceptable detector loop sealant as outlined by the TDOT 730 and 730K Specifications, Section 730.19 and the qualified products list maintained by the Department's Material and Test Division for sealing saw cuts.

H. Traffic Control

1. Work Plans - The contractor will be responsible for providing the City of Knoxville with Traffic Control Work Plan which will illustrate a typical lane closure which will be used as part of the traffic signal detector loop installation. Any deviations need to be provided to the City of Knoxville Traffic Systems Engineer, for review and approval prior to beginning work on those locations.

2. Roadway - All work zone traffic control used to install the detector loop will conform to the latest revision of the Manual on Uniform Traffic Control Devices (MUTCD). It is the responsibility of the contractor to provide flagmen and traffic control officers where needed. The work zone traffic control will not be a separate item and will be included in bid price.

3. Sidewalk – All sidewalk work will require traffic control to warn pedestrians in the area that the sidewalk is closed during times work is being performed. All work zone traffic control used to install the detector loop will conform to the latest revision of the Manual on Uniform Traffic Control Devices (MUTCD).

I. Work Time Restrictions

1. Weekdays – All work within the roadway, or that requires lane closures, will be restricted on weekdays between the hours of 9:00 am – 3:00 pm and 7:00 pm – 6:00 am. These time restrictions include all times the contractor needs to be in the roadway such as placing or removing traffic control measures.

2. Weekends – All work within the roadway, or that requires lane closures, will be restricted on weekends between the hours of midnight – 10:00 am. These time restrictions include all times the contractor needs to be in the roadway such as placing or removing traffic control measures.

3. Clothing – All personnel working for the contractor and his subcontractors are required to wear all the safety clothing required by the latest revision of Manual on Uniform Traffic Control Devices that comply with both roadway and lighting condition requirements.

4. Safety Gear – All personnel working for the contractor and his subcontractors are required to utilize all the safety gear as outlined by both Federal and State Occupational Health and Safety Organization, e.g., eye protection, footwear, hearing protection, etc.

J. Curing Time - Contractor will insure that detector loop sealant is dry prior to opening to traffic. The contractor is responsible for resolving all problems arising from exterior damage due to not allowing the sealant to dry properly before opening roadway section to traffic.

K. Storm Water Considerations

1. The contractor is responsible for providing adequate erosion and sediment control BMPs to prevent sediment from reaching the storm drain system, drainage courses, or adjacent properties. In the event the prevention measures are not effective, the contractor shall remove, not wash down, any debris, silt, or mud and restore the Right of Way, or adjacent properties to original or better condition. All penalties for sediment discharges to the storm water system incurred by contractor from either the City or TDEC shall be the sole responsibility of the contractor.

2. The successful bidder representative will be required to attend a training session put on by the City of Knoxville Storm Water Division which will outline standard practices for preventing infiltration of the storm water system by run-off water and particulates from the traffic signal detector loop installation process. Also, they will provide a list of acceptable devices to be uses for this purpose.

L. Inspection

1. Scheduling Inspector. The contractor is responsible for notifying City of Knoxville, Signal Maintenance Supervisor via email 4 working days in advance of beginning work on the detector loop package to schedule an inspector to oversee the work.

2. Inspection Sheet

a. An approved inspection sheet must be completed by the inspector for each traffic signal detector loop install before the loop work can be forwarded for final payment.

b. Approval will be based on the contractor providing work that meets the specifications outlined in this document as well as meeting the required operational specifications for the particular type of loop being installed.

3. Inspection Personnel. All traffic signal detector loop inspection personnel will have as a minimum International Municipal Signal Association, Work Zone, Traffic Signal Level II and Traffic Signal Inspector certification.

M. Pay Items

1. 730-14.01 Shielded Detector Cable (LF) – All shielded detector cable will be IMSA Specification 50-2, 2 Conductor Stranded Wire.

2. 730-14.02 Saw Slot (LF) – All saw slot payments will be based on the resources required to install the new saw slot which should include required loop sealant, backer rod, traffic control, storm water control, mobilization, project

personnel and all other items required to install the saw slot. This will also be used in calculating the saw slot installations across curb and sidewalk areas adjacent to the roadway.

3. Loop Wire (LF) – All loop wire will be a separate items which will include the wire that is required within the saw slot, wire that exits the roadway, 5 feet of trenching outside of the roadway, project personnel and all other items required to install the saw slot.

B. Pedestrian Push Buttons

Where shown on the Plans furnish and install pedestrian push buttons of substantial tamper-proof construction. They shall consist of a direct push type button and single momentary contact switch in a cast metal housing.

1. Operating voltage for pedestrian push buttons shall not exceed 24 volts.

2. Transient protection that meets and exceeds NEMA specifications.

3. Activated with less than two pounds of force.

4. Withstand severe impacts and wind, hail, and vibration have no negative effects. The button requires a normal push action to activate a pedestrian call.

5. Provide a weatherproof assembly, constructed to prevent electrical shocks under any weather condition. Superior grade pre-treatment and powder coat tested and rated NEMA 250 (6P).

Where a pedestrian push button is attached to a pole, the housing shall be shaped to fit the curvature of the standard or post to which it is attached to provide a rigid installation.

Unless otherwise specified, install the push button and sign on the crosswalk side of the pole.

C. Radar Detectors

1. General - This item shall govern the purchase of above ground radar presence detector (RPD) equivalent to the SmartSensor or approved equivalent.

2. Sensor Outputs **-** The RPD shall present real-time presence data in 10 lanes. The RPD shall support a minimum of 16 zones. The RPD shall support a minimum of 16 channels. The RPD shall support user-selectable zone to channel mapping. The RPD shall use AND logic to trigger channels when all selected zones are active. The RPD shall use OR logic to combine multiple zones to a channel output, and shall have channel output extend and delay functionality. The RPD algorithms shall mitigate detections from wrong way or cross traffic. The RPD system shall have fail-safe mode capabilities for contact closure outputs if communication is lost.

3. Detectable Area - The RPD shall be able to detect and report presence in lanes with boundaries as close as 6 ft. (1.8 m) from the base of the pole on which the RPD is mounted. The RPD shall be able to detect and report presence in lanes located within the 140 ft. (42.7 m) arc from the base of the pole on which the RPD is mounted. The RPD shall be able to detect and report presence for vehicles within a 90 degree field of view. The RPD shall be able to detect and report presence in up to 10 lanes. The RPD shall be able to detect and report presence in curved lanes and areas with islands and medians.

4. System Hardware **-** For each approach to be detected, one RPD corner radar shall be used. Each RPD shall be used with a preassembled backplate or a cabinet interface device. If a traffic cabinet preassembled backplate, it shall have the following:

a. AC/DC power conversion

b. Surge protection

c. Terminal blocks for cable landing

d. Communication connection points

e. The preassembled backplate for the RPD shall be a cabinet side mount or rack mount

If a cabinet interface device, it shall be a single device that performs the following functions:

a. Provide DC power to up to four connected sensors

b. Provide surge protection for those sensors

c. Communicate between the device and a connected computer

d. Forward detection data from detectors

The RPD may use contact closure input file cards with 2 or 4 channel capabilities.
The contact closure input file cards for the RPD shall be compatible with industry standard detector racks.

5. Maintenance **-** The RPD shall not require cleaning or adjustment to maintain performance. The RPD shall not rely on battery backup to store configuration information, thus eliminating any need for battery replacement. Once the RPD is calibrated, it shall not require recalibration to maintain performance unless the roadway configuration changes. The mean time between failures shall be 10 years, which is estimated based on manufacturing techniques.

6. Physical Properties **-** All external parts of the RPD shall be ultraviolet-resistant, corrosion-resistant, and protected from fungus growth and moisture deterioration. The RPD shall be enclosed in a Lexan EXL polycarbonate enclosure or approved equivalent. The enclosure shall be classified "f1" outdoor weatherability in accordance with UL 746C. The RPD shall be classified as watertight according to the NEMA 250 standard. The RPD enclosure shall conform to test criteria set forth in the NEMA 250 standard for type 4X enclosures. Test results shall be provided for each of the following type 4X criteria:

a. External icing (NEMA 250 clause 5.6)

b. Hose-down (NEMA 250 clause 5.7)

c. 4X corrosion protection (NEMA 250 clause 5.10)

d. Gasket (NEMA 250 clause 5.14)

The RPD shall be able to withstand a drop of up to 5 ft. (1.5 m) without compromising its functional and structural integrity. The RPD enclosure shall include a connector that meets the MIL-C-26482 specification. The MIL-C-26482 connector shall provide contacts for all data and power connections.

7. Electrical - The RPD shall consume less than 10 W. The RPD shall operate with a DC input between 10 VDC and 28 VDC. The RPD shall have onboard surge protection.

8. Communication Ports **-** The RPD shall have two communication ports, and both ports shall communicate independently and simultaneously. The RPD shall support the upload of new firmware into the RPD's non-volatile memory over either communication port. The RPD shall support the user configuration of the following:

a. Response delay

b. Push port

The communication ports shall support a 9600 bps baud rate.

9. Radar Design. The RPD shall be designed with a matrix of 16 radars. *The matrix of 16 radars enables the sensor to provide detection over a large area.* The circuitry shall be void of any manual tuning elements that could lead to human error and degraded performance over time. All transmit modulated signals shall be generated by means of digital circuitry, such as a direct digital synthesizer, that is referenced to a frequency source that is at least 50 parts per million (ppm) stable over the specified temperature range, and ages less than 6 ppm per year.

Any upconversion of a digitally generated modulated signal shall preserve the phase stability and frequency stability inherent in the digitally generated signal.

The RPD shall not rely on temperature compensation circuitry to maintain transmit frequency stability. The vertical beam width of the RPD at the 6 dB points of the two-way pattern shall be 65 degrees or greater. The antennas shall cover a 90 degree horizontal field of view. The sidelobes in the RPD two-way antenna pattern shall be -40 dB or less. Low sidelobes ensure that the performance from the antenna beam widths is fully achieved. The RPD shall transmit a signal with a bandwidth of at least 245 MHz.

The RPD shall provide at least 8 RF channels so that multiple units can be mounted in the same vicinity without causing interference between them. The RPD shall have a self-test that is used to verify correct hardware functionality. The RPD shall have a diagnostics mode to verify correct system functionality.

10. Configuration. The RPD shall have a method for automatically defining traffic lanes, stop bars and zones without requiring user intervention. This auto-configuration process shall execute on a processor internal to the RPD and shall not require an external PC or other processor. The auto-configuration process shall work under normal intersection operation and may require several cycles to complete. The auto-configuration method shall not prohibit the ability of the user to manually adjust the RPD configuration. The RPD shall support the configuring of lanes, stop bars and detection zones in 1-ft. (0.3-m) increments.

The RPD shall include graphical user interface software that displays all configured lanes and the current traffic pattern using a graphical traffic representation. The RPD shall include the ability to do counting and pulsed channels. The graphical interface shall operate on a Windows platform in the .NET framework.

The software shall support the following functionality:

a. Operate over a TCP/IP connection

b. Give the operator the ability to save/back up the RPD configuration to a file or load/restore the RPD configuration from a file

c. Allow the backed-up sensor configurations to be viewed and edited

d. Provide zone and channel actuation display

e. Provide a virtual connection option so that the software can be used without connecting to an actual sensor

f. Local or remote sensor firmware upgradability

11. Operating Conditions. The RPD shall maintain accurate performance in all weather conditions, including rain, freezing rain, snow, wind, dust, fog and changes in temperature and light, including direct light on sensor at dawn and dusk. RPD operation shall continue in rain up to 1 in. (2.5 cm) per hour.

The RPD shall be capable of continuous operation over an ambient temperature range of -40°F to 165.2°F (-40°C to 74°C). The RPD shall be capable of continuous operation over a relative humidity range of 5% to 95% (non-condensing).

12. Testing. Each RPD shall be certified by the Federal Communications Commission (FCC) under CFR 47, part 15, section 15.249 as an intentional radiator. The FCC certification shall be displayed on an external label on each RPD according to the rules set forth by the FCC. The RPD shall comply with FCC regulations under all specified operating conditions and over the expected life of the RPD. The RPD shall comply with the applicable standards stated in the NEMA TS 2-2003 standard. Third party test results shall be made available for each of the following tests:

a. Shock pulses of 10 g, 11 ms half sine wave

b. Vibration of 0.5 g up to 30 Hz

c. 300 V positive/negative pulses applied at one pulse per second at minimum and maximum DC supply voltage

d. Cold temperature storage at -49°F (-45°C) for 24 hours

e. High temperature storage at 185°F (85°C) for 24 hours

f. Low temp, low DC supply voltage at -29.2°F (-34°C) and 10.8 VDC

g. Low temp, high DC supply voltage at -29.2°F (-34°C) and 26.5 VDC

h. High temp, high DC supply voltage at 165.2°F (74°C) and 26.5 VDC

i. High temp, low DC supply voltage at 165.2°F (74°C) and 10.8 VDC

13. Manufacturing. The RPD shall be manufactured and assembled in the USA. The internal electronics of the RPD shall utilize automation for surface mount assembly, and shall comply with the requirements set forth in IPC-A-610C Class 2, Acceptability of Electronic Assemblies. The RPD shall undergo a rigorous sequence of operational testing to ensure product functionality and reliability. Testing shall include the following:

a. Functionality testing of all internal sub-assemblies
b. Unit level burn-in testing of 48 hours' duration or greater

c. Final unit functionality testing prior to shipment

Test results and all associated data for the above testing shall be provided for each purchased RPD by serial number, upon request.

14. Support. The RPD manufacturer shall provide both training and technical support services. The manufacturer-provided training shall be sufficient to fully train installers and operators in the installation, configuration, and use of the RPD to ensure accurate RPD performance. The manufacturer-provided training shall consist of comprehensive classroom labs and hands-on, in-the-field, installation and configuration training. Classroom lab training shall involve presentations outlining and defining the RPD, its functions, and the procedures for proper operation. These presentations shall be followed by hands-on labs in which trainees shall practice using the equipment to calibrate and configure a virtual RPD. To facilitate the classroom presentation and hands on labs, the manufacturer-provided training shall include the following items:

a. Knowledgeable trainer or trainers thoroughly familiar with the RPD and its processes

b. Presentation materials, including visual aids, printed manuals and other handout materials for each student

c. Computer files, including video and raw data, to facilitate the virtual configuration of the RPD

d. Laptop computers or Windows CE handheld devices with the necessary software, and all necessary cables, connectors, etc.

e. All other equipment necessary to facilitate the virtual configuration of the RPD

Field training shall provide each trainee with the hands-on opportunity to install and configure the RPD at roadside. Training shall be such that each trainee will mount and align the RPD correctly.

Manufacturer-provided technical support shall be available according to contractual agreements, and a technical representative shall be available to assist with the physical installation, alignment, and auto-configuration of each supplied RPD. Technical support shall be provided thereafter to assist with troubleshooting, maintenance, or replacement of RPDs should such services be required.

15. Documentation. RPD documentation shall include an instructional training guide and a comprehensive user guide as well as an installer quick-reference guide and a user quick-reference guide.

The RPD manufacturer shall supply the following documentation and test results at the time of the bid submittal:

a. FCC CFR 47 certification (frequency compliance)

b. CE certification

c. IED 6100-4-5 class 4 test report (surge)

16. Warranty. The RPD shall be warranted free from material and workmanship defects for a period of two years from date of shipment.

D. Video Detectors - This Section specifies the minimum requirements for Video Detection System (VDS) equipment furnished and installed. The video processor shall be capable of TS1 or TS2 operation. The video frame rate or frames per second shall be no less that 24fps. The video processor shall have an Ethernet port. Video processor shall have a USB port. Video detection cameras shall be waterproof and weather resistant. The video system should be able to be set from Windows© computer or USB mouse and video screen.

The work shall consist of providing all labor, materials, equipment, and incidentals necessary to furnish, install, and test Video Detection Equipment. This work consists of furnishing and installing video detection equipment complete and ready for service. The video detection system shall consist of power supply, hard-wired video cameras, all necessary video and power cabling with end connectors, mounting brackets, lightning protection as recommended by the manufacturer, video detection processors/extension modules capable of processing the number of camera and phase combination video sources shown on the project plans. Provide sufficient number of cameras to process vehicle presence, passage and system detection zones as shown on the project plans.

E. Magnetometers Detectors - Wireless Magnetometer Vehicle Detection System (WMVDS) Reference Specification

A wireless magnetometer vehicle detection system (WMVDS) uses one or more battery- powered wireless sensors/detectors embedded in the road surface, which communicate by radio to one or more central transceivers. Wireless magnetometer systems detect vehicle presence and provide a detection output to traffic controllers or other devices that can generate volume, occupancy, and speed data.

1. The communication link of the WMVDS between the in-road sensors and the central transceivers shall be termed the primary communication link. The communication link between the central transceivers and the traffic controller cabinet assembly shall be the secondary communication link.

2. Sensor/Detector and Communications - The sensor/detector shall be installed in a maximum 4.5 inch diameter by 3 inch deep hole. The primary communications link between the in-road sensor/detector and the transceiver shall operate at or below the U.S. 900-MHz ISM band. Only frequency bands that do not require licensing shall be used.

3. The operational distance between the sensor/detector and a central transceiver shall be a minimum of 200 feet when using an omni-directional antenna.

4. The operational distance between the sensor/detector and a central transceiver shall be a minimum of 500 feet when using a directional (or sector) antenna.

5. In-road sensors/detectors shall communicate directly with the central transceiver. Repeaters shall not be used in the primary communication link.

6. The secondary communications link between the transceiver and the traffic controller cabinet assembly shall support both wired and wireless methods.

7. A minimum of 75 detectors/sensors shall be supported by a central transceiver assembly. Multiple central transceiver assemblies shall be supported by the WMVDS.

8. A minimum of 150 detector/sensors shall be supported by the WMVDS at one site (e.g., an intersection).

9. Wireless devices shall be certified by the Federal Communications Commission (FCC). The FCC identification number shall be displayed on an external label. All devices shall operate within their FCC frequency allocation.

10. Presence detection accuracy shall be a minimum of 98% when measured over a random sample of 1,000 vehicles.

11. Controller/Equipment Interface - The WMVDS shall support a synchronous data link control (SDLC) serial communication interface to the traffic control equipment per TS2-2003, sections 8.8.1 and 8.8.2. The WMVDS shall be user-configurable to respond to one or more Bus

12. Interface Unit (BIU) addresses 9, 10, 11, and 12.

13. The WMVDS shall support a minimum of 32 solid-state detection outputs. The outputs shall meet the requirements of NEMA TS2-2003, section 6.5.2.26.

14. The WMVDS shall provide two 10/100 Ethernet communications interfaces for local and remote configuration and status monitoring.

15. System Configuration and Operation - A graphical user interface (GUI) shall be provided for local and remote configuration, and operation of the WMVDS. All programmable parameters shall be able to be set or changed using the GUI. A graphical display shall be provided, showing detector status and zone status superimposed on a graphical image.

16. Detection outputs shall be configurable as presence or pulse output. In presence mode, the output shall be active when a vehicle is in the zone of detection. In pulse mode, a detection output shall be active for between 100 and 150 milliseconds when a vehicle enters the detection zone.

17. Sensors/detectors shall be combined by logical AND and logical OR functions to create zone outputs. Zone outputs shall be able to be mapped to detection outputs for interface to a traffic controller.

18. Environmental Requirements:

a. The WMVDS shall operate over an input voltage range of 89 to 135 VAC.

b. The in-road sensor/detector shall operate over a temperature range of -40°C to 85°C.

c. The other components of the WMVDS shall meet the environmental requirements of NEMA TS2-2003, sections 2.1.5 through 2.1.10.

COORDINATION

730.30 Coordination - The following are the minimum design and operating requirements for all types of local coordinating units. The general design requirements apply to master coordinating units and secondary coordinating units; as a separate unit or internal to the controller; both dial electro-mechanical, and digital full solid state. Local coordinating units provided for an interconnected signal system shall be completely compatible with the master controller and all local controllers in that system. Use the coordinating units described herein in conjunction with solid state traffic actuated signal controllers and traffic adjusted master controllers. The coordinators shall inhibit the external extension limit in the local controllers and provide external maximum control. Background cycle lengths, splits, system offsets, and other coordination functions as required shall be called in by a master controller or coordinator. These functions may also be called in by local or master override or time switches. Furnish coordinating units capable of at least the following:

1. Three background time cycles.

2. Three splits per cycle.

3. Three offsets per cycle.

4. Multiple and adjustable permissive periods for yielding to non-coordinated phases.

5. Force off capability for all non-coordinated phases.

6. Capability of generating as a minimum cycle lengths of 50, 60, 70, 80, 90, 100, and 120 seconds.

7. Master intersection control and supervision of other coordinating units as required.

8. Free operation when called for by the system master, time switch, or manual override.

It shall be possible to set offset splits and all synchronization functions from the front of the coordinating unit, and to make these settings in at least 1% steps to any percentage of the associated cycle length. Absence or conflict of offset or cycle information on the inter-connect shall place the coordinating unit in cycle number 1 (average offset) or a preset standby cycle.

730.31 Time-Based Coordination Units - This Subsection covers traffic signal system time-based coordination units of solid state design. Time-based coordination units are used to control the timed relationship between intersections to maintain a system interconnect plan without the use of interconnect cable.

A. Background Cycle - Provide time-based coordination units with at least three independently programmable background cycles. The background cycles shall be in fixed increments, not exceeding 1 second.

B. Offsets - Provide time-based coordination units with at least three independently programmable offsets per background cycle.

C. Splits - Each split shall have at least six independently programmable force-off points, one for each non-coordinated phase. Provide two splits per background cycle.

D. Timing Requirements - Provide color-or function-coded time controls for programming the background cycle, offsets, force-off points, and permissive periods. Timing of all functions shall be digital, with an accuracy of ±100 milliseconds from the programmed value. Ensure that the minimum timing ranges and maximum increments of adjustment for the various timing function meet Table 730.31-1.

Table 730.31-1: Timing Requirements

Function	Minimum Timing Range	Maximum Increment of Adjustment
Background Cycle	30 to 255 seconds	1 second
Offset	0 to 255 seconds	1 second
Force-off Points and Permissive Periods	0 to 99% of cycle	1% of cycle

The clock circuit of time-based coordination units may use either the 60-hertz AC power source or a crystal oscillator as the timing reference. If a crystal oscillator is used as the timing reference, the frequency tolerance of the clock circuit shall be ±0.005%. The clock circuit of the time - based coordination unit shall allow for setting to the nearest second.

Provide the time-based coordination unit with a programmable feature that automatically changes from standard time to daylight savings time and vice versa.

E. Battery Power - Provide time - based coordination units with a battery to power the clock circuit and memory for a minimum of 100 hours when the 120 volt AC power source is disconnected.

F. Manual Override - Time - based coordination units shall be designed so that the programmed time of day function can be manually overridden to select a different function, such as cycle, offset, or splits.

G. Indicator Requirements - Time - based coordination units shall provide the following minimum indications:

1. Time of day (hours, minutes, and seconds)
2. Day of week or calendar date
3. Outputs controlled by day program
4. Cycle count - indicates time in background cycle
5. Day program in effect
6. Week program in effect
7. Battery status

H. Construction - Time based coordination units shall be a built-in component to the controller.

I. Data Transfer - Time based coordination units shall provide transferring of all programmed data from unit to unit by using a data transfer cable. Supply a cable with each unit.

TRAFFIC SIGNAL SUPPORTS

730.32 Cantilever Signal Supports - This Subsection applies to the manufacture of steel poles and mast arms for the support of traffic signals. The height of poles, shaft dimensions and wall thickness shall meet the design requirements and mounting

height of traffic signals as set forth in these Specifications and shown on the Plans. The Plans indicate bracket arm lengths. Furnish poles consisting of a straight or uniformly tapered shaft, cylindrical or octagonal in cross-section, having a base welded to the lower end and complete with anchor bolts. All castings shall be clean and smooth with all details well defined and true to pattern. Steel castings shall conform to ASTM A27, Grade 65-35. Gray iron castings shall conform to ASTM A126, Class A.

All mast arms shall be compatible with the poles in material, strength, shape, and size.

A. Anchor Base

Secure an anchor base of one-piece cast steel or steel plate of adequate strength, shape, and size to the lower end of the shaft. Place the base so as to telescope the shaft, and weld at the top and bottom faces with continuous fillet welds so that the welded connection develops the full strength of the adjacent shaft section to resist bending action. Provide each base with a minimum of four holes to receive the anchor bolts. Provide cast steel bases with removable cast iron covers for anchor bolts and tapped holes for attaching covers with hex head cap screws.

Provide a welded frame hand-hole, 5 x 8 inches minimum and located 1 foot above the base. Weld a 1/2-inch 13 UNC grounding nut to the inside of the pole at a point readily accessible for wiring.

B. Shaft

Fabricate shafts from the best, hot-rolled basic open hearth steel. The shaft shall have only one longitudinal electrically welded joint and may have electrically welded intermediate transverse full penetration circumferential joints, at intervals of not less than 10 feet. The shaft shall be longitudinally cold-rolled to flatten the weld and increase the physical characteristics so that the metal will have a minimum yield strength of 48,000 pounds per square inch. Where transverse full penetration circumferential welds are used, the shaft fabricator shall furnish to the Engineer certification that: (1) all such welds have been radiographed and ultrasonically tested by an independent testing laboratory using a qualified Nondestructive Testing (NDT) technician and (2) the NDT equipment has been calibrated annually.

Fit the shaft with a removable pole cap, a J-hook wire support welded inside near the top, and a flange plate assembly to match that welded to the butt end of the mast arm.

C. Mast Arms

Provide mast arms fabricated and certified in the same manner as the upright shafts and that have the same physical characteristics. The mast arms shall meet the design requirements necessary to support rigidly mounted traffic signals as shown on the Plans. All arms shall include a removable cap at the tip, grommeted wire outlets, and signal hanger assemblies of the type and number shown on the Plans, and a flange plate welded to the butt end to provide a rigid connection to the mast. The assembly shall be constructed so that all wiring can be concealed internally.

Connect mast arms to the upright pole at a height necessary to provide a minimum clearance of 16 feet 6 inches and a maximum clearance of 19 feet under the traffic signal heads. Install separate signal heads to provide the same clearance.

D. Finish

Galvanize steel poles, mast arms, and hardware in accordance with ASTM A123. Galvanize all steel and cast iron components, hardware, and threaded fasteners, except anchor bolts, after fabrication in accordance with ASTM A123, or A153 or A385, as applicable.

730.33 Steel Strain Poles - Provide steel strain poles consisting of a uniformly tapered or equivalent upright shaft fitted with a removable pole top, J-hook wire support and 45-degree wire inlet near the top, a span wire clamp, a 5 x 8 inch hand-hole

with reinforced frame and cover, bent anchor bolts, and all other accessories needed to make a complete installation. The pole and its entire component parts shall be designed to support tethered traffic signals of the type and number shown on the Plans, suspended from a span wire assembly. Fabricate and certify the poles as specified for the upright shafts in **730.32**.

Determine the shaft length required to meet field conditions and vertical clearances of signal heads over the roadway. The signal head clearance shall be a minimum of 16 feet 6 inches and a maximum of 19 feet. Fasten the span wire no closer than 1 foot 6 inches from the top of the pole.

Unless otherwise specified, provide all strain pole traffic signal supports with a one-piece anchor type base, fabricated from drop forged or cast steel of sufficient cross-section to fully develop the ultimate strength of the poles. Fasten the base to the pole with a welded connection that develops the full strength of the pole. Provide the base with a minimum of four holes of sufficient size to accommodate the proper size anchor bolts that are capable of resisting at yield strength stress, the bending moment of the shaft at its yield strength stress. Provide removable cast iron covers for the anchor bolts.

The shaft shall be fabricated from material providing minimum yield strength of 48,000 pounds per square inch after fabrication.

Galvanize the steel poles and hardware in accordance with ASTM A123.

Galvanize all steel and cast iron components, hardware, and threaded fasteners, except anchor bolts, after fabrication in accordance with ASTM A123, or A153 or A385, as applicable.

730.34 Pedestal Support Signal Poles - Provide pedestal poles consisting of one upright pole with suitable base and other accessories or hardware as required making a complete installation. All poles shall be made of one continuous piece from top of base connection for the entire height of the pole. The cross-section shall be either cylindrical or octagonal and may or may not be uniformly tapered from butt to tip. The cross-section at the tip shall have a 4-1/2 inch outside diameter.

A. Type "A" Pedestal (Aluminum)

Pedestals shall be of uniform octagonal or cylindrical cross-section of the tubular tapered type fabricated of one full length sheet.

Bases shall be octagonal or square in shape, of the ornamental type fabricated of cast material. Provide a hand-hole in each base.

Caps shall be of the nipple or tenon type mounting fabricated of cast material.

Furnish bases with four steel anchor bolts of sufficient size and length to securely anchor the base to the concrete footing. Weld the shaft to the cast metal base. Refer to the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (current edition).

Type A pedestal shaft shall be fabricated from aluminum tubing 6063-T4 heat treated to T-6 temper after fabrication, and meeting ASTM B221.

Type A anchor base shall be made of sand-cast aluminum alloy 356-T6 meeting ASTM B26 - SF 70A-T5 specifications.

B. Type "B" Pedestal (Steel)

Pedestals shall be fabricated from a 4-1/2 inch (outside diameter) seamless steel pipe.

Bases shall be octagonal in shape of the ornamental type fabricated of cast or malleable iron and shall have minimum height of 12 inches. The top opening of the base shall be threaded to receive the shaft. Provide a hand-hole in each base.

Furnish bases with four steel anchor bolts of sufficient length to securely anchor the base to the concrete footing.

730.35 Wooden Pole Signal Supports

A. General

Provide wooden poles of the class and length shown on the Plans and that meet **917.11**. Set poles to the depth shown on the Plans, and fit them with all the necessary hardware to make the installation complete.

The signal head clearance shall be 16 feet 6 inches minimum and 19 feet maximum. Fasten the span wire at least 2 feet below the top of the pole.

B. Guying Components

Guy clamps shall be steel, 3-bolt type, 6 inches in length, and of the proper strand size to fit the wire used. The clamp bolts shall have upset shoulders fitting into the clamp plate. Substitution of the cable grip is subject to the Engineer's approval.

Attach guy wire to the pole with a 5/8-inch diameter x 12-inch length single strand angle-type eye bolt with 2 x 2 inch square cut washers, lock washer, and square nut.

Instead of the eye bolt specified above, an angle single strand eye of drop forged steel may be used, fastened on threaded end of span wire eye bolt.

Sidewalk guy fittings shall consist of 2-inch inside diameter standard galvanized steel pipe of required length with malleable iron pole plate and guy clamp. Fasten the pole plate to the pole with a 3/8-inch thru bolt and 1/2-inch lag screws.

All guying components and hardware shall be galvanized in accordance with ASTM A123 or A153.

Anchors for guys shall be of the pressed steel four-way expanding fluke type or of the steel or malleable iron sliding plate type. The minimum unexpanded diameter shall be 8 inches, and the minimum expanded area shall be 110 square feet. Coat anchors with a black asphaltic paint.

Guy anchor rods shall be drop-forged steel, 3/4-inch diameter and 7-foot minimum length, threaded, of the single thimble eye type, with a square anchor bolt nut.

730.36 Pole Location

Install all signal support poles at the locations shown on the Plans or where directed by the Engineer.

COMPENSATION

730.37 Method of Measurement - Measurement for traffic signals will be on a per item basis for each item to be furnished and installed, as specified herein and shown on the Plans. With regard to items for signal head assemblies, each item to be furnished, installed, or both furnished and installed shall be distinguished with a code number as follows:

1. The first digit is the number of faces per assembly.

2. The second digit will indicate the number of 12-inch lenses per assembly (including arrow lenses).

3. The third digit is the quantity of 8-inch lenses per assembly.

4. The letter "A" indicates an arrow lens and the digit following the "A" indicates the number of 12-inch arrow lenses per assembly.
5. The letter "H" or "V" indicates the arrangement of arrow signal lenses to be horizontal or vertical with respect to solid ball indications.

EXAMPLE: 1 5 0 A 2 H
Digits indicate the following:

1 = one face
5 = five 12-inch lenses
0 = zero 8-inch lenses
A2 = two 12-inch arrow lenses
H = Arrow lenses placed horizontally with respect to circular indications

A. Removal of Signal Equipment

The Department will measure items of equipment or material designated or required for removal on a per each intersection basis. Removal and salvage of all signal heads, poles, control equipment, cabinets, span wire, cable, and similar features to be performed at an intersection shall be included as a unit cost per each intersection. This includes the cost of stockpiling salvable equipment for pick-up by the appropriate agency, as noted in the Plans.

B. Signal Head Assembly (includes Pedestrian Signal Heads)

The Department will measure signal heads of the type shown on the Plans by the individual assembly complete in place, per each. This item shall include the signal heads, terminals, lamps, attachment hardware, cable connection, and testing.

C. Pull Box

The Department will measure each pull box of the type required as one complete unit, installed, per each. This item includes the pull box, excavation, backfilling, crushed stone base, and other incidental items as called for in the Plans or Standard Drawings.

D. Electrical Service Connection

The Department will measure Electrical Service Connections on a per each signal installation basis. This item includes the electrical service supplied to the weather head by the local utility, all necessary materials and labor for connection of the electrical service from the controller to the weather head, the wiring of the controller and detectors, and all incidentals necessary to render a complete and operable system.

E. Signal Cable

The Department will measure the length of Signal Cable of each size (number of conductors) installed in linear feet to the nearest foot from point to point along the routing for each cable. The Department will make horizontal measurements by center to center measurement from:

1. Pole to pole

2. Pole to signal head (when terminating in a signal head)

3. Pull box to pull box

4. Pull box to pole

5. Pull box to pole-mounted or base-mounted controller

For cable inside mast arms, the Department will measure from center of vertical support to signal head where cable terminates. The Department will make vertical measurement by one of the following:

1. For cable inside poles or conduit risers, the distance from ground level to the point of attachment of the span wire.

2. For cable inside mast arm supports, the distance from ground level to the mast arm connection.
3. For cable to pole-mounted controller,
    a. From ground level to bottom of controller.
    b. From bottom of controller to point of attachment of span wire.

4. For cable to pole-mounted signal head or pushbutton,
    a. From ground level to bottom of signal head or pushbutton
    b. From bottom of signal head or pushbutton to point of attachment of span wire.

The Department will make no additional allowance for slack length, length inside equipment or supports (except as noted), length for the required 360-degree drip loop, and similar instances requiring additional length of cable.

F. Span Wire

The Department will measure Span Wire Assembly, Tether Wire Assembly, and Messenger Cable by type in linear feet to the nearest foot. The measurement will be made from center to center of poles. These items include attachment hardware, strain insulators, and other hardware shown in the Plans as part of the assembly. The Department will make no additional allowance for slack length and other instances requiring additional length of wire.

G. Steel Conduit Riser Assembly

The Department will measure conduit riser assemblies per each for each size conduit riser installed on the outside of a pole, as shown on the Plans. This item includes conduit, weatherhead, condulet, fittings, nuts, washers, banding, clamps, grounding, and other items necessary for installation.

H. Conduit

The Department will measure conduit in linear feet to the nearest foot for each size and type of conduit installed.
The Department will measure underground conduit along the conduit by one of the following:

1. From the face of curb to the center of a pull box, pole or controller foundation,

2. From center to center of pull boxes,

3. From center to center of a pull box and a pole or controller foundation, or730.37

4. From center to center of pole foundations or pole foundation and controller foundation.

The Department will add:

1. 1 foot to the above measurements for each entry to a pull box or pole foundation and each exit of a pull box or pole foundation.

2. 3 feet to the measurement for each capped extra entry (conduit stub) or exit to a pull box or pole foundation installed, as shown on the Plans.

3. 3 feet to the measurement for each connection between underground conduit and above ground riser.

4. 3 feet to the measurement for each entry or exit to a foundation for a base-mounted controller.

This item includes trenching, backfilling, sealing, capping, fittings, bushings, banding, grounding, and other accessories and hardware required for installation of the conduit system.

I. Vehicle Loop Detector (Amplifier) (See 730.29.A)

The Department will measure vehicle detector loop amplifier per each unit, including the cable and associated hardware necessary to electrically connect the amplifier to the controller and loop lead in.

The Department will measure two and four channel card rack type amplifiers per each unit, including the cable, card rack(s), and associated hardware necessary to electrically connect the amplifiers to the controller and loop lead-ins.

J. Shielded Detector Cable (See 730.29.A)

The Department will measure the two-conductor shielded detector cable installed between the controller cabinet and the loop detector wires in linear feet to the nearest foot. The Department will make horizontal measurements (overhead and underground) by one of the following:

1. From center to center of pull boxes,

2. From center to center of pull box and pole,

3. From center to center of poles, or

4. From center to center of pull box or pole and controller foundation.

The Department will make vertical measurements by one of the following:

1. From ground level to the point of attachment of span wire, inside pole or conduit riser,

2. From the bottom of controller cabinet to the point of attachment of span wire, or

3. From ground level to the bottom of controller.

The Department will make no additional allowance for slack length, length inside equipment or supports (except as noted), splices, and similar instances requiring additional length of cable.

K. Saw Slot (See 730.29.A)

The Department will measure the length of saw slot for installation of detection loop and lead wiring in linear feet to the nearest foot. Measurement for detection loops in the traffic lanes will be made based on the loop size shown on the Plans (the nominal length plus the nominal width) times 2. The Department will make no additional allowance for saw overruns to obtain full depth of saw slot or diagonal cuts to prevent sharp bends in the loop wire. The Department will measure saw slot for detection loop leads from the conduit entry at the face of curb or edge of pavement and along the route of the lead-in to the detection loop.

This item includes backing rods, or polyethylene foam sealant, loop sealant, and all other incidentals necessary to render a complete and operable system.

L. Loop Wire (See 730.29.A)

The Department will measure the length of loop wire for installation of detection loops and lead-ins in linear feet to the nearest foot. Measurement will be made from the pull box or pole to the detection loop, around the loop the required number of turns and back to the pull box, pole, or point of splice. The Department will make no additional allowance for slack length, length inside equipment or supports, splices, and similar instances requiring additional length of wire.

This item includes electrical connections, testing, and all other incidentals necessary to render a complete and operable system.

M. Controller

The Department will measure controllers as one complete unit, installed, per each. This item includes all auxiliary equipment shown the Plans to provide signalization control as shown on the Plans, and all hardware, including the cabinet (and cabinet foundation, if base mounted), necessary for installation.

N. Wood Pole

The Department will measure Wood Poles, of the type and size shown on the Plans, per each, installed.

O. Guying Device

The Department will measure Guying Devices, of the type shown on the Plans, per each, installed. This item includes the guy wire, anchor, clamps, and all other components shown on the Plans necessary for installation.

P. Steel Strain Pole

The Department will measure Steel Strain Poles of the type and size shown on the Plans, per each, installed. This item includes the pole, foundation, anchor bolts, grounding, and all other hardware shown on the Plans necessary for a complete installation.

Q. Cantilever Signal Support

The Department will measure Cantilever Signal Supports, of the type and size shown on the Plans, per each, installed. This item includes the vertical pole shaft, mast arm, foundation, anchor bolts, grounding, and all other hardware shown on the Plans necessary for a complete installation.

R. Service Cable

The Department will measure two conductor power service cable, of the type and size shown on the Plans, in linear feet to the nearest foot, installed. Horizontal runs will be measured center to center of poles. Vertical runs will be measured from the ground to the weatherhead inside a pole or conduit riser, or from the ground to the bottom of the controller, or from the bottom of the controller to the weatherhead. This item includes all necessary attachment hardware. The Department will make no additional allowance for slack length or other instances requiring additional length of cable.

S. Pedestrian Pushbutton with Sign

The Department will measure Pedestrian Pushbutton with Sign as one complete unit, in place, per each. This item includes the pushbutton, sign, mounting hardware, wiring of pushbutton, testing, and all other incidentals necessary for a complete installation.

T. Pedestrian Signal Display with Pushbutton and Sign

The Department will measure Pedestrian Signal Display with Pushbutton and Sign as one complete unit, in place, per each. This item includes the signal heads, terminals, lamps, cable connections, pushbutton, sign, all attachment hardware, testing, and other incidentals necessary for a complete installation.

730.38 Basis of Payment

The Department will pay for accepted quantities, complete in place, at the contract prices as follows:

Item	*Pay Unit*
Traffic Signal	Lump Sum
Removal of Signal Equipment	Each
Signal Head Assembly (Description)	Each
Install Pull Box (Description)	Each
Electrical Service Connection	Each

Install Conduit (Description)	Linear Feet
Signal Cable – (Description)	Linear Feet
Span Wire Assembly (pounds min. break strength)	Linear Feet
Tether Wire Assembly – __" Diameter	Linear Feet
Messenger Cable – __" Diameter	Linear Feet
Riser Assembly (Description) Each Conduit __" Diameter (Type)	Linear Feet
Vehicle Detector (Description)	Each
Shielded Detector Cable	Linear Feet
Saw Slot Linear	Feet
Loop Wire Linear	Feet
Controller (Description)	Each
Wood Pole (Description)	Each
Guying Device (Description)	Each
Steel Strain Pole (Description)	Each
Cantilever Signal Support (Description)	Each
Service Cable	Linear Feet
Pedestrian Pushbutton with Sign	Each
Pedestrian Signal Display with Pushbutton and Sign	Each

The unit price to be paid includes the cost of furnishing and installing, complete in place, each of the various types of equipment required by the Summary of Quantities shown on the Plans. Total payment is full compensation for all materials, labor, equipment, and incidentals necessary to produce a completely operative and finished installation of a traffic signal or traffic signal system as shown on the Plans and as specified herein, including restoration of pavements, sidewalks, and appurtenances damaged or destroyed during construction and tests. All additional materials and labor not specifically shown or called for, which are necessary to complete the traffic signal installation or traffic signal system described, will be considered incidental to the system and no additional allowance will be made.

FIBER OPTIC HYBRID COMMUNICATIONS SYSTEM ADDENDUM

A. SCOPE

This work shall consist of furnishing, installing, and testing fiber optic cable in accordance with these Special Provisions and as shown on the Plans. The work includes all materials associated with the installation of fiber optic cable including distribution equipment, splicing, and fiber optic jumper cables.

B. GENERAL

Fiber optic cable, jumper cable, and distribution equipment shall be fabricated by a certified ISO 9001 manufacturer. All fiber optic cable provided under this Contract shall be from the same manufacturer utilizing identical specifications. All fiber optic cables shall be dielectric.

C. MATERIALS

1. Fiber optic cable shall be all-dielectric cable and shall contain single mode and/or multi mode optical fibers as specified, loose tube, filled with a water–blocking material, and shall be suitable for overhead installation or in underground conduit and field cabinets. Fiber optic cable shall comply with the requirements of RUS 1755.900 except as modified herein. All cable manufacturers shall comply with RUS Bulletin 1753F-601 and be currently ISO 9001 certified. Loose tube cable shall be designed with 20 foot buffer tube storage compatibility for midspan entry applications.

a. Fiber Optic Cable Life Expectancy - The cable design shall be rated to achieve a life expectancy of 20 years when installed to manufacturer's specifications.

b. Buffer Tubes - Optical fibers shall be contained inside a loose buffer tube. Each buffer tube shall contain 6 fibers for cable sizes less than or equal to 36, larger cable sizes shall contain buffer tubes of 12 fibers as shown on the Plans. The buffer tubes shall allow free movement of the fibers without fiber damage during installation or normal operation, including expansion and contraction of the buffer tubes. The diameter of all buffer tubes in a cable shall match.

Each buffer tube shall be filled with a non–hygroscopic, non–nutritive to fungus, electrically non–conductive, homogenous gel. The gel shall be free from dirt and foreign matter. The gel shall be readily removable with conventional nontoxic solvents.

Distinguish each fiber and buffer tube from others by means of color coding that meets EIA/TIA-598.

c. Stranding - Buffer tubes shall be stranded around a central member using the reverse oscillation, or "S–Z", stranding process. When less than 5 buffer tubes are required in the loose tube cable, filler rods shall be included in the cable core to lend symmetry to the cable cross–section. The diameter of the filler rods shall match the diameter of the buffer tubes.

d. Central Strength Member - The cable shall have a central member designed to prevent buckling of the cable. Central member shall consist of a dielectric glass reinforced plastic rod.

e. Cable Core - The cable core interstices shall be filled with a non–nutritive to fungus, electrically non–conductive, water–blocking material such as water–swellable tape that is dry to the touch. The water blocking material shall be free from dirt and foreign matter.

f. Cable Rip Cord - The cable shall contain at least one (1) ripcord under the sheath for easy sheath removal.

g. Tensile Strength Members - The cable shall have tensile strength members that minimize cable elongation due to installation forces and temperature. The cable shall withstand a 607lb tensile load applied per EIA–455–33. The change in attenuation shall not exceed 0.2dB during loading and 0.1dB after loading. The cable shall be rated for an installed tensile service load of 200lb or more.

h. Cable Jacket - The cable jacket shall be dielectric (with no armoring) and consist of either high density polyethylene (HDPE) or medium density polyethylene (MDPE). Jacketing material shall be applied directly over the tensile strength members and water–blocking material. Jacket shall be free of holes, splits, and blisters, and containing no metal elements.

i. Cable Markings - The markings that are provided on the fiber optic cable jacket shall include cable length markings, number and type (MMFO or SMFO) of strands, and the year of manufacture. In addition, the cable shall be tagged with a label identifying the cable as belonging to “City of Knoxville”. See tagging instructions in section D.4.

j. Environmental - The fiber optic cable shall be capable of withstanding the following conditions without damage or decrease in function:

(1) Cable freezing per EIA/TIA–455–98–A.

(2) Total immersion in water with natural mineral and salt contents.

(3) Salt spray or salt water immersion for extended periods.

(4) Wasp and hornet spray.

k. Multi Mode Optical Fiber Physical and Performance Requirements - All multi mode optical fiber in the cable shall, as a minimum, comply with the following requirements:

(1) Cladding diameter: 125 $\pm$ 2.0 μm
(2) Core diameter: 50 $\pm$ 2.0 μm
(3) Cladding non–circularity: $\leq$ 0.7 percent
(4) Maximum attenuation: $\leq$ 3.0 dB/km at 850 nm; $\leq$ 1.0 dB/km at 1300 nm
(5) Microbend attenuation (100 turns, 75 mm dia.): $\leq$ 0.05 dB at 850 nm and 1300 nm
(6) Attenuation uniformity: no point discontinuity greater than 0.1 dB at 1300 nm
(7) Maximum chromatic dispersion: $\leq$ 0.11 ps/(nm x km) from 1295 nm to 1310 nm and $\leq$ 0.001 ps/(nm x km) at 1310 nm to1340 nm
(8) Fiber polarization mode dispersion: $\leq$ 0.1 ps/(km)1/2
(9) Fiber coating: dual layered, UV cured acrylate applied by the fiber manufacturer that can be stripped mechanically or chemically without damaging fiber
(10) Coating diameter: 245 μm $\pm$ 10 μm
(11) Minimum storage temperature range: –40°F to +158°F
(12) Minimum operating temperature range: –40°F to +158°F

l. Single Mode Optical Fiber Physical and Performance Requirements - All single mode optical fiber in the cable shall, as a minimum, comply with the following requirements:

(1) Cladding diameter: 125 $\pm$ 1.0 μm
(2) Core–to–cladding offset: $\leq$ 0.8 μm
(3)Cladding non–circularity: $\leq$ 1.0 percent
(4) Maximum attenuation: $\leq$0.35 dB/km at 1310 nm; $\leq$ 0.25 dB/km at 1550 nm
(5) Microbend attenuation (100 turns, 25 mm dia.): $\leq$ 0.05 dB at 1310 nm and 1550 nm
(6) Attenuation uniformity: no point discontinuity greater than 0.1 dB at either 1310 nm or 1550 nm
(7) Maximum chromatic dispersion: $\leq$ 3.5 ps/(nm x km) from 1285 nm to 1330 nm; $\leq$ 18.0 ps/(nm x km) from 1530 nm to 1565 nm
(8) Fiber polarization mode dispersion: $\leq$ 0.2 ps/(km)1/2
(9) Fiber coating: dual layered, UV cured acrylate applied by the fiber manufacturer that can be stripped mechanically or chemically without damaging fiber
(10) Coating diameter: 245 μm $\pm$ 10 μm
(11) Minimum storage temperature range: –40°F to +158°F
(12) Minimum operating temperature range: –40°F to +158°F

m. Single Mode Fiber Optic Drop Cable - Single mode fiber optic drop cables shall be installed from underground or aerial splice enclosures into termination units located in cabinet enclosures. Cable shall contain 6 strands of single mode fiber optic cable. Fiber ends at termination units shall be made with ST type connectors.

n. Multi Mode Fiber Optic Drop Cable – Multi mode fiber optic drop cables shall be installed from underground or aerial splice enclosures into termination units located in cabinet enclosures. Cables shall

contain 6 strands of multi mode fiber optic cable. Fiber ends at termination units shall be made with ST type connectors.

o. Single Mode Fiber Optic Interconnect Cable - Single mode fiber optic interconnect cables shall be installed in both underground and aerial environments. Cable shall contain 48 strands of single mode fiber optic cable. Fiber ends at termination units shall be made with ST type connectors.

p. Single Mode/Multi Mode Fiber Optic Interconnect Cable - Hybrid single mode/multi mode fiber optic interconnect cables shall be installed in both underground and aerial environments. Cables shall contain 48 strands of single mode and 12 strands of multi mode fiber optic cable for a total of 60 fiber strands. The multi mode fiber optic 12 strand bundle shall be sheathed in a white buffer tube. Fiber ends at termination units shall be made with ST type connectors. Contractors will be permitted the option to provide separate multi-mode and single-mode cables in lieu of a single hybrid combination cable. If the multiple cable option is accepted, the combined two-cable installation will be paid at the unit price provided for the hybrid single mode/multi mode fiber cable.

q. Connectors **-** Connectors shall be ST type throughout the fiber optic installation at the field cabinets. The measured attenuation of the connector (inclusive of coupler and mated test connector) shall not exceed an average of 0.3 dB for all connectors provided. Any connector found in excess of 0.5 dB will be rejected. Reflectance shall be less than –40 dB, from 14°F to 140°F (–10°C to +60°C).

The connector shall be able to withstand an axial pull of 25lb with no physical damage to the connector and no permanent optical degradation more than 0.3 dB. Connectors shall be pre–wired by the manufacturer.

2. SPLICE ENCLOSURE

Fiber optic splice enclosures shall consist of a single housing that are re-enterable using a mechanical dome-to-base seal with a flash test valve, and are impervious to the entry of foreign material (water, dust, etc.). Ensure enclosures are manufactured in such a manner to be suitable for aerial, pedestal, buried junction box and manhole installation. Provide enclosures with a minimum of one over-sized oval port that will accept two cables with a minimum of four round ports (for single cables) that will accommodate all cables entering enclosure. Provide heat shrink cable shields with enclosure to ensure weather tight seal where each cable enters enclosure. Within enclosures, provide enough hinged mountable splice trays to store the number of splices required, plus the capacity to house 12 additional splices. Provide a fiber containment basket for storage of loose buffer tubes expressed through the enclosure. Ensure enclosures allow sufficient space to prevent microbending of the buffer tubes when coiled. Provide splice trays that hold, protect, and organize optical fibers, and that secure fibers inside the splice tray. Provide splice trays that are dielectric.

3. FIBER OPTIC STORAGE BRACKET

Furnish fiber-optic storage brackets (snowshoes) that are non-conductive and resistant to fading when exposed to UV sources and changes in weather. Ensure snowshoes have a captive design such that fiber-optic cable will be supported when installed in the rack and fiber-optic cable's minimum bending radius will not be violated. Provide stainless steel attachment hardware for securing snowshoes to messenger cable or for securing snowshoes to manhole walls as indicated on the plans. Provide black UV resistant tie-wraps for securing fiber-optic cable to snowshoe. Ensure that snowshoes are stackable so that multiple cable configurations are possible.

4. FIBER TERMINATION PANEL

Furnish and install fiber termination panels in cabinets as shown on plans. Panels shall be a single housing, low profile no larger than 8"h x 8"w x3"d and capable of being wall mounted. Fiber termination panel shall be provided with 12 ST fiber optic coupler connectors. Couplers shall have an attenuation of less than 0.3 dB. Housing shall be high-impact UL rated for a minimum of 94V. Couplers not in use shall be properly caped. Labels shall be applied indicating fiber number and MM or SM.

D. CONSTRUCTION REQUIREMENTS

1**.** CABLE LENGTH AND SHIPPING REQUIREMENTS - Cable shall be furnished in one (1) continuous length per reel, and shall be free from optical splices. A minimum length of 6 feet. on each end of the cable shall be accessible for testing. Information accompanying the reel shall include the following either stenciled or lettered on the reel, or provided on a weatherproof tag firmly attached to the reel:

a. Factory order number
b. Job number
c. Ship date
d. Manufacturer's cable code
e. Type of cable (single mode, outdoor, indoor)
f. Beginning and ending length markings
g. Measured length and attenuation

2. INSTALLATION OF FIBER OPTIC CABLE - The fiber optic cable shall be installed in conduit, cabinets, pullboxes, and aerially as shown in the Plans and in accordance with manufacturer's installation techniques and procedures. The Contractor shall furnish and install all jumper cables and termination equipment that are functionally necessary to connect fiber optic cable to the required end equipment.

The Contractor shall install fiber optic cable as a continuous run and splice only at locations shown on the plans. The Contractor shall determine the length of fiber optic cable necessary to reach from one end of the cable run to the other end of the cable run, including cable slack requirements. The Contractor shall label all fiber optic cables at each end of the cable run, at the point the cable enters a cabinet and at the point the cable exits the cabinet for mid–cable access locations, and in all pull boxes.

The cable shall not be pulled along the ground or over or around obstructions. Optical cable shall not be pulled over edges or corners, over or around obstructions, or through unnecessary curves or bends. Bend radius criteria of 10 times the cable diameter under no stress and twenty times cable diameter under stress shall not be exceeded. Manufacturer approved pulling grips, cable guides, feeders, shoes, and bushings shall be used to prevent damage to the cable during installation.

When cable is removed from the reel prior to installation, it shall be placed in a “figure–eight” configuration to prevent kinking or twisting. Care shall be taken to relieve pressure on the cable at the crossover by placing cardboard shims (or equivalent method) or by creating additional “figure–eights”.

Before installing any fiber optic cable in conduit, the Contractor shall provide the Engineer the cable manufacturer's recommended and maximum pulling tensions. Included with these pulling tensions shall be a list of the cable manufacturer's approved pulling lubricants. Lubricants shall be used in quantities and in accordance with the procedures recommended by the lubricant manufacturer.

Before installing any fiber optic cable in conduit, all cable pulling equipment shall be approved by the Engineer and the cable manufacturer. The cable pulling equipment shall come with a meter to display pulling tension and a mechanism to ensure that the maximum allowable pulling tension cannot be exceeded at any time during installation. The Contractor shall furnish attachment hardware, installation guides, and other necessary equipment, not specifically listed herein, as necessary to install the fiber optic cable.

Fiber optic cable in pull boxes shall be appropriately looped and tied to the side wall. Fiber optic cable shall be routed to the field cabinets as shown on the plans. The existing foundation may be either a pole foundation, or a cabinet foundation. The conduit shall be paid for separately.

3. SPLICING METHODS - All splices shall be accomplished by means of the fusion splice technique and shall not induce more than 0.1 dB attenuation for each splice, and 0.07 dB averages for all splices. Splices found to exceed 0.1 dB attenuation shall be re–spliced, at no additional cost to the City, by the Contractor until this requirement is met.

Each splice shall be packaged in a protective sleeve or housing and secured in splice trays located in the fiber optic splice unit or integrated fiber optic splice and termination unit. Bare fibers shall be completely re–coated with a protective heat–shrink coating prior to placement in a sleeve or housing. Heat shrink coating type shall be as recommended by the manufacturer of the fiber optic cable. The heat–shrink coating shall be approved for use by the fiber optic cable manufacturer and installed in such a manner as to protect the fiber from scoring, dirt accumulation, moisture intrusion, and micro–bending.

The Contractor shall only splice fibers at locations that are identified in the Plans. At these splicing locations, the Contractor shall splice all the fibers that are identified on the associated Splice Diagrams in the Plans. Splice Diagrams in the Plans shall not be revised without approval from the Engineer. All splices shall be protected and stored in fiber optic splice closures or aerial splice enclosures.

The fully sheathed, multi–fiber cable of each connector module shall be routed into and secured in a splice tray. Fiber optic cable shall enter the rear of the fiber optic splice. The fiber optic cable sheath and central member shall be secured inside the unit prior to buffer tube fan–out. All entry holes not utilized shall be plugged. Buffer tubes with fiber designated for splicing shall be routed into and secured in a splice tray. Remaining buffer tubes shall be secured within the splice unit and not accessed.

a. Mid–cable access: Only fibers within a buffer tube that are designated for splicing shall be individually accessed, spliced to the appropriate fibers from the connector module(s), and secured neatly within the splice tray. The remaining fibers in the buffer tube that are not designated for splicing shall be secured neatly within the splice tray and not cut. Removal of the buffer tube to access the fibers shall be accomplished using equipment specifically designed for buffer tube removal without damaging the individual coated fibers (Corning OFT–000 or equivalent).

b. Full–cable termination: All fibers including spares, shall be spliced to the appropriate fibers from the interconnect cable and pigtails, and secured neatly within the splice tray.

4. CABLE TAGGING - Furnish yellow communications cable identification markers that are resistant to fading when exposed to UV sources and changes in weather. Use markers designed to coil around fiber-optic cable, and that do not slide or move along the surface of the cable once installed. Ensure exposure to UV light and weather does not affect the markers natural coiling effect or deteriorate performance. For all fiber optic cables except those indicated on the Plans, furnish cable wraps containing the following text in black:

WARNING
CITY OF KNOXVILLE
FIBER OPTIC CABLE
CONTACT TELEPHONE NUMBER: (865) 215-6730
WARNING
FIBER OPTIC CABLE

Overall Marker Dimensions: 7”(l) x 4”(w).
Lettering Height: 3/8 inch for WARNING, ¼” for all other lettering.
Aerial Fiber Optic Cable shall be tagged at every other pole attachment.
Submit a sample of the proposed communications cable identification markers to the Engineer for approval before

installation.

5. FIBER OPTIC TERMINATION PANEL INSTALLATION

Fiber terminations shall be neatly and permanently labeled on the connector module to designate as follows:

Label	Cable/Strand	Label	Cable/Strand
MM-1	6 Strand Multi Mode – Blue Strand	**MM-2**	6 Strand Multi Mode – Orange Strand
MM-3	6 Strand Multi Mode – Green Strand	**MM-4**	6 Strand Multi Mode – Brown Strand
MM-5	6 Strand Multi Mode – Slate Strand	**MM-6**	6 Strand Multi Mode – White Strand
SM-1	6 Strand Single Mode – Blue Strand	**SM-2**	6 Strand Multi Single – Orange Strand
SM-3	6 Strand Single Mode – Green Strand	**SM-4**	6 Strand Multi Single – Brown Strand
SM-5	6 Strand Single Mode – Slate Strand	**SM-6**	6 Strand Multi Single – White Strand

Only the new fiber terminations shall be labeled with the above convention. Any existing fiber terminations shall be labeled at the discretion of the Engineer.

Blank connector panels, of same finish and manufacture as the connector modules shall be installed for all unused connector module spaces.

Until jumper cables are installed, the Contractor shall provide and maintain protective covers over the optical connectors and termination. Protective covers on terminations not used shall remain.

Jumper cables shall be installed from connector module to end equipment, and from end equipment to end equipment in multiple cabinet configurations. Jumper cables shall be secured to provide strain relief at both the connector module and the end equipment. Manufacturer recommended installation and minimum bend radius requirements shall be adhered to. Jumper cables, which connect to end equipment, shall be labeled at both ends. At field cabinet locations, the label at both ends shall contain the string number, the ring number, transmit or receive, and primary or secondary.

a. New Installations

Mount on proposed termination panels securely on side of cabinet free of any obstructions and labeled as indicated above.

b. Existing Installations

Existing cabinets with existing fiber optic termination panels shall be modified to accept 6 additional ST single mode fiber optic cable terminations and labeled as indicated above.

6. FIBER OPTIC STORAGE BRACKET - Provide fiber optic storage brackets in locations indicated on the plans. Aerial installations shall be securely fastened to messenger cable. Underground installations shall be securely fastened to the wall using masonry screws.

7. FIBER OPTIC TESTING - Fiber optic testing and installation tools shall be maintained and calibrated in accordance with the tool manufacturer's recommendations. Contractor to provide tool manufacturer certified calibration documentation upon Engineer's request. Installation and testing tools include but are not limited to; Fusion splicer, Cable pulling strain dynamometers and breakaway links, OTDR's, or Optical attenuation tester (light source and power meter)

Fiber optic testing equipment should only be operated by contractor personnel who have been trained and certified by the tool manufacturer.

The Contractor shall conduct testing of all fiber optic infrastructures as required in this TSP. The project testing for fiber optic infrastructure shall include but is not limited to, the additional specific requirements in this subsection. All test results shall confirm physical and performance compliance with this TSP including, but not limited to, optical fibers and fusion splices. No event in any given fiber may exceed 0.10 dB. Any event measured above 0.10 dB shall be replaced or repaired at the event point.

Contractor shall provide the tentative date, time and location of fiber optic infrastructure testing no less than 7 days in advance of the test. Provide confirmed date, time and location of fiber optic infrastructure testing no less than 48 hours before conducting the test.

Provide test result documentation in electronic format (1 copy) and printed (3 copies) format. Electronic formats shall be readable in Microsoft Excel or other approved application. Printed copies shall be bound and organized by cable segment.

Provide all test results in English units of measure of length. Submit all test result documentation to the Engineer within 14 days of completion of the tests.

a. Pre-Installation Test (PIT) - Perform a PIT on all FO Cable prior to any cable removal from the shipping reels. Perform a PIT on each cable reel delivered to the job site. The PIT for FO Cable shall include but is not limited to:

(1) A visual inspection of each cable and reel

(2) An OTDR Test and documentation as required in the SAT below, for three randomly selected fibers from each buffer tube.

(3) An Optical Attenuation Test is not required. If the contractor decides to perform one for their own protection, said test should be documented and provided to the engineer.

b. Standalone Acceptance Test (SAT) - Perform an SAT on all fiber optic infrastructure on this project after field installation is complete, including, but not limited to, all splicing and terminations. An SAT for each fiber in each cable shall include OTDR Tests and Optical Attenuation Tests. All fibers in all FO Cables and FO Branch Cables shall be tested from termination point to termination point, including:

(1) Fibers from FO Termination Cabinet to FO Termination Cabinet

(2) Fibers from FO Termination Cabinet to FO Branch Panel

(3) Fiber from FO Branch Panel to FO Branch Panel

(4) Fibers from FO Termination Cabinet to the end of the cable run in the last FO Closure

All test results shall confirm compliance with this TSP including, but not limited to, optical fibers and fusion

splices. No event in any given fiber may exceed 0.10 dB. Any event measured above 0.10 dB shall be replaced or repaired at the event point.

c. Test documentation shall include but is not limited to:

Cable & Fiber Identification

(1) Cable & Fiber ID and Location – Physical location (device ID and station number of FO Termination Cabinet, FO Branch Panel, or cable end FO closure), fiber number, and truck or branch cable ID for both the beginning and end point.

(2) Operator Name

(3) Engineer's Representative

(4) Date & Time

Setup and Test Conditions Parameters

(1) Wavelength

(2) Pulse width Optical Time Domain Reflectometer (OTDR)

(3) Refractory index (OTDR)

(4) Range (OTDR)

(5) Scale (OTDR)

(6) Ambient Temperature

Test Results for OTDR Test (each direction and averaged)

(1) Total Fiber Trace (miles)

(2) Splice Loss/Gain (dB)

(3) Events > 0.05 dB

(4) Measured Length (Cable Marking)

(5) Total Length (OTDR Measurement)

Test Results for Attenuation Test (each direction and averaged)

(1) Measured Cable Length (Cable Marking)

(2) Total Length (OTDR Measurement from OTDR Test)

(3) Number of Splices (Determined from As-Builts)

(4) Total Link Attenuation

d. OTDR Test - Conduct the OTDR Test using the standard operating procedure and recommended materials as defined by the manufacturer of the test equipment.

Use a factory patch cord ("launch cable") of a length equal to the "dead zone" of the OTDR to connect the OTDR and the fiber under test.

Conduct bi-directional OTDR Tests for each fiber. Calculate bi-directional averages.

e. Optical Attenuation Test - Conduct the Optical Attenuation Test using the standard operating procedure and recommended materials as defined by the manufacturer of the test equipment.

Conduct bi-directional Optical Attenuation Tests for each fiber. Calculate bi-directional averages.

8. FIBER OPTIC SPLICING TRAINING - Contractor shall provide fiber optic splicing training for both multi-mode and single-mode fiber optic cable and terminations. Training will also provide an overview of the installed fiber optic cable network. Instructor shall be certified to provide training by the equipment manufacturer of the fiber splicer. The training shall be provided at the Traffic Signal Shop for at least ten (10) personnel with individual copies of all training materials and manuals provided to each participant. The training must include a complete demonstration of fiber optic cable splicing and testing. The training should also consist of a hands-on demonstration of all hardware and specialty software controlled equipment and functionality where applicable. Each training day shall include a mixture of classroom style training in equipment operation, hands-on operator training, and question and answer sessions. The Contractor shall submit the trainers' qualifications to the Engineer for approval prior to scheduling the training. The qualifications of the trainers must meet, at a minimum, the recommended qualifications of the equipment manufacturer. If qualified personnel are not on the Contractor's staff, a representative of the manufacturer shall provide the training. The Contractor shall submit to the Engineer for approval a detailed Training Plan including course agendas, detailed description of functions to be demonstrated, and a schedule. The training shall be no more than two (2) days in duration.

9. PAY ITEM AND METHOD OF MEASUREMENT

a. Fiber Optic Drop Cable (6 SMFO Cable) shall be measured in linear feet and will be paid for at the Contract unit price per linear foot. This price shall include all materials, labor, tools, equipment, backlashing, and incidentals necessary to complete the work, and all testing and documentation.

b. Fiber Optic Drop Cable (6 MMFO Cable) shall be measured in linear feet and will be paid for at the Contract unit price per linear foot. This price shall include all materials, labor, tools, equipment, backlashing, and incidentals necessary to complete the work, and all testing and documentation.

c. Interconnect Cable - Fiber Optic (48 SMFO Cable) shall be measured in linear feet and will be paid for at the Contract unit price per linear foot. This price shall include all materials, labor, tools, equipment, backlashing, and incidentals necessary to complete the work, and all testing and documentation.

d. Interconnect Cable - Fiber Optic (12 MMFO/48 SMFO Cable) shall be measured in linear feet and will be paid for at the Contract unit price per linear foot. If the contractor elects the alternate to install separate SM and MM cables, the price covered in this bid item will cover both cables. This price shall include all materials, labor, tools, equipment, backlashing, and incidentals necessary to complete the work, and all testing and documentation.

e. Fiber Optic Splice Closure shall be measured in units of each and will be paid for at the Contract unit price. This price shall include all materials, labor, tools, equipment, and incidentals necessary to complete the work, and all testing and documentation.

f. Fiber Optic Aerial Splice Closure shall be measured in units of each and will be paid for at the Contract unit price. This price shall include all materials, labor, tools, equipment, and incidentals necessary to complete the work, and all testing and documentation.

g. Fiber Optic Termination Panel shall be measured in units of each and will be paid for at the Contract unit price per each. Termination panels shall contain the necessary fiber optic connector modules, labels covers and associated splicing for locations indicated on the Plans. This price shall include all materials, labor, tools, equipment, and incidentals necessary to complete the work, and all testing and documentation.

h. Fiber Optic Fusion Splice shall be measured in units of each splice location and paid for at the contract price per each. The price bid shall include but not limited to, all fusion splices at that given location, all

ancillary and incidental materials, testing, documentation, and all labor and equipment necessary to complete the work for all necessary splices at a given location. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

i. Fiber Optic Storage Bracket (Aerial) shall be measured in units of each and will be paid for at the contract unit price per each. This price shall include all materials, labor, tools, equipment, and incidentals necessary to complete the work, and all testing and documentation.

j. Fiber Optic Connectors are included in the quantities of other pay items and will not be measured separately for payment.

k. Fiber Optic Patch Cables are included in the quantities of other pay items and will not be measured separately for payment.

l. Cable Labels are included in the quantities of other pay items and will not be measured separately for payment.

m. Fiber Optic Splicing Training shall be measured as lump sum quantity this price includes all training information, training schedule, equipment, and materials to provide the training.

n. Payment will be made under:

Item Number	Pay Item	Pay Unit
725–10.01	Fiber Optic Drop Cable (6 SMFO Cable)	Lin. Feet
725–10.02	Fiber Optic Drop Cable (6 MMFO Cable)	Lin. Feet
730–08.40	Interconnect Cable - Fiber Optic (48 SMFO Cable)	Lin. Feet
730–08.41	Interconnect Cable - Fiber Optic (12 MMFO / 48 SMFO Cable)	Lin. Feet
725–10.03	Fiber Optic Splice Closure	Each
725–10.04	Fiber Optic Termination Panel (12F)	Each
725–10.05	Fiber Optic Fusion Splice	Each
725–10.06	Fiber Optic Aerial Splice Closure	Each
725–10.07	Fiber Optic Storage Bracket (Aerial)	Each
725–10.08	Modify Existing Fiber Optic Termination Panel	Each
725–10.20	Training	Lump Sum