

**STATE**  
(Rev. 9-12-19)

**O F**

**TENNESSEE**  
January 1, 2015  
City of Knoxville  
Knox County

**SPECIAL PROVISION**

**REGARDING**

**SECTION 730 – TRAFFIC SIGNALS**

**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 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.

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.

Maintain responsibility for the traffic signal system until such time a final inspection is performed and all discrepancies found in the inspection are corrected to the satisfaction of the City of Knoxville and the City assumes maintenance responsibilities in writing.

**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 and the NESC; 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 Traffic Operations Division, 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
14. Preemption Systems and Associated Equipment
15. Pedestrian Push Buttons
16. Battery Backup Systems

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 delay to the Work prior to such approval.

In addition to the above, 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. Any material substitutions requested by the maintaining agency shall meet minimum Department standards and shall be approved by the Department in writing prior to purchase or installation. The Department will not be liable for any materials purchased; labor performed, or delay to the Work regarding such approval.

Submit an electronic copy in PDF format 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 the electronic copy 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. MTRs 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**

<b>Component Materials</b>	<b>MTR</b>	<b>Certification</b>
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 installed and 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.

**730.07 Training**

Provide to the maintaining agency and/or the Department 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 and/or the Department 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.

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. Contact the City of Knoxville for current dimensions for cabinet foundations. The typical pad foundation is 3' X 5', with a minimum height of 12 inches in a sidewalk and 28 inches above finished grade. Contact City of Knoxville Traffic Systems prior to constructing foundation. 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 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 Rods**

Furnish, with anchor-base type rods, anchor bolts meeting the requirements of ASTM F1554, grade as required by design. Fit each anchor bolt with two heavy hex nuts. Hot-dip galvanize all 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 1/4 inch 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**

Construct and install pull boxes as shown on the Plans and the Standard Drawings or as directed by the Engineer. The pull boxes described in this section are industry standards. Refer to the plans and drawings for what type of pull box to use. Typical pull boxes used are: 12" X 12" X 12", 11" X 17" X 12", 23" x 17" x 18", and 17" X 30" X 12" 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 feet long. Each pull box shall include one extra minimum 2 inches. Install pull boxes wherever practicable out of the line of traffic. Set covers level with the pavement, or with the curb or sidewalk grade, or with the surrounding ground as required.

Place electrical conductors within pull boxes so as to be clear of the metal frame and cover.

Rest the bottom of the pull box firmly on a bed of crushed stone with a minimum depth of 12 inches below the bottom, and extending 6 inches beyond the outside edge of the pull box, unless otherwise directed by the Engineer.

Installation shall be as per guidelines of the TDOT Standard Specifications for Road and Bridge Construction, latest version T-SG-2 or City of Knoxville COK-SG-2 details. Pull boxes and covers shall be installed per the design details.

#### **A. Concrete Pull Boxes**

Construct concrete pull boxes of a mixture of one part cement, two parts sand, and four parts gravel or 1-inch crushed stone with reinforcement placed as shown on the Standard Drawings. Reinforcement shall consist of welded wire reinforcement, 4 x 4 inches - No. 4/4 at 85 pounds per 100 square feet, meeting the requirements of **907.03**. Pull boxes may be poured in place or precast. The color of the pull box concrete material shall match the surrounding concrete color.

Install a cast iron frame and cover of the dimensions shown on the Drawings in each pull box. Provide castings of Class 30, meeting the requirements of **908.07**. The covers shall have a roughened top surface of 1/8 inch in relief. Provide notches for removing the cover. Inscribe the words "TRAFFIC SIGNALS" on top of the covers with letters 1-1/2 inches high and 1/8 inch in relief as shown on the Drawings.

The frame shall have a minimum weight of 42 pounds. The cover shall be of the “Extra Heavy” type with a minimum weight of 54 pounds.

**B. Reinforced Plastic or Epoxy Mortar Pull Boxes**

Ensure that pull boxes composed of reinforced plastic or epoxy mortar are designed and tested to temperatures of -50 °F and meet the requirements of the following: ASTM D543, ASTM D570, ASTM D790, and ASTM D635, and are based on a 30,000-pound single axle load over a 10 x 20 inch area. The top of the pull box shall consist of a concrete frame (ring) and cover. The color of the pull box concrete material shall match the surrounding concrete color. Inscribe the words “TRAFFIC SIGNALS” on top of the covers.

**C. Fiber Optic Pull Boxes****1. Type A**

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.

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

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.

Pull Box shall meet NEC 2014 for handhole enclosures.

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

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.

**2. Type B**

Minimum dimensions: 49”W x 32” Lx 36”D 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. Note this is a different pull box than shown in TDOT Standard Drawings.

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

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.

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

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

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

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

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

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 handhole, 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 handhole opening.

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

When a transformer base is required, no handhole 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 a minimum 2 inches in diameter, and detector conduit a minimum 1 inch in diameter, unless otherwise specified or directed by the Engineer. Conduit for service connections shall be 1 inch in diameter. Do not use conduits smaller than 1 inch in diameter unless otherwise specified, except grounding conductors at service points shall be enclosed in 3/4-inch diameter conduit. Larger-sized conduit may be used, at no additional cost to the Department, in which case it shall be for the entire length of the run with no reducing couplings allowed.

#### **A. Materials**

Provide conduits and fittings of the type as shown in the construction plans or as directed by the Engineer and 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 80.
- 3. **High-Density Polyethylene (HDPE).** Materials used for the manufacture of HDPE conduit and fittings shall be per ASTM F2160 and consist of a Standard Dimension Ratio (SDR) 9-11. No other substitutions shall be allowed unless directed by the Engineer. HDPE conduit can be used with preassembled cable and rope-in-conduit. 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.

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

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

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.

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.

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

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

Conduit Bank Type 1

Green	Drop Fiber and/or RDS Cable
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Conduit Bank Type 2

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

Conduit Bank Type 3

Green	Drop Fiber and/or RDS Cable
Blue	RDS Cable or Second Drop Fiber
White	Second RDS Cable or Spare

Conduit Bank Type 4

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

2", 3", and 4" Electrical Conduit

Grey Electrical wire

1¼" 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

2" 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

**Coupling**

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

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.

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

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

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

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**

The multi-cell conduit system shall be a pre-assembled conduit manufactured from a minimum of a 4 inch round outer duct containing 4 factory installed round 1-1/4" inner ducts.

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

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.

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

**a. Outer duct:**

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.

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

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.

Outer duct 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.

Physical and Mechanical Properties and Test Methods:

Ultimate Tensile Strength - 11,000 PSI Min.	ASTM D-2105
Dielectric Strength - $\geq$ 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

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 outer duct described above.

**b. Inner duct:**

Inner ducts shall be manufactured from polyvinyl chloride (PVC) or high density polyethylene (HDPE). Inner ducts shall be factory treated with an atomized silicone or manufactured in a manner to reduce friction during pulling of fiber optic cable. Inner duct 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 inner duct shall meet the requirements of the manufacturer's catalog cuts approved by the Department.

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

HDPE inner duct shall conform to the following requirements:

Color of inner ducts - 4-way (orange, blue, brown, white)

Nominal Inner Size - 1 1/4"

Coupling Body:

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.

Water tightness - 6 PSI Minimum

Air tightness - no leakage at 100 PSI

Bends and Sweeps

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.

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

- 4 ft. radius:            11 ¼ degrees
- 6 ft. radius:            22 ½ degrees
- 9 ft. radius:            45 and 90 degrees

**B. Installation**

All bends shall be in strict compliance with the NEC.

Lay conduits to a minimum depth of 6 inches below subgrade 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 80) encased in concrete.

Conduits shall be continuous and extend from end point (i.e. pull box, foundation signal pole, pedestal pole, etc.) to another end point, or as directed by the Engineer. Conduit splicing shall not be permitted between end points.

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 or 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**

Furnish and install conductors in accordance with these Specifications and close conformity as shown on the Plans, or as directed by the Engineer.

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. 50-2.

### **730.16 Cable**

All signal cable shall conform to applicable IMSA Specification No. 19-1 or 20-1. 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 solderless connectors, and insulate splices with weatherproof tape applied to a thickness equal to the original insulation. Use of heat shrinkable crimps or self-amalgamating tape is recommended to ensure weather-proof connections in pull boxes or wet locations.
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.
5. Exterior wiring shall have a 360' drip loop in advance of entering any signal head, disconnect, gooseneck, or pole-arm.

City of Knoxville Wiring Specs (See Data Sheets)

- a. Pedestrian Buttons  
IMSA 50-2, Shielded 2 Pair 14 AWG  
If two pedestrian buttons are at the same structure or pole install (1) 2 Pair shield.  
Individual pedestrian buttons at different structures install (1) 2 Pair shield to each button.
- b. Pedestrian Signals  
IMSA 19-1 or 20-1, 7 conductor 14 AWG  
If two pedestrian signals are at the same structure or pole install (1) 7 conductor.  
Individual pedestrian signals at different structures install (1) 7 conductor to each signal.
- c. Traffic Signals  
IMSA 19-1 or 20-1, 12 conductor 14AWG  
When installing in span mounted signal heads run one 12 conductor to each approach. Each cable is terminated in a 12 position signal disconnect and then daisy-chained to the next signal in the approach and so on.

When installing on mast arms run a 12 conductor to the base of each individual pole. From the signals mounted on the mast arm run IMSA 19 or 20-1 7 conductor from each signal housing to the hand-hole at the base and splice the 12 conductor to the 7 conductors.

IMSA 50-2 Shielded 1 pair 14 AWG is only used for vehicle detector loops and preemption systems.

**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. New service will be established by contacting the City of Knoxville Traffic Engineering.

**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 permittivity 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.

**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.

A 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, conduit, transformer bases, anchor bolts, and 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 copperweld ground rod not less than 8 feet in length and 1/2 inch in diameter, installed in accordance with the NEC. 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 copperweld 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 in circuit. Per NEC 2014 250.53 Grounding Electrode System Installation  
Rod, Pipe, and Plate Electrodes shall meet the requirements of 250.53(A)(1) through (A)(3).
  - a. 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.

b. 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.

c. Supplemental Electrode

If multiple rod, pipe, or plate electrodes are installed to meet the requirements of this section, they shall not be less than 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.

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 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**

Signal heads shall meet the latest requirements published in the Equipment and Materials Standards of the Institute of Transportation Engineers (ITE) for Adjustable Face Vehicle Traffic Control Signal Heads” and the National Electrical Code. The arrangement of traffic signal heads shall be mounted as shown on the Plans or as specified by the Engineer and be in accordance with the latest versions of the MUTCD and the TDOT Traffic Design Manual.

All circular indications shall use 12-inch lenses unless otherwise shown on the Plans. All arrow indications shall use 12-inch lenses. All new vehicle signal heads installed at any one intersection shall be of the same style and from the same manufacturer. All exposed metal signal housings, doors, visors, backplates and framework parts shall be painted with a powder coated finish and be in accordance to the MUTCD specifications. 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.

Signal head housings shall be cast aluminum and all associated parts/hardware shall be of non-corrosive material. In addition to these requirements, comply with the following:

#### **A. Optical Units**

Traffic signal indications shall be LED type and meet the Institute for Transportation Engineers (ITE) latest LED specifications. All LED indications shall have a five year warranty. Traffic Signal Indicators LED Vehicle specifications shall comply with the following.

1. Operating voltage between 80 to 135 volts AC.
2. All LED Circular 12” indications shall be fully compliant to the latest adopted ITE VTCSH LED Circular Supplement, evidence of full compliance is required.
3. All LED 12” Arrow Signal Modules shall be fully compliant to the omnidirectional specifications of the latest adopted ITE VTCSH - LED Vehicle Arrow Traffic Signal.
4. Each LED lamp shall have the word “Top” marked on its flange to indicate proper positioning of the lens.
5. The external lens shall be slanted down, curved and smooth on the outside to prevent excessive dirt/dust/snow buildup and to minimize sun phantom reflections.
6. The lens and its gasket shall provide weather and dust from entering signal housing.
7. The front lens shall be replaceable and shall not be fixed using mechanical screws.
8. The gasket shall be of molded heat resistant neoprene.
9. LED Lamp removal shall be designed such that personnel can easily replace the lamp.

10. The module shall not protrude more than 4 inches between inside flange to back of module housing, allowing more space to clear cables and terminal blocks.
11. LED signals shall have color coded 16 AWG wires for identification of the signal color as follows;
  - a. Circular LED
    - 1) RED LED w/ RED with WHITE neutral
    - 2) YELLOW LED w/ YELLOW with WHITE neutral
    - 3) GREEN LED w/ GREEN or Brown with WHITE neutral.
  - b. Arrows LED
    - 1) YELLOW ARROW LED w/ YELLOW/WHITE with WHITE neutral
    - 2) GREEN ARROW LED w/ GREEN/WHITE or Brown/White with WHITE neutral
12. Wires shall be terminated with Bowma-Crimp style forked spade lugs, 6-8 stud / 16-14 wire size.
13. All signals shall be supplied with minimum 36 inches of wire for connection to signal connector block.
14. A filtered power supply engineered to electrically protect the LEDs and maintain a safe and reliable operation.
15. In addition to, and in excess of the applicable ITE specification compliance, the on-board circuitry of all LED traffic signal modules shall include voltage surge protection, to withstand high-repetition noise transients and low-repetition high-energy transients.
16. The LED module shall have a board to board mechanical connection between the LEDs and the power supply. (no wires inside the lamp will be allowed)
17. All lamps shall be capable of flash operation with no restrictions or degradation of performance.
18. Clear Lenses are required for Green, Yellow, Green Arrow, or Yellow Arrow LED's.
19. The LED module shall have a visual appearance similar to that of an incandescent lamp (i.e. smooth and non-pixelated).

**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.

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 both plumb or 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. Louvers shall be painted with a powder coated finish.

**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. 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 in the front and back.

#### **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**

Pedestrian signal heads shall meet the latest requirements published in the Equipment and Materials Standards of the Institute of Transportation Engineers (ITE) for Adjustable Face Pedestrian Signal Heads”, the National Electrical Code and be compatible with NEMA standards. The arrangement of pedestrian signal heads shall be mounted as shown on the Plans or as specified by the Engineer and be in accordance with the latest versions of the MUTCD and the TDOT Traffic Design Manual. The pedestrian indications shall be LED symbols and in conformance with the Institute for Transportation Engineers (ITE) latest LED specifications. All LED indications shall have a five year warranty. Traffic Signal Pedestrian Indicators LED signal specifications shall comply with the following.

1. All LED Pedestrian Signal Modules shall be fully compliant to the ITE PTCSI latest adopted version.
2. The 16in.by 18 in. optical sections shall be configured so the display is side by side.
3. The two optical systems shall be configured so the display is overlapping, 9 inch symbol Full “Hand” and “Person” (Outline symbols are not acceptable).
4. The first displays the International Symbol of Hand (Solid) for (“DON’T WALK”) when illuminated, then the display of International Symbol of the Walking Person (Solid) for (“WALK”).The signal shall use LED traffic signal lamps to display either the Hand Symbol in Portland Orange or, Walking Person symbol in White.
5. Two seven segment digits will be utilized for time display.
6. The signal shall be one section and designed in conformance with 2009 M.U.T.C.D Section 4E.04.
7. Operating Voltage 80 to 135 volts.
8. The lamp shall be capable of partial loss of LED’s and still maintain message integrity.
9. Pedestrian Signals shall have color coded 16AWG wires for identification of circuits as follows;
  - a. Walk Indication: (Person) Brown or Blue
  - b. Don’t Walk: (Hand) Red or Orange
  - c. Ground: White
10. All signals shall be supplied with minimum 36 inches of wire for connection to signal connector block.
11. Wires shall be terminated with Bowma-Crimp style forked spade lugs, 6-8 stud / 16-14 wire size.
12. There shall at least two power supplies, one for powering the walking Person icon and other(s) to power the upraised Hand icon and countdown timer.

- 13. The supplies shall be a filtered power supply engineered to electrically protect the LED and maintain a safe and reliable operation.
- 14. The LED module shall have a visual appearance similar to that of an incandescent lamp (i.e. smooth and non-pixelated) and fully populated.
- 15. When not energized signal shall maintain a blanked outlook.

In addition, where pedestrian signal heads are provided, they shall:

- 1. Include a pedestrian change interval countdown display where the calculated pedestrian change interval is more than 7 seconds;
- 2. Include Accessible Pedestrian Signals and pedestrian pushbuttons complying with MUTCD Accessible Pedestrian Signals section;
- 3. Incorporate a locator tone meeting the requirements of the MUTCD Accessible Pedestrian Signals;
- 4. Include a pedestrian pushbutton with tactile vibrating arrow button and audible sound.

The pedestrian countdown display shall conform to the latest FCC regulation on Emission of Electronic Noise.

The manufacturer must supply certification, which includes a copy of the test report by an independent technical laboratory as to the 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.

The housing door, door latch, and hinges shall be of aluminum or polycarbonate 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 a powder coated finish (if aluminum) or colored resin (if polycarbonate) in accordance to MUTCD specifications.

**G. Signal Head Installation**

Install signal heads and pedestrian signal heads with the faces completely covered until the entire installation is ready for operation.

**CONTROLLERS – GENERAL**

**730.25 Controllers**

The City of Knoxville uses the TS2 Type 2 Trafficware 980ATC controller. The 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.

Controller equipment shall be permanently marked with the manufacturer’s name or trademark, part number, and serial number.

Controllers must meet the following applicable industry standards and amendments:

- 1. NEMA TS2 Controller ..... NEMA TS-2-2016
- 2. ATC Controller..... AASHTO/ITE/NEMA ATC 5.2b
- 3. All NEMA TS2 and ATC controllers must provide functionality that meets or exceeds operational characteristics, including NTCIP support, as described in NEMA TS-2-2016.

4. NEMA TS2 Type 2 controllers shall be used when downward compatibility to existing TS1 cabinets is desired.

Except for replacing controllers in existing systems, all new installations must include controllers that capture high resolution event-based data elements to provide the automated traffic signal performance measures.

The manufacturer must supply certification of the conformance to the above requirements at the time of the bid.

In addition to the above requirements, the controller shall:

5. Have all timing values entered via a front panel mounted keyboard. This keyboard shall be an integral part of the controller unit.
6. Have an English language menu for programming or reading all controller features.
7. Continue to operate the intersection as values are inspected or altered.
8. Include the ability to upload and/or download the controller software operating system and user programmed database to or from external media (datakey, usb, sd card etc).
9. Support Flashing Yellow Arrow for Permissive Left-turn Movements applications.

### **Surge Protection Devices**

The cabinet shall have Surge Protective Devices (SPDs) for the main AC power input, all signal head field wiring terminals, interconnect cable terminals and loop lead-in cable terminals which are located in the cabinet. Furnish SPDs to provide effective defense against high transient voltages caused by lightning discharges or other sources. SPDs must be unobstructed and accessible from the front side of any panel used in the cabinet. The SPD for the main AC power input of the cabinet must be connected on the load side of the cabinet circuit breaker. SPDs must meet the following minimum requirements:

1. AC power SPD:
  - a. Must be UL 1449 4<sup>th</sup> Edition Listed
  - b. Parallel connected device
  - c. UL Nominal Surge Rating (In): 20kA
  - d. UL Short Circuit Current Rating (SCCR): 150kA minimum
  - e. Surge current rating: 50kA per phase minimum
  - f. Visual status indication
  - g. Remote signalization contacts for monitoring purposes
  - h. 10 year manufacturer's warranty minimum
2. DC power SPD:
  - a. Must be UL 1449 4<sup>th</sup> Edition recognized
  - b. Parallel connected device
  - c. UL Nominal Surge Rating (In): 10kA minimum
  - d. Must provide protection between all +/-Gnd connections
  - e. Surge current rating: 20kA per phase minimum
  - f. Visual status indication
  - g. Remote signalization contacts for monitoring purposes
  - h. 10 year manufacturer's warranty minimum
3. Data and communication SPD:
  - a. Must be UL 497B listed
  - b. 10 year manufacturer's warranty minimum
4. Signal and interconnect cable field wiring terminal SPD:

- a. Clamp the surge voltage to a level no greater than twice the peak operating voltage of the circuit being protected.
  - b. Withstand a surge current of 1000A with an 8 by 20  $\mu$ s waveform six times (at 1 second intervals between surges) without damage to the suppressor.
  - c. 10 year manufacturer's warranty minimum
5. Loop lead-in cable field wiring terminal SPD:
- a. Protect the detector unit loop inputs against differential (between the loop lead) surges, and against common mode (between loop leads and ground) surges
  - b. Clamp the surge voltage to 25 V or less when subjected to repetitive 300A surges
  - c. Withstand repetitive 400A surges with an 8 by 20  $\mu$ s waveform without damage
  - d. 10 year manufacturer's warranty minimum

All SPDs must be installed according to the SPD manufacturer's instructions and not affect the operation of equipment. SPD leads must be kept as short and straight as possible.

## **CABINETS – GENERAL**

### **730.26 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 plan sheets and specifications for a particular project, all of the following shall be included;

#### **1. Material, Workmanship, Dimensions and Layout**

- a. All cabinets shall be of weather tight construction fabricated from aluminum sheet minimum 0.125 in. thickness or cast aluminum alloy minimum 0.25 in. 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 X 16.5" 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.
- 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<sup>3</sup> 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” (H) x 16”(W) x 14”(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, under document drawer, 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 2 cavities measuring 10” X 17” X 3” shall be mounted to the bottom shelves 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:
  - 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. Cord shall be a minimum of 6 feet.

- 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) and must be anodized black.
- 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 block 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.

**730.27 Auxiliary Equipment for Traffic Signal 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 shall:

- 1. Meet NEMA standards.
- 2. Have front-face mounted LED indicators to indicate the “On” condition of both the Input and Output circuits.
- 3. Use replaceable “cube” type circuitry or encapsulated discrete component construction. No unencapsulated 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**

- 1 **Scope.** This specification defines the requirements of a nickel-zinc battery-based, green uninterruptible power supply (battery backup) system
- 2 **Definitions**
  - a. UPS – Uninterruptible Power Supply
  - b. GUI – Graphical User Interface
- 3 **Requirements**
  - a. **Compatibility.** The UPS shall be compatible with the agencies current traffic controller cabinet, controller and cabinet components, including the safety monitor, for full time operation. The UPS shall include all necessary cables to connect the UPS and batteries.
  - b. **Run-time.** The UPS shall provide a 2-amp cabinet load a minimum run-time of four (4) hours of full color operation.

- c. **Output Voltage** .When under battery power, the UPS output voltage shall be 120 VAC,  $\pm 3\%$ , pure sine wave output, with  $<2\%$  total harmonic distortion (THD), and frequency of 60 Hz  $\pm 0.5\%$ .
- d. **Transfer Time.** The maximum transfer time allowed, from disruption of utility line voltage to stabilized inverter line voltage from batteries shall be eight (8) milliseconds (typical). The UPS shall be capable of allowing the user to program the line qualifying period as ten (10), twenty (20) or thirty (30) seconds.
- e. **Operating Environment.** Operating temperature for the UPS Inverter and Power Interface Module (PIM) shall be  $-35^{\circ}\text{F}$  to  $+165^{\circ}\text{F}$  ( $-37^{\circ}$  to  $+74^{\circ}\text{C}$ ).
- f. **Certifications.** The UPS battery cells shall be recognized UL-2054, CSA 22.2 No. 60950-1
- g. **Power & Control Connections.** The UPS shall utilize a Power Interface Module (PIM) to connect utility AC input to the UPS and batteries as well as routing UPS output power to the cabinet load.
  - 1) **AC Connection.** The AC input and output shall be separate panel mounted plug/receptacles that allow no possibility of accidental exposure to dangerous voltages.
  - 2) **Battery Connection.** The battery connections shall include separate AC power as well as digital battery bus connections to the UPS and PIM devices with locking connectors.
- h. **Battery**
  - 1) The standard and extended run-time UPS batteries must utilize a Sealed Nickel-Zinc (NiZn) battery technology. Lead-Acid or Lithium battery technologies will not be accepted.
  - 2) The standard run-time battery panel(s) must incorporate a bendable design, which allows the battery panel(s) to flex or bend for installation between the 19" EIA rack and the sidewall of the 33X cabinet.
  - 3) The standard run-time module(s) must have the capability of being installed on/under a shelf or be rack mountable within the 19" EIA rack. Extended run-time battery solutions shall come with an intelligent management system that consolidates all battery connections to the UPS and manages the battery string.
  - 4) The charging/battery monitoring circuitry shall be incorporated within the battery panel, module or intelligent management system.
  - 5) The UPS must allow the user to 'Hot Swap' any of the battery form-factors while on utility power or battery backup power.
  - 6) The UPS must offer 6 battery ports that can accommodate a mix of any form-factor NiZn batteries available.
  - 7) The UPS must be capable of accepting batteries of different capacities at once, giving the user the ability to utilize different battery sizes to achieve required run-times.
- i. **Charge.** The UPS must be able to recharge batteries from 0% to 100% state of charge (full capacity) within 4.5 hours of complete discharge when AC utility line voltage is available. The number of batteries connected to the UPS shall have no effect on the recharge time. The batteries

must be able to charge at up to 50°C ambient temperature. The UPS must not require trickle/float charging.

- j. **Unit failure.** The UPS must have a fail-safe utility tie feature (bypass mode) with a visual indicator that automatically cuts back to the utility line in the event of a UPS or battery failure, or complete battery discharge.
- k. **Operating Modes.** The UPS shall have intelligent two-stage operation defined as:  
Stage One: Line Conditioner, Waveform Monitoring and Switchover to Battery Backup  
Stage Two: Waveform Monitoring, Return to AC Power
- l. **Oscilloscope Function.** The UPS shall have an oscilloscope function continuously monitoring the incoming utility AC waveform at a 6kHz sampling rate. The oscilloscope function shall continuously evaluate three (3) measures of the incoming utility AC waveform:
  - 1) Voltage: A continuous RMS measurement with user programmable AC voltage thresholds.
  - 2) Waveform Anomalies: Oscilloscope enhanced sensitivity mode compares incoming utility waveform to a mathematically pure sine wave reference waveform.
  - 3) Frequency: Continuously measured with frequency deviation detected as quickly as 1 cycle and a default threshold of 60Hz  $\pm$ 6Hz.

**4. Functionality and Operational Requirements**

- a. **LCD Display.** The UPS shall have a 64 x 128 Pixels LCD display with white LED backlight. From the main screen, the LCD display shall provide the following information;
  - 1) Utility line voltage
  - 2) UPS status
  - 3) Cabinet consumption in watts
  - 4) Battery backup run-time in hours and minutes as well as battery capacity in State of Charge percentage
- b. **LCD Display Menu.** The LCD Display Menu shall provide the user the ability to program and monitor all UPS parameters;
- c. **Local User Interface.** The UPS shall include a navigational dial to allow users the ability to navigate the menu to setup the UPS.
- d. **Voltage thresholds**
  - 1) The UPS shall allow the user to set high and low AC line voltage thresholds to determine parameters to transfer from utility line power to battery backup power.
  - 2) The UPS shall bypass utility line power if the utility line voltage is outside of the set high and low voltage parameters.
  - 3) The UPS shall have a programmable utility AC qualification time after restoration of utility AC power to within specified voltage thresholds with choices of 3, 10 or 30 seconds.
- e. **Notifications.** All alarm functions shall be available on SNMP, SMTP and Programmable Relay.
- f. **Programmable Relays.** The UPS Inverter/Controller shall include eight (8) Class 2 programmable relays, which can be triggered by power line conditions, and user selected settings

of the UPS. Each relay shall have the ability to trigger by multiple conditions simultaneously. The programming options are as follows;

- 1) Power Fail without delay / Power fail with delay
  - 2) Time of Day
  - 3) Battery Capacity
  - 4) System Fault
- g. **Event Log.** The UPS shall provide an event log with a 1000 event capacity, which will allow the user to view the date, time and duration of a given event. The data shall be recorded in a FIFO format, so the oldest event is purged as the newest is entered.
- h. **Automatic Bypass Switch.** The UPS shall have an automatic bypass function with a visual indicator to bypass the UPS and allow the utility line voltage through to the cabinet.
- i. **Circuit Breakers.** The Power Interface Module (PIM) must be equipped with a 20A circuit breaker and automatic bypass capability.
- j. **Cold Start.** The UPS shall be equipped with “Cold Start” capabilities, which provides the user the ability to turn the UPS on and supply battery backup power when no utility line voltage is available. This allows the user the ability to install a UPS and provide backup AC power at an intersection that has no utility line voltage available.
- k. **Audible Indicators.** The UPS shall have audible indicators for the following parameters:
- 1) System Startup
  - 2) Cold Start
  - 3) Inverter On/Off
  - 4) Inverter Output Over Current
  - 5) AC Mis-wire
  - 6) Rotating Navigation Dial, Pushing Enter or Back Button On Front Panel
  - 7) UPS Fault
- l. **Visual Indicators.** The UPS shall have visual indicators on its front panel for the following:
- 1) Red indicator - UPS Fault
  - 2) Green indicator - Backup Mode On
  - 3) Yellow - Relay Triggered

The batteries shall have the following visual indicators through a multi-color LED providing battery status and alarms

- 1) Green - Battery discharging / UPS battery backup mode
- 2) Blue - Battery charging
- 3) Blinking White - Battery fully charged and available

**5. Communication**

- a. The UPS must have the capability to provide Ethernet and IP addressing communications with the capability for remote monitoring and programming as well as remote firmware updating

capability. This capability must be provided through embedded webserver software within the UPS.

- b. The UPS shall be equipped with an Ethernet port. The Ethernet port shall be an RJ45, EIA 568B pin out type connector. The Ethernet port shall be 10/100Mbps, TCP/IP capable.

#### **6. Graphical User Interface**

- a. The embedded webserver will provide a Graphical User Interface (GUI) that shall be password protected and require a user ID, password and the UPS IP address to access.
- b. The GUI shall have a status area that details the UPS status, location, available AC line voltage status and real-time cabinet power consumption as well as the most recent power failure duration. The status area must be displayed on every page.
- c. The GUI shall have a Home screen with clickable icons and tabs, which will allow the user to navigate the GUI with ease. The home screen shall allow the user to view real-time graphical charts of the cabinet power consumption and AC line voltage status. The home screen must allow the user the ability to view a live waveform from the AC utility line in the cabinet.
- d. The GUI shall have an Event Log page to allow the user to view the time, date and duration of a given event. The GUI must provide the user the capability of viewing the waveform of the given event.
- e. The GUI shall have a relay Configuration page to allow the user to program the relay contacts.
- f. The GUI shall have a System Configuration page that allows the user to configure all the setup parameters of the UPS.
- g. The GUI shall communicate notification and alerts through SNMP and SMTP protocols.

#### **7. Warranty**

The UPS, as a complete system including batteries, must be warranted to be free from defects in material and workmanship for a minimum of 5 years for the battery cells and 2 years for the electronics from the date of original receipt.

#### **F. Environmentally Hardened Managed Ethernet Switch**

The CommNet 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 ports of 10/100/1000T(X) RJ-45 ports and 2 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 System**

The City uses Sonem 2000 preemption by Traffic Systems LLC or as noted in the plans.

## **MISCELLANEOUS TRAFFIC SIGNALS**

### **730.28A 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 LED lenses shall be yellow in color and a minimum of 8 inches in diameter. The LED lenses shall be part of a weather-proof and water-tight optical unit. The LED lenses shall meet the same requirements for vehicular signal head LED lenses. Mount the lenses in the sign using a molded endless rubber gasket with the sign being mounted to the signal case.
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**. 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.

In addition, the Time Clock Unit/Switch used for Flashing School Signals shall be a programmable module that allows a user to define the time and day that the school speed zone flasher assembly will initiate and terminate flashing operation. The module shall be installed within the pole-mounted signal cabinet provided as part of project. The time clock shall be compatible with the cabinet's wiring relays and termination panels and the battery power supply system. The time clock switch provided shall also have the following features/capabilities outlined below:

1. Daylight Savings Time shall be a user-programmable setting, in addition to having automated compensation per TDOT specifications.
2. The unit shall provide a minimum 12-character, multi-line alpha-numeric LCD back-lit display capable of displaying all programming parameters.
3. The unit shall be capable of being programmed manually (using an integral keyboard pad) or programmed externally using an optional software program via a laptop computer and cable

connection (compatible software program is a separate and distinct item from the time switch unit, and if required, will be separately specified and noted in list of estimated project quantities).

4. Unit shall provide automatic Leap Year compensation.
5. The time clock switch shall be capable of up to minimum 24-hours of capacitive back-up operation, 48 hours desirable, in the event of power interruption.
6. Unit shall be compatible with the supplied solar powered power system / battery unit
7. Time clock switch shall be capable of being programmed for one (1) Normal / Main program, and an additional minimum of 12 Exception periods /programs allowing holiday, vacation and custom skip plans. The exception programs will allow for the Normal / Main program to be skipped or allow for flasher operation on alternative schedules (i.e. early release days, summer school, etc).
8. Unit shall conform to TDOT standard specification subsection 730.27 – Auxiliary Equipment for Traffic Actuated Controller – Time Clock Switches except as superseded herein.
9. Unit shall have non-volatile program memory to allow retention during power loss.

**730.28B Solar Power Flashers**

When required, the solar power flasher equipment listed below shall meet the following requirements:

1. Solar panel and mounting equipment shall be installed on cantilever pole shaft as illustrated on layout detail sheet and as directed by manufacturer instructions.
2. Solar power unit assembly shall include all required mounting equipment, wiring/cables, battery supply, battery charging unit and other ancillary equipment necessary to operate the solar panel and properly charge the battery. The photovoltaic array shall include mounting bracket assembly to permit adjustment of the array to optimal sun exposure. The photovoltaic module shall be mounted and aligned per manufacturer recommendations to maximize solar exposure.
3. Battery unit shall meet manufacturer specifications required to operate and power L.E.D. signal displays and continuous time clock switch operation. Battery shall be compatible with cabinet equipment, including the time clock switch and the flasher signal displays. Battery unit shall meet minimum environmental and performance specifications required for system operation as recommended by solar panel and time clock switch manufacturers.
4. Solar panel and battery supply shall be of a size and power rating necessary to provide required power to time switch clock and flasher signal displays. Obtain the power load requirements from the solar power equipment manufacturer and provide as required. On a typical school day, it should be expected that the flasher system will operate up to four (4) hours per day with the time clock continuously operating to maintain its clock timer. Provide a solar system sizing report from the manufacturer indicating the power supply requirements of the proposed system required to meet the expected power demand.
5. The photovoltaic modules shall be warranted for a minimum of five (5) years from date of installation.
6. The battery system shall be a gelled-electrolyte type battery with capacity to provide a minimum of five (5) days continuous operation of the flasher assembly without charging. Batteries shall be field replaceable. Batteries shall have prorated warranty of a minimum of five (5) years from date of installation.

**730.28C Portable Traffic Signals**

Portable Traffic Signals (PTS) consists of furnishing, installing and configuring a complete PTS system that may be used in construction zones or in other temporary signal locations. The work will be at various sites throughout the state of Tennessee and will consist of providing all labor, materials, equipment and incidentals necessary to make functional the PTS in accordance with these specifications.

The PTS shall be trailer or cart mounted units that provide for easy transportation and quick setup and deployment. There shall be 2 unit options and each unit shall be self-contained.

1. Type 1 units are typically used for long term projects (i.e. projects 5 days or longer in duration) and shall include 2 signal heads per trailer with an upper signal head mounted on an overhead mast arm that can be extended over the travel lane, and a lower signal head mounted on the vertical upright of the trailer.
2. Type 2 units are typically used for short term projects (i.e. projects 4 days or shorter in duration) and shall include 1 signal head that is mounted on the vertical upright of the trailer or cart. Cart-mounted units shall be successfully crash tested to NCHRP 350 TL-3, or equivalent MASH standards. If the project duration is extended beyond 4 days, then Type 1 units should be substituted in lieu of the Type 2 units for all PTS within the signal system.

The PTS shall be MUTCD Compliant and utilize standard ITE signal heads, and adhere to the ITE Specifications and Standards for Vehicle Traffic Control Signal Heads, Light Emitting Diode (LED) Circular Signal Supplement. The unit shall be solar powered and communicate via a wireless or hardwire connection. The unit shall include all the major components listed below or be able to perform the functions of these components. The major components of the unit shall include but are not limited to the trailer or cart, telescoping mast arm (on Type 1 units only), signal head(s) and back plates, traffic signal controller with operating software, solar charging system with batteries, input and output devices, flasher units, conflict monitor, relays, communications system and other equipment required for the safe operation and installation of the unit.

The PTS signal heads and all applicable components of the PTS shall meet the physical display and operational requirements of conventional traffic signals as specific in the MUTCD.

1. For Type 1 units, each unit shall contain 2 signal heads with an upper signal head mounted on an overhead mast arm that can be extended over the travel lane with a minimum clearance of 17 feet measured from the bottom of the signal head unit to the road surface. The lower signal head shall be mounted to the vertical upright of the trailer at a minimum height of 8 feet from the bottom of the signal head unit to the road surface. The signal heads shall also include black back plates that can be easily removed. The signal heads shall have the ability to be rotated 180 degrees to face in the opposite direction and shall have the ability to rotate and lock in approximately 10 degree increments to position the signal head for the optimum visibility to motorists.
2. For Type 2 units, the signal head of the unit shall be mounted to the vertical upright at a minimum height of 8 feet from the bottom of the signal head unit to the road surface. The signal head shall also include black back plate that can be easily removed. The PTS shall be easily rotated to position the signal head for optimum visibility to motorists.

The PTS shall include a solid-state controller with operating temperature range of -40°F to +180°F and compliance with NEMA TS-5 Performance Standard. The controller or programming module shall have an easy to read front panel indicator display. The display shall be backlit and have the capability to facilitate programming and display the currently operating program for each vehicular approach. The controller shall be capable of operating the PTS system in a fixed time, traffic actuated, or manual control mode. Each PTS in a connected system shall have the capability to serve as either the master or slave signal. Each PTS shall include a Conflict Monitor Unit (CMU), or Malfunction Management System (MMS) to ensure phase conflicts do not exist during operation.

1. A minimum of 5 automatic time-of-day timing plans within a 24-hour period should be available in fixed time mode. The operating system should have the ability to control a minimum of 4 traffic phases with

programmable cycle time adjustments and user adjustable red, amber, minimum green and maximum green times. The operating system shall also have the capability of facilitating standby modes of red, red flash and yellow flash.

2. The system shall also have the ability to operate in vehicle actuation mode when vehicle detection detectors are used. The operating system shall have the capability to allow the PTS to be connected to and controlled by a standard NEMA controller.
3. The system shall have the capability to be configured and controlled remotely using a handheld wireless remote control with the capability of being operated at a distance up to ¼ mile from the master.
4. The system shall have the capability of remote monitoring for reporting, at a minimum, signal location and status, battery voltage and system defaults. The remote monitoring shall have capability to alert designated individuals if a fault condition occurs.
5. The operating system shall include password protection to prevent unauthorized programming.

The PTS shall communicate with all other PTS within the signal system via license-free wireless 900 MHZ radio link communications. The radio units shall maintain communications at a minimum distance of 1 mile. The radio system shall conform to the applicable Federal Communications Commission (FCC) requirements, including FCC 90.17, and all applicable state and local requirements. The PTS shall be in direct communication at all times either by wireless or hardwire connection to provide for the required conflict monitor.

The system shall also have the ability to operate in vehicle actuation mode when vehicle detection detectors are used. For Type 1 units, the PTS detector shall be a high-definition, multi-beam, microwave radar stop bar detector for each vehicular approach. The Type 1 radar detector shall have a minimum range of 140 feet and shall be mounted at a minimum height of 17 feet measured from the top of the road surface. For Type 2 units, the PTS detector shall be a radar detector for each vehicular approach. The Type 2 radar detector shall have a minimum range of 140 feet and shall be mounted and have complete radar detection functionality at a minimum height of 8 feet measured from the top of the road surface.

The PTS shall be equipped with a solar power array, charging unit and battery system. For Type 1 units, the number and size of batteries shall be sufficient to operate the signal for a minimum of 21 days at 70 degrees without additional charging or assist from the solar array. An on-board battery charger shall be compatible with both the solar array and with a 120V AC power source. The solar panel array shall provide for a minimum of 440 watts of solar collection capability. For Type 2 units, the PTS shall have batteries sufficient to operate the signal for a minimum of 5 days at 70 degrees without additional charging or assist from a solar array. All instrumentation for the electrical system and battery compartment shall be mounted in a lockable weatherproof enclosure. Solar panels shall be secured to the mounting brackets for theft prevention. All wiring for the unit shall be protected against weather and damage.

The trailer or cart, and all mounted components, shall conform to the wind loading requirements (90 mph minimum) as described in the AASHTO Standard Specifications for Highway Signs, Luminaries and Traffic Signals. The wind load calculations shall be completed by an independent third-party, and stamped by a U.S. Registered Professional Engineer. The trailer or cart shall be made of structural steel and shall include 4 leveling/stabilizer jacks capable of lifting the trailer or cart a minimum of 6 inches. The trailer or cart shall be equipped with a hydraulic or electric lift system sufficient for 1 person to be able to raise and lower the vertical upright and/or horizontal mast arm to and from the operating position. For Type 1 or 2 units, the trailer or cart shall be equipped to provide legal and safe transport on the public highway system at speeds up to 55 mph. All exterior metal surfaces, except signal heads and back plates, shall be powder-coat painted highway safety orange.

The PTS work shall meet the following general requirements:

1. Be responsible for locating the PTS in the appropriate location based on MUTCD and ITE standards for visibility to motorists and for safe operation.
2. Be responsible for providing all hardware, software, communications equipment and licenses to operate a complete PTS system.
3. Be responsible that all PTS equipment is installed according to the manufacturer's recommendations including wireless or hardwire connections.
4. Be responsible for transport, setup, configuration, operation and monitoring of the PTS throughout the entire project. The Engineer shall approve all timing and settings that are used for operation of the signal.
5. As directed by the Engineer, it may be necessary to relocate the PTS during the project. The cost of the relocation shall be included in the PTS price bid.

**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 unit must withstand repeated 400-ampere surges on a 9 x 20 microsecond waveform. Also, the unit must be a two-stage device capable of clamping a minimum of one hundred 300-ampere surges to 25 volts within 40 nanoseconds for surge applied across the two detector leads.

**A. Inductive Loop Detection System**

Inductive loop detector units (loop amplifiers) shall meet at a minimum, the following requirement:

NEMA TS2 Inductive Loop Detector Units ..... NEMA TS 2 2016

Loop amplifiers may be single or multi-channel and shall be of the totally self-contained type.

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. Be 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 and the details noted in the following.

### **1. Installation Requirements**

- a. Wire Routing. 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.
- b. Types of Loops include:
  - 1) 6' x 45' vehicle power head detector loop
  - 2) 6' x 20' vehicle power head detector loop
  - 3) Type and Size to be detailed in the Notice to Proceed.
- c. Loop Termination Location. This is the location that loop homerun needs to be taken back to in order to reconnect to the detection system.
- d. Termination Description
  - 1) Type of wire connection
  - 2) Pull box attachments location
  - 3) Phase association for labeling

### **2. Saw Slot**

- a. 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.
- b. Roadway. Saw slot in the roadway will be 3” 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.

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

**3. Backer Rod**

- a. 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.
- b. 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.

**4. Wire**

- a. All detector loop wire used shall be I.M.S.A. Specification No. 51-3 1997 XHHW detector wire, 14 AWG, single conductor stranded.
  - b. 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.
  - c. All loop head and homerun wire to be continuous with no splices within the roadway.
  - d. 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.
  - e. At all pavement joints or cracks, slack should be provided in the wiring to prevent future insulation breaks.
- 5. Wire Labeling.** Pull box and Cabinet wiring shall be heat shrink labeled and meet all ANSI and TIA/EIA-606-B industry labeling standards.
- 6. Sealant.** Once the wire has been placed 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.

**B. Video Detection System (VDS)**

When specified in the plans, the equipment shall consist of all items necessary to provide a complete functional video detection system that process images and provide detection outputs to the traffic signal controller. The video processor shall be capable of TS1 or TS2 operation. The video frame rate or frames per second shall be no less than 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.

The VDS shall be capable of the following:

1. Be capable of NEMA TS2 operation.
2. Be waterproof and weather resistant.
3. Provide user-defined detection zone programming via a graphical user interface (GUI) and any necessary equipment for future programming. The configuration database shall have the ability to be stored on removable data storage external to the video card.
4. Display programmable detection zones and detection activations overlaid on live video inputs. It shall detect vehicles in real time as they travel across each detection zone.
5. Have a minimum of 24 programmable detection zones per camera.
6. Shadow rejection without special hardware.
7. Non-impaired operation under light intensity changes.
8. Maintain operation during various weather conditions (e.g. rain, fog, snow).
9. Anti-vibration, 5% rejection based on image change.
10. Ability to select direction of flow parameters.
11. Ability to properly detect directionally.
12. Ability to configure presence, pulse, extend and delay outputs.
13. Ability to set up a minimum of six detection zones per camera view to count the number of vehicles detected and stores the information for retrieval.
14. Variable focus providing a minimum of 4 to at least 40 degree horizontal field of view.
15. Store detection zones in non-volatile memory.
16. Have no splices between the processors and the cameras.
17. Provide LED indicators to show active detection.
18. Have an internal heater to assure proper operation of the equipment during low temperatures.
19. Have surge ratings as set forth in NEMA specifications.
20. Have a two-year warranty and updates of all software shall be available without charge during the warranty period.

### **C. Radar Presence Detector (RPD)**

1. **General.** This item shall govern the purchase of above ground radar presence detector (RPD) equivalent to the Smart Sensor 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. 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. 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 back-plate or a cabinet interface device. If a traffic cabinet preassembled back-plate, 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 back-plate 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 up conversion 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 side lobes in the RPD two-way antenna pattern shall be -40 dB or less. Low side lobes 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. 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 inch 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 milliseconds 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. Wireless Magnetometer Vehicle Detection System (WMVDS)**

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.

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

Provide a weatherproof assembly, constructed to prevent electrical shocks under any weather condition.

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.

Pedestrian push buttons shall have a transient protection that meets NEMA specifications.

Accessible pedestrian push button stations, which comply with the Manual of Uniform Traffic Control Devices.

These stations shall include the following functions:

1. Locator tones, which assist visually impaired pedestrians with locating the push button before crossing;
2. Light Emitting Diodes (LED), which illuminate and latch on all of the push buttons after any of the push buttons is pressed. This LED will only turn off when the exclusive pedestrian phase commences;
3. Arrow shaped vibrotactile push buttons aimed toward the adjacent sidewalk ramp, which vibrate during the walk interval of the exclusive pedestrian phase to indicate the exclusive pedestrian phase is operational;
4. A verbal message indicating 'Wait' after the push button was already pressed;
5. A programmable verbal message indicating "The walk sign is on";
6. A locator tone to assist a visually impaired pedestrian with locating the opposite sidewalk ramp;
7. All audible tones and messages shall automatically adjust to the ambient noise level
8. A 9" wide by 15" high crossing sign (MUTCD Sign No. R10-3e)

**730.30 Fiber Optic Hybrid Communications System****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 feet buffer tube storage compatibility for misspent 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-swellaable 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:  $125 \pm 2.0 \mu\text{m}$
  - 2) Core diameter:  $50 \pm 2.0 \mu\text{m}$
  - 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 to 1340 nm
  - 8) Fiber polarization mode dispersion:  $\leq 0.1$  ps/(km)<sup>1/2</sup>
  - 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:  $245 \mu\text{m} \pm 10 \mu\text{m}$
  - 11) Minimum storage temperature range:  $-40^{\circ}\text{F}$  to  $+158^{\circ}\text{F}$
  - 12) Minimum operating temperature range:  $-40^{\circ}\text{F}$  to  $+158^{\circ}\text{F}$
- 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:  $125 \pm 1.0 \mu\text{m}$
  - 2) Core-to-cladding offset:  $\leq 0.8 \mu\text{m}$
  - 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:  $\leq 0.2 \text{ ps}/(\text{km})^{1/2}$
  - 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:  $245 \mu\text{m} \pm 10 \mu\text{m}$
  - 11) Minimum storage temperature range:  $-40^{\circ}\text{F}$  to  $+158^{\circ}\text{F}$
  - 12) Minimum operating temperature range:  $-40^{\circ}\text{F}$  to  $+158^{\circ}\text{F}$
- 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. The option to provide separate multi-mode and single-mode cables in lieu of a single hybrid combination cable is permitted. If the multiple cable option is chosen, 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  $-40 \text{ dB}$ , from  $14^{\circ}\text{F}$  to  $140^{\circ}\text{F}$  ( $-10^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$ ).

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 cables 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 capped. 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 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. Furnish and install all jumper cables and termination equipment that are functionally necessary to connect fiber optic cable to the required end equipment.

Install fiber optic cable as a continuous run and splice only at locations shown on the plans. 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. 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, 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.

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 Method

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 Department or the City, 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.

Only splice fibers at locations that are identified in the Plans. At these splicing locations, 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: ((xxx-xxx-xxxx))  
 WARNING  
 FIBER OPTIC CABLE**

Overall Marker Dimensions: 7”(l) x 4”(w).

Lettering Height: 3/8 inch for WARNING, 1/4” 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:

<b><u>Label</u></b>	<b><u>Cable/Strand</u></b>	<b><u>Label</u></b>	<b><u>Cable/Strand</u></b>
<b>MM-1</b>	6 Strand Multi Mode – Blue Strand	<b>MM-2</b>	6 Strand Multi Mode – Orange Strand
<b>MM-3</b>	6 Strand Multi Mode – Green Strand	<b>MM-4</b>	6 Strand Multi Mode – Brown Strand
<b>MM-5</b>	6 Strand Multi Mode – Slate Strand	<b>MM-6</b>	6 Strand Multi Mode – White Strand
<b>SM-1</b>	6 Strand Single Mode – Blue Strand	<b>SM-2</b>	6 Strand Multi Single – Orange Strand
<b>SM-3</b>	6 Strand Single Mode – Green Strand	<b>SM-4</b>	6 Strand Multi Single – Brown Strand
<b>SM-5</b>	6 Strand Single Mode – Slate Strand	<b>SM-6</b>	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, 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. 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 personnel who have been trained and certified by the tool manufacturer.

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.

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 test is performed, then the 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.

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 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. 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 no qualified personnel are not on the staff, then a representative of the manufacturer shall provide the training. 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 2 days in duration.

#### **730.31 (Reserved)**

### **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 handhole, 5 x 8 inches minimum and located with a clear distance above the base of no less than the pole diameter, "D". 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 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 handhole with reinforced frame and cover, bent anchor bolts, and all other accessories needed to make a complete installation. The

pole and all of its 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 handhole 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 handhole 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.

**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.

**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.

**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 weatherhead by the local utility, all necessary materials and labor

for connection of the electrical service from the controller to the weatherhead, the wiring of the controller and detectors, and all incidentals necessary to render a complete and operable system.

**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 mastarms, 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.

**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.

**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, conduit, fittings, nuts, washers, banding, clamps, grounding, and other items necessary for installation.

**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, or
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.

#### **Vehicle Loop Detector (Amplifier)**

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.

#### **Shielded Detector Cable**

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.

**Saw Slot**

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.

**Loop Wire**

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.

**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.

**Wood Pole**

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

**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.

**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.

**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.

**Service Cable**

The Department will measure two conductor power service cables, 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.

**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.

**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.

**Portable Traffic Signal**

The Department will measure Portable Traffic Signal, of the type shown on the Plans or as directed by the Engineer, per each, installed. This item includes the all of the software and hardware necessary for a complete installation.

**Fiber Optic Drop Cable**

The Department will measure the Fiber Optic Drop Cables by the linear feet to the nearest foot. This item includes all materials, labor, tools, equipment, backlashing, and incidentals necessary to complete the work, and all testing and documentation.

**Interconnect Cable - Fiber Optic**

The Department will measure the Interconnect Cable-Fiber Optic Cables by the linear feet to the nearest foot. If the alternate to install separate SM and MM cables is selected, this bid item will cover both cables. This item includes all materials, labor, tools, equipment, backlashing, and incidentals necessary to complete the work, and all testing and documentation.

**Fiber Optic-Splice Closure & Aerial Splice Closure**

The Department will measure the Fiber Optic-Splice Closure and Aerial Splice Closure per each. This item includes all materials, labor, tools, equipment, and incidentals necessary to complete the work, and all testing and documentation.

**Fiber Optic Termination Panel**

The Department will measure the Fiber Optic Termination Panel per each installed. Termination panels shall contain the necessary fiber optic connector modules, labels covers and associated splicing for locations indicated on the Plans. This item includes all materials, labor, tools, equipment, and incidentals necessary to complete the work, and all testing and documentation.

**Fiber Optic Fusion Splice**

The Department will measure the Fiber Optic Fusion Splice per each splice location. The item shall include but not limited to, all 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.

**Fiber Optic Storage Bracket**

The Department will measure the Fiber Optic Storage Bracket per each. This item includes all materials, labor, tools, equipment, and incidentals necessary to complete the work, and all testing and documentation.

**Fiber Optic Splicing Training**

The Department will measure the Fiber Optic Splicing Training by the lump sum. This item includes all training information, training schedule, equipment, and materials to provide the training

**730.38 Basis of Payment**

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

<i>Item</i>	<i>Pay Unit</i>
Traffic Signal	Lump Sum
Removal of Signal Equipment	Each
Signal Head Assembly (Description)	Each
Install Pull Box (Description)	Each
Electrical Service Connection	Each
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
Portable Traffic Signal (Type)	Each
Fiber Optic Drop Cable (Description)	Linear Feet
Interconnect Cable-Fiber Optic (Description)	Linear Feet
Fiber Optic Splice Closure	Each
Fiber Optic Termination Panel (Description)	Each
Fiber Optic Fusion Splice	Each
Fiber Optic Aerial Splice Closure	Each
Fiber Optic Storage Bracket (Description)	Each
Modify Existing Fiber Optic Termination Panel	Each
Training	Lump Sum

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.

The Fiber Optic Connectors, Patch Cables, and Cable Labels are included in the quantities of other pay items and will not be measured separately for payment.