

STATE
(Rev. 6-24-19)

OF

TENNESSEE
January 1, 2015
City of Morristown
Hamblen 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.

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 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

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

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

730.05 Working Drawings

Vendor Requirements

Be familiar with the specifications. Note any exceptions with the bid documents, no matter how small, and reference the specific paragraph(s) where the exception(s) occurs.

Provide a complete documentation package with the control equipment provided, to include the following, at a minimum:

1. A manual on the operation, maintenance, and installation of the equipment to be provided in this contract. This manual shall contain detailed instructions for the proper operation and maintenance of the equipment provided.
2. Electrical schematic / logic diagrams for all equipment are to be housed in the cabinet. Such diagrams shall be detailed to provide sufficient knowledge regarding the proper maintenance of the unit. Circuit designations on the schematic logic diagrams shall correspond to the circuit designation of components on the circuit boards. Circuit board component designations shall be permanently affixed to the circuit board by a permanent process such as silk-screening.
3. Controller cabinet wiring diagrams for each cabinet. Such diagrams shall include all cabinet wiring for the particular cabinet supplied. "Typical" drawings will not be accepted. Drawings will be assigned a specific drawing number, which shall relate to the City order as well as the equipment supplied. The controller vendor shall retain the original copy of the cabinet drawing for file reference for the future.

Certify with the bid that the cabinet engineering, design, and fabrication were accomplished at facilities under the direct control of the manufacturer. The controller manufacturer shall be required to maintain all records documenting the engineering, fabrication, and quality control of the equipment supplied. Such records shall be available to the City upon request at no charge to the City.

Provide each cabinet with a clear sealable envelope for the storage of cabinet drawings.

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 a technical training session for all equipment to be provided in this contract. Such training shall be supplied at a facility agreed upon by the vendor and the City and at a time of not more than 90 days after request for training by the City. Such training shall be of a highly technical nature and shall be conducted by a person in the employ of the controller manufacturer or distributor.

The training shall be available for up to five persons to be named by the City. The training shall involve at least one eight hour class or work session in the field, unless the maintaining agency determines a lesser time is adequate. Provide a complete set of documentation materials for each person in attendance. Material covered shall include the operation as well as maintenance of all elements provided. Submit a draft outline of the proposed training topics to the City of Morristown for approval at least 14 days in advance of scheduled performance.

Provide the training for City personnel at no cost to the City. After the required training, certify to the Engineer that training has been completed.

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.

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. Additional pull boxes may be required where conduit runs are more than 150 feet long. The maximum spacing between pull boxes shall be 150 feet, unless otherwise directed by the Engineer. 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.

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.

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 40 or 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.

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 40) 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.
3. Attach cables to messenger with non-corrosive lashing rods or stainless steel wire lashings.
4. All wiring within enclosed cabinets shall be neatly formed and harnessed and shall have sufficient length for access and servicing.

730.18 Service Connection

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

730.19 Sealant

Provide sealant material selected from the Qualified Products List maintained by the Department's Material and Test Division for sealing saw-cuts. The sealant material shall resist the upward movement of loop and lead-in and shall exhibit stable dielectric characteristics, including a low 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.

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.
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.

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. 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 polycarbonate and all associated parts/hardware shall be of non-corrosive material. All signal head doors, visors, and signal bodies shall be black in color. Visors shall be tunnel visors. 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.

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.

Mount signals to mast arms with a bracket secured by cables to the mast arm, so that the signal head is rigidly mounted but adjustable in height, horizontal direction, and vertical direction. Signal head brackets shall be aluminum or galvanized metal. If the masts are painted, signal head mountings shall have one or more coats of primer followed by two coats of high quality resin enamel to match mast arms.

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 cylinders and vanes of polycarbonate whose color matches the signal bodies.

D. Back Plates

Where shown on the plans furnish back plates and attach to the signal heads. All back plates shall be polycarbonate. Construct back plates so as to permit installation after signal heads are in place. Back plates shall have a black appearance and shall provide a 5" wide border around the signal head. Provide a retroreflective strip which meets or exceeds MUTCD.

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.

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.

The APS shall have the capability to provide the following audible options: agency-created verbal messages and sounds (audible locating tone, chirp sound, and cuckoo sound).

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

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.
10. Be a Siemens m60 Series ATC, which meets the minimum requirements listed in this section.
11. Include a front mounted 10/100 Mbps Ethernet Port that can be configured with specific network parameters such as an IP address. The controller shall also include an available serial port for connection to the conflict monitor so that its information can be uploaded through the controller. The controller shall have a Data key option to carry data from controller to controller.
12. Include an RS-232C interface and connector for interconnecting to a printer, another like controller unit, a local personal computer, or a remote personal computer through an external modem. Peripherals are to be supplied by others.
13. Contain the necessary communications ports to provide the communications called for in the Plans, Specifications, and/or Special Provisions. All controller units shall be capable of interconnection by twisted pair cable, spread spectrum radio, Ethernet, or fiber optic cable as required on the Plans, Specifications, and/or Special Provisions.

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 4th 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 4th 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
 - c. The external data communications pair (twisted pair FSK cable) shall be protected at the cabinet entry point by a two-stage series of hybrid device capable of withstanding a peak surge of 4,000 amps, 8 - 20 microsecond waveform. The device shall have a minimum life of 50 surges at 4000 amps with a response time of less than 20 nanoseconds.
 - d. If radio communication is required in the cabinet assembly, install a coax arrester in line with the coax input from the antenna meeting the following:
 1. Surge protector type: blocking cap and gas tube
 2. DC handling: DC block
 3. Frequency range: 10 – 1,000 MHz
 4. Impedence: 50 ohms
 5. Voltage standing wave ratio (VSWR): 1.1:1 minimum
 6. Return loss: 26 dB maximum
 7. Insertion loss: 0.1 dB maximum
 8. Input power: 1.5 kW maximum
 9. Surge current: 20 kAmps maximum, IEC 61000-4-5 8/20 μ s waveform
 10. Turn on voltage: 600 V \pm 20%
 11. Throughput energy: 3,500 μ J @ 3 kA 8/20 μ s waveform
 12. Connectors: N Female input & output
 13. Temperature: operating range -50 to 50 °C; storage range -55 to +85 °C

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 μ 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 μs 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

Cabinets must be permanently marked with a label including the manufacturer's name or trademark, model/part number, and the year and month of manufacture. The label should be placed on the inside of the main door using a water resistant method. The label must be visible after installation.

Cabinets shall be provided as a complete unit and have all terminals and facilities necessary for traffic signal control as shown on the plans and shall meet at a minimum, the following requirement:

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The manufacturer must supply certification of the conformance to the above requirements at the time of the bid. Cabinets shall also be in accordance with the latest version of the TDOT Traffic Design Manual.

Two paper copies of the cabinet wiring diagram shall be provided with each cabinet. The nomenclature of signal heads, vehicular movements and pedestrian movements on the wiring diagram must be in accordance with the signal operating plan. Documentation must include a list identifying the termination points of cables used for vehicular and pedestrian signal heads, detector loop lead-ins, and pedestrian pushbutton wires. A heavy duty, resalable plastic bag must be mounted on the backside of main cabinet door for storing cabinet documentation.

House the controller in a rigid, weatherproof cabinet, constructed, finished, and equipped as follows, and as shown on the Standard Details:

1. **Material.** Provide weather-tight cabinets fabricated from aluminum sheet or cast aluminum alloy with a minimum 0.125-inch thickness. All welds on fabricated cabinets shall be internal and continuous; spot welding is not acceptable. Painting of cabinets is only required if the final finish presents an unsightly appearance.
2. **Doors.** Type III, IV, and V cabinets shall have a hinged front opening door that shall include substantially the full area of the front of the cabinet. Equip the door 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. The holdfast device shall be easily secured and released without the use of tools. Equip doors for Type II, III, IV, and V cabinets with a switch compartment, and provide the manual switches, specified in **730.26.6.k**, with a hinged front opening auxiliary door. Each door shall have a gasket to provide a weatherproof seal when closed. Doors for the cabinet and police subpanel shall be right-hinged.

Provide the main door with a No. 2 pin-tumbler cylinder lock, and the auxiliary door with a standard police sub-treasury lock. Provide four keys for each lock.

Provide a switch which is to be tied to the cabinet light so that cabinet light will be on when the door is open and off when the door is closed.

- 3. **Cabinet Mounting.** Mount cabinets as shown on the Plans or Standard Details.

- 4. **Ventilation.** Unless otherwise specified, provide ventilation as follows:
 - a. On all cabinets housing controllers, mount a screened, rain-tight vent, 1-1/2 inches in diameter or larger, on the cabinet top.
 - b. Provide screened or filtered inlet ventilation openings, equal to or greater in area than top vents, located in the bottom or lower back side of Type I and II cabinets or around the lower 8 inches portion of Type III cabinets.
 - c. Construct the vents so as to project within the cabinet no more than necessary to provide for lock nuts and gaskets to retain the vent.
 - d. Locate vents so as to not interfere with the mounting of controller equipment.

- 5. **Cabinets with Exhaust Fans.** Exhaust fans shall consist of an electric fan with ball or roller bearings and a capacity of at least 100 cubic feet per minute. Mount the fan in a rain-tight housing attached to the top of the controller cabinet.

The fan shall be controlled by a thermostat having a temperature differential between turn-on and turn-off of 15 °F (-0, +5 °F), adjustable for turn-on through a minimum calibrated range of from 100 °F to 150 °F.

Whenever a fan is to be installed, provide the air inlet filter and filter holder shown in the Standard Details, or approved equal. Internally seal other air inlets. Provide exhaust fans in all cabinets that house controllers, with the exception of flasher controllers.

- 6. **Auxiliary Equipment.** With the exception of cabinets used in special applications (Type I and II), provide all cabinets with the following:
 - a. Substantial shelves or brackets to support controller and auxiliary equipment.
 - b. Panel for terminals arranged for adequate electrical clearance. Panels should be located in the cabinet as described below:

- Detectors Lower left wall
- AC power Lower right wall
- Auxiliary/police switches Door
- Load switch bay Back wall

Place all controller wiring, signal monitor wiring, etc., on a single panel mounted on the rear wall. Silk-screen label all terminals on the rear wall panel according to a number sequence, which will identify all termination points.

- c. The cabinet shall include an LED light and GFI duplex receptacle which can be used when the main circuit breaker is off.
- d. Control panel assembly consisting of:
 - 1. Power supply connections made to a 30-ampere circuit breaker mounted on the cabinet separate from the signal terminal panel. The circuit breaker shall be a magnetic trip type, having an interrupting capacity of at least 2,000 amperes at 125 volts AC. The circuit shall trip between 101% and 125% of rated load, with an inverse time delay characteristic provided. Instantaneous tripping shall occur at ten times the nominal rating. All controllers shall be internally fused.
 - 2. Service line surge protection
 - 3. Electrical service termination point sized to accept No. 4 AWG copper wire

4. Ground fault receptacle
 5. Porcelain lamp receptacle to accept a standard traffic signal lamp. If LED lenses are utilized, they shall be dimmable and switchable to reduce glare at night time.
 6. Circuit breakers in accordance to the National Electric Code for:
 - (a) Main power input to provide all power associated with normal operation.
 - (b) Flasher power input to provide all power associated with flash operation.
 - (c) Service power to provide power for the lamp and duplex receptacle and cabinet light.
 7. Copper ground bus (minimum of 12 positions).
- e. Flasher mechanism independent of controller. The cabinet shall be wired for and include a NEMA flasher mounted on the back panel. All cabinets shall have a two-circuit flasher. The flasher shall have output indicators mounted on the front of the flasher case and shall be rated at a minimum of 15 amperes. The cabinet wiring shall be such that it shall be possible to program each phase output to flash Red, Yellow, or No Flash. Flash programming shall employ simple measures using color-coded jumper wire(s) to indicate flash output.
- f. General purpose relays, where required to perform specified functions. All relays external to the controller or appurtenances shall meet NEMA standards. In addition:
1. Flash transfer relays shall be of heavy-duty type and have a minimum contact rating of 10 amperes. Contacts shall be of silver material to reduce contact pitting.
 2. Unless otherwise specified, each cabinet shall include six (6) flash transfer relays.
 3. Flash transfer relays shall support Flashing Yellow Arrow for Permissive Left-turn movement applications.
- g. Type II, III, IV, and V cabinets, when specified as housing for traffic actuated controllers, with two or more insulated terminal blocks mounted within the housing, one or more for terminating each field wire.
- h. A minimum of 12 available bare ground positions tied to AC Common Return.
- i. Earth (driven) ground tie point to terminate a single No. 4 AWG copper ground.
- j. A tie point to tie all ground systems within the cabinet to a single reference point. All grounds (AC - return, Chassis, and Logic Ground) must be referenced to a single ground point at the electric service.
- k. A panel (police subpanel) shall contain the following:
1. A main power switch, which shall be wired to remove all cabinet power when in the Off position.
 2. An Automatic Flash switch, which shall be wired as follows:
 - (a) The Flash position shall cause the cabinet to provide Flash Operation. The controller shall continue to operate, and Stop Time shall be applied to the controller.
 - (b) Auto/Manual switch to activate Manual Control Enable.
 - (c) Manual control pushbutton switch with self-coiling cord. Cord shall attach to a 2 position terminal strip via fork type connector
 - (d) Upon return from Flashing to Automatic, the controller shall initialize in the Start-Up Display condition as programmed in the controller, typically major road phases.
 3. A panel mounted inside the main door shall contain the following switches:
 - (a) A technician Stop-Time switch to apply Stop Time to each controller ring.
 - (b) An Interval Advance switch, enabled only by the Stop Time switch, to be momentary pushbutton switch to apply Interval advance to the timer.
 - (c) A Signal On-Off switch, which shall remove the AC power applied to the signal heads for normal operation while the controller continues to operate.

- (d) Individual phase vehicle and pedestrian detector test switches to be miniature toggle of the On-Off Momentary type to place:
 - i. No Call - Call provided by detectors
 - ii. Locked detector call
 - iii. Momentary detector call

Insulate or shield switch terminals on back of main cabinet door so that no live parts are exposed.

Leads from the terminal block to the auxiliary door switches shall be no less than No. 18 AWG stranded, with TW plasticized polyvinyl chloride or nylon insulation enclosed in an insulating loom, and shall be of sufficient length to allow full opening of the main cabinet door.

- l. The cabinet shall be wired with the appropriate number of load switches to accommodate vehicular and pedestrian phasing according to plans. At a minimum, cabinets shall include 16 load switch bases. The load switch wiring shall support Flashing Yellow Arrow for Permissive Left-turn Movement applications. Provide resistor loads for any unused Load Switch Outputs. Mount load switches on the rear panel near the field outputs.
- m. All cabinet wiring shall be neatly routed and labeled, laced and permanently secured. All cable shall be secured to the panel, where practical. There shall be no holes drilled through the cabinet walls to mount panels or secure cables.
- n. All terminals in the cabinet shall be of the barrier type. The following field connector terminals shall be provided:
 - 1. Four (4) signal output positions per load switch bay (R-Y-G-FL).
 - 2. Ten (10) positions per phase for vehicle loop detector harness.
 - 3. One position per phase for pedestrian detector inputs.
- o. Cabinets shall have SDLC communication between the controller, MMU, Detector Rack, Radar Detector (if applicable) and Video Detection (if applicable).
- p. Cabinets should have an electrical outlet (Non GFI) that has 120 VAC from the OUTPUT side of the Main Power Surge unit.
- q. Cabinets shall support Flashing Yellow Arrow for Permissive Left-turn Movements applications.
- r. All cabinets shall be supplied with a shelf-mountable, 16 channel, solid-state Malfunction Management Unit (MMU) with Ethernet capability. The MMU shall meet, as a minimum, all applicable sections of the current NEMA Standards. Where differences occur, this specification shall govern. The system supplied must be fully compatible with the Controller Timer specified in this provision.

Supply all cabinets with an EDI MMU2-16LEIP SmartMonitor. The MMU shall have the following features:

- 1. Liquid Crystal Display to show all data in English language format.
- 2. Capability to monitor all Green/Yellow/Red/Walk/Don't Walk field display outputs.
- 3. Capability to monitor the Controller 24 VDC output and be user programmable to have this monitor function Latch On.

4. Capability to monitor the Controller Voltage Monitor output, and be user programmable to have this monitor function Latch On.
5. Per Channel monitoring of Phase Yellow Clearance Interval, and shall cause flash operation if Yellow Clearance is less than the MMU programmed time (2.7 - 9 seconds).
6. Front panel mounted over-current protection (no internally mounted fuses are acceptable).
7. Front panel mounted reset switch.
8. Fault logging features - the MMU shall log all faults as to the:
 - (a) Date of fault
 - (b) Time of fault
 - (c) Fault condition
 - (d) Power failure

and store these fault conditions in no-volatile memory for user retrieval. The monitor shall be able to store at least ten such faults. The internal time clock shall automatically adjust for Daylight Savings Time changes. There shall be a keyboard method for the user to display and clear the stored event log.

9. There shall be an RS-232 port on the MMU to allow the user to print all data stored in the MMU. The printer shall interface with the MMU via a standard RS-232 cable. Printer to be supplied by others.
10. The MMU shall detect the following conditions and place the cabinet in the flash mode by de-energizing the Flash Transfer Relays:
 - (a) Absence of an active AC input on a channel
 - (b) Green/Yellow both active on a channel
 - (c) Yellow/Red both active on a channel
 - (d) Green/Red both active on a channel
 - (e) Walk/Yellow active on a channel
 - (f) Green/Green active on conflicting channels
 - (g) Green/Yellow active on conflicting channels
 - (h) Green/Walk active on conflicting channels
 - (i) Low 24 VDC sample
 - (j) Controller Voltage Monitor active
 - (k) Clearance time less than programmed
11. On circuits where all field outputs are not used (such as left-turn phases), unused circuits shall be terminated at a load resistor and the monitor plus features shall function.
12. No functional field display shall be permitted unless monitored by the MMU.
13. Terminate the MMU sampling inputs at the closest tie point to the field termination.

In addition, the MMU shall meet the following:

1. Front Panel and Connectors
The MMU shall include a four line by 20 character alpha-numeric LCD display to report MMU status, time and date, menu navigation, etc. This display shall be separate from the full intersection channel status display.

The MMU shall have separate indicators for the Red, Yellow, and Green channel statuses which shall display simultaneously on the LCD screen. For Type 12 mode operation, the MMU shall provide separate Red, Yellow, Green and Walk indicators. The MMU shall provide individual icons to indicate channels involved in a fault.

The MMU shall have an Ethernet port capable of both 10 and 100 Mbps operation on the front panel. The Ethernet port shall be electrically isolated from the MMU electronics using optical couplers and shall provide a minimum of 2500 VRMS isolation. The connector shall be an RJ45 eight pin connector.

2. Monitor Configuration Parameters
All NEMA standard configuration parameters shall be provided by a program card meeting the requirements of NEMA. All configuration parameters for functions and options beyond the requirements of the standard shall be stored in non-volatile memory within the MMU. This memory shall be programmable from the front panel menu driven interface, data downloaded via the Ethernet port, or loaded from shadow memory located on the program card.
3. Ethernet Port HTML Interface
An HTML based capability shall be provided in the MMU to configure the network parameters of the MMU Ethernet port using a standard HTML browser.
4. Reports
Traffic controller and MMU shall transfer data via RS232 and Ethernet ports for purposes of data logging when requested. Logs will provide, at a minimum:
 - (a) Date and time stamp of all AC power line disturbances
 - (b) MMU faults
 - (c) Program card and front panel programming
 - (d) Intersection station ID and text description of the location at the top of each report
- s. Provide noise suppression as follows:
 1. Provide auxiliary relays, fan, and thermostat with a resistor/capacitor circuit to suppress generated noise.
 2. Provide an RF Filter in controller cabinets capable of filtering of RF noise over the range of 60 kilohertz through 20 megahertz. The RF filter may be incorporated as part of the Main Power Suppressor.
 3. Provide cabinet noise suppression as required by the particular controller.
- t. Provide adequate cabinet space and clearances to house any standardized NEMA device with maximum allowed NEMA dimensions without modifications to or adjustments of cabinet wiring or appurtenances.
- u. Certify in writing that the vendor has operated the controller and all of the auxiliary equipment successfully for a period of not less than 50 hours burn-in time.
- v. When required in the plans, provide priority control systems for establishing priority for detected movements to allow preemption for emergency vehicles or priority for transit vehicles. All priority control equipment shall meet NEMA environmental specifications. Provide ample lightning protection to provide effective defense against high transient voltages caused by lightning discharges or from other sources.

Provide priority control systems of the following type: 3M Opticom Infrared, GPS. The system shall be a data encoded matched component system to ensure system security and prevent unauthorized use.
- w. Where specified in the plans, include an Ethernet access device (EAD) with the cabinet assembly.

The traffic interconnect network element (client network element) shall operate on the existing Morristown Utility Service (MUS) Virtual Private LAN Service (VPLS) Network operated and maintained by the MUS.

The MUS VPLS network shall provide IP network access from traffic control equipment to a client point of service. The VPLS connection shall be located in a traffic control cabinet and be connected to an Ethernet field switch.

1. **Integrated Ethernet Switching Capabilities**

For the purpose of this specification, the Managed Ethernet Switch (MES) shall be a managed layer 2 switch, having (7) 10/100 RJ45 ports and (2) 1000Mb SFP Gigabit ports and meeting the following requirements.

 - (a) The SFP slots can be populated with user selected SFP gigabit fiber transceivers.
 - (b) The MES shall consume 10 Watts of power or less under full operating conditions.
 - (c) The MES shall use convection cooling and require no venting of the case. This will prevent dirt and contaminants from being introduced into the electronics of the switch.
 - (d) The RJ45 ports of the MES shall automatically negotiate both speed and duplex. Power input shall be supplied to the MES by a fully integrated power supply.
 - (e) Warranty shall be 5 years for all parts and labor.
2. **Device Management Capabilities**

The MES shall:

 - (a) Support remote management via SNMP, web (HTTP), and Telnet.
 - (b) Have CLI command line interface, accessible via serial cable, telnet, and SSH.
 - (c) Support SNMP v1, v2, and v3, rich commands including access control and remote monitoring via third party network management software.
 - (d) Support SNMPv3 for encrypted authentication and enhanced access security.
 - (e) Support RMON (RFC 1757).
 - (f) Support ability to enable/disable ports, MAC based port security.
 - (g) Support VLAN (802.1Q) to segregate and secure network traffic.
 - (h) Support Radius Server and TACACS+ for enhanced security and a centralized means of managing switch access.
3. **Switching Capabilities**

The MES shall:

 - (a) Provide 1.8 Gbps switching bandwidth
 - (b) Have a latency of no more than 8 μ s (100Mbps)
 - (c) Support 8152 MAC addresses
 - (d) Support store and forward with IEEE 802.3x full-duplex flow control. All ports non-blocking.
 - (e) Support MAC and IP Address Conflict Detection.
 - (f) Perform Enhanced Broadcast Storm Control.
4. **Protocol Support**

The MES shall support:

 - (a) 802.1Q VLAN tagging and VLAN trunking support.
 - (b) Industry standard Spanning Tree Protocol, 802.1D, and the latest 2004 version of industry standard Rapid Spanning Tree Protocol, IEEE 802.1w for interoperability.
 - (c) Link Aggregation 802.3ad port trunking.
 - (d) QoS, multi-level 802.1p.
 - (e) IGMP v1 and v2 for Snooping and multicast pruning.
 - (f) IGMP Snooping, which allows management of multicast streams, while remaining a layer 2 device.
 - (g) Port Mirroring for selective traffic analysis.
 - (h) The following additional protocols: IEEE802.3, IEEE802.3u, IEEE802.3x, IEEE802.1q
5. **Mechanical Specifications**

The MES shall:

 - (a) Have an enclosure of a minimum of 20 gauge galvanized steel.
 - (b) Be capable of DIN rail or panel mounting. Approximate dimensions shall be 2.5" x 7.5" x 5.0" (W x H x D).
 - (c) Weigh less than 3.0 lbs.

- (d) Have status LED indicators for Power and System Status. It shall also have status LEDs for each Ethernet port showing Ethernet Link and Activity.
 - (e) Have an operating temperature rating of -40 to 85°C (-40 to 185°F).
6. Industrial Certifications and Approvals
The MES shall have met or complied with, at a minimum, all the following approvals or standards.
- (a) IEC61000-4-2(ESD)
 - (b) IEC61000-4-3(RS)
 - (c) IEC61000-4-4(EFT): ±4KV power line
 - (d) IEC61000-4-5(Surge): power line ±4KV CM/ ±2KV DM, data line ±2KV
 - (e) IEC61000-4-6(CS): 10V (150 KHz-80MHz)
 - (f) IEC61000-4-8(Power frequency magnetic field):100A/m ct.
 - (g) IEC61000-4-10(Damped oscillatory):30A/m
 - (h) IEC61000-4-12/18(Damped oscillatory wave):2.5KV CM, 1KV DM
 - (i) IEC61000-4-16(Common mode conduct):30V cont. 300V, 1s
 - (j) FCC CFR47 Part 15/EN55022: Class A&B
 - (k) IEC61000-6-2 (Industrial Standards)
 - (l) IEC61850-3 (Substations)
 - (m) IEEE1613 (Electric Power Substations)
 - (n) NEMA TS-2 (Traffic Control Equipment)
- x. When specified on the plans or the bid documents, wire card rack assembly in place. The card rack assembly shall have slots spaced at 2.25" to facilitate the use of 2" or 2.25" detectors.

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

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.

When required in the traffic signal plans, the auxiliary equipment listed below shall meet the following requirements:

A. Uninterruptable Power Supply (UPS)

Provide Uninterruptable Power Supply (UPS) equipment at required intersections as shown in design plans. The UPS shall also include the items listed in the specifications as well as other equipment required for the operation and maintenance of the traffic signals and associated equipment. Conduct a performance design study for the UPS. The UPS shall be able to fully operate the intersection for the time specified on the plans.

1. Components**a. Electronics Module**

The Electronics Module shall consist of the following:

1. True on line, double conversion, pure sine wave, high frequency inverter utilizing IGBT or other City-approved technology.
2. 3-stage, temperature compensated, battery charger.
3. Dedicated harnesses with quick-release, keyed connectors and braided nylon sleeving over all conductors, for connection to the Battery System.
4. Local individual LED indicators for AC input, inverter, summary alarm, UPS output, battery status, load levels, with backlit LCD screen to display additional information via menu inputs.
5. Local and remote communications capabilities.
6. Capability of accepting an NTCIP-ready adapter capable of accepting Ethernet or fiber optic communications.
7. Two external serial ports located on the front panel.
 - (a) The Signal serial port shall provide the option to select alarm output functions. These functions shall be open collector type contact closures that the user can assign as signal utility interrupt, low battery and inverter active conditions or utility fail indicate.
 - (b) The RS232 Signal port shall provide an intelligent interface for connection to software systems for monitoring and control, including internet connections.
8. Connectors or terminal strips which can be used to send open collector type contact closures that the user can assign as signal utility interrupt, low battery and inverter active conditions to the signal controller auxiliary alarm inputs.
9. On-site programming without the use of attached computers.
10. Option for power connection to the front or back of the UPS chassis to support NEMA or rack-mounted cabinetry.

b. Manual Bypass Switch Module

1. The UPS shall incorporate an automatic, internal safety bypass capability and a manual Bypass Switch module that contains a manual switch and a terminal strip for input and output power connections.
2. An optional interface connector shall be available that allows an external generator or vehicle inverter to supply utility power when commercial utility has failed.
3. The UPS shall supply 120Vac, 60Hz, true sinewave power when connected to either a generator or digital inverter power system in addition to maintaining the 3-stage battery charging system.

c. Battery System

1. The battery panel size and capacity shall be based on the cabinet size and load requirements of the intersection.
2. Batteries shall have an ampere-hour rating as appropriate for the load.
3. Batteries shall meet MIL SPEC B-8565J for hydrogen gas emissions.
4. The battery shall be comprised of extreme temperature, deep cycle, AGM/VRLA (Absorbed Glass Mat/Valve Regulated Lead Acid) batteries that have been field proven and tested by the U.S. military. An alternative battery type may be approved at the City's discretion.
5. Batteries shall be certified to operate at extreme temperatures (from -40°C to +74°C (-40°F to +165°F)) and shall not require the aid of any external devices to cool or heat the batteries.
6. The batteries shall connect to the Electronics Module via a provided keyed interconnect wiring harness with a minimum length of 5 feet.

7. The interconnect cable shall be protected with abrasion-resistant nylon sheathing and shall connect to the base module via a quick-release connector.
8. Battery construction shall include heavy-duty, inter-cell connections for low-impedance between cells, and heavy-duty plates to withstand shock and vibration.
9. A cabinet shall be provided meeting the following requirements.
 - (a) A single cabinet may be used to house the signal equipment and battery system, provided it meets all requirements of the specifications for the signal cabinet and that it has a compartment for housing the batteries which is physically separated from the other equipment by a partition.
 - (b) A separate external cabinet may also be used to house the battery system. The external cabinet shall be a Universal Design style cabinet with EIA rack, light, fan, and vents with front and back door. The enclosure shall be installed on a concrete or fiberglass pad, as specified by the City, to extend a minimum of two feet beyond the cabinet on the front and back sides.

2. Specifications

a. Electrical

1. Nominal Input Voltage: 120 VAC, Single Phase
2. DC Battery Bus: As Appropriate for Load
3. Input Voltage Range: 85 VAC to 140 VAC
4. Input Frequency: 60 Hz (+/-5%)
5. Input Configuration: 3 Wire (Hot, Neutral & Ground)
6. Nominal Output Voltage: 120 VAC (+/- 3%), Single Phase
7. Power Rating: As Appropriate for Load
8. Output Voltage Regulation: +/-2% for 100% step load change and from High battery to Low battery condition
9. Output Frequency: 50 or 60 Hz (+/-5%)
10. Output Configuration: Keyed connectors and duplex receptacle
11. Output Wave Form: True sine wave
12. Overload capability: 110% for 10 minutes, 200% for 50 milliseconds
13. Fault clearing: Current limit and automatic shutdown
14. Short circuit protection: Current limit and automatic shutdown
15. Efficiency: 85% at full load
16. Load Power Factor: 0.7 lagging through unity to 0.7 leading

b. Environmental

The UPS system, including batteries, shall:

1. Meet or exceed NEMA temperature standards from -40° C to +74° C (-40°F to +165°F).
2. Be certified and field proven to meet or exceed NEMA temperature standards. A certificate of compliance from an independent testing facility shall be made available upon request.

c. Physical

The Electronics Module shall be no larger than:

1. Rack-mount: Width = 19", Depth = 13", Height = 3.5" (2U)
2. Shelf-mount: Width = 19", Depth = 13", Height = 3.5"
3. Wall-mount: Width = 19", Depth = 13", Height = 3.5"

d. Mounting/Configuration

1. Universal Design, 170 Style, 19" rack-mount.

3. Surge Suppression

Provide surge suppression that meets NEMA standard to protect the entire UPS.

4. Operation

- a. The UPS shall be capable of simultaneously producing fully regenerated and regulated, conditioned and true sine wave power with continuous and hot standby AC output capability to all connected devices requiring backup power.
- b. The UPS inverter shall be on at all times to produce continuous, clean, regulated power to all loads. The continuous power output shall be provided for all equipment at the site up to the

maximum load rating; also, a programmable digital delay timer shall be included for short-term battery run under full cycling operation.

- c. Upon loss of utility power the UPS shall utilize battery power in support of the system via a supplied Electronics Module. In the normal operation, the UPS shall be operated in the real-time true on-line mode with the inverter supplying power to all cabinet loads, at all times. In addition, the UPS can be operated in hot standby mode with power transfer being accomplished in 100 msec or less. In the event of UPS failure and/or battery depletion, the Electronics Module will ensure that the UPS will drop out and, upon return of utility power; the system will default to normal operating mode.
 - d. The Electronics Module shall enable removal and replacement of the UPS without shutting down the system (i.e. "hot swap" capability). Connectors shall be equipped with a "safety interlock" feature. The UPS shall support generator input without going to batteries.
 - e. The UPS shall be fully power factor corrected under all operating conditions.
 - f. Each UPS shall be provided with a media containing Windows based configuration software.
 - g. The UPS shall be capable of starting solely from batteries when no utility AC is available.
 - h. The UPS will be able to exercise and determine the status and capacity of all battery strings on a continuing basis and calculate an accurate backup time. The depth of discharge value can be adjusted if more backup time is required versus battery life.
 - i. The voltage at which the UPS switches to battery power and then back to the AC line shall be settable by the user. An over-voltage point can also be set where the UPS switches to battery power if too high of a voltage is sensed on the AC power line.
5. Communication, Controls and Diagnostics
- a. Alarm function monitoring through the UPS shall be through a standard DB9F connector with open collectors (40V@20mA) indicating:
 1. Loss of utility power
 2. Inverter failure
 3. Low battery
 - b. An RS232 interface shall be provided via a DB9F connector or USB to allow full interactive local computer monitoring and control of the UPS functions.
 - c. A 10/100 Mbps Ethernet Port shall be provided on the front panel to allow full interactive remote computer monitoring and control of the UPS functions.
 - d. Front panel controls shall consist of no less than: Power On, Cold (DC) Start, Alarm Silence, Battery Test, Bypass Breaker, and DC/Battery Breaker.
6. SNMP Internal/External Adapter
- The UPS shall be equipped with a SNMP/HTTP card which functions as an SNMP agent and includes an embedded HTTP server (web server). This will allow the UPS system to be monitored and controlled from one central location. The SNMP adapter shall allow alarms ('traps') to be configured to ensure automatic notification of events such as low battery, power outage, or UPS overload. MIBs shall be included with the product for integration into the City's third party traffic management system software. Control and management functions shall also be available through any standard web browser (Internet Explorer, Chrome, or Firefox).
- a. Additional SNMP Features
 1. Configurable from serial port or web browser
 2. Management from SNMP manager or web browser
 3. Supports most network management systems via MIB definitions
 4. Firmware upgrades by TFTP via serial port
 5. Full-featured GUI runs in web browser
 6. Accessible from any workstation on the network using SNMP/HTTP
 7. UPS warning broadcast capability
 8. Real time monitoring of all functions
 9. Full history logs
 10. Scheduling functions
 11. Certifications: CE, FCC Class B
 - b. SNMP Technical Specifications

1. LAN Interface: Auto-sensing 10/100Mbps Fast Ethernet
2. Serial Port: Two asynchronous serial ports
3. SNMP MIB: RFC1213, RFC1268, USHA MIB
4. Network Protocol: TCP/IP, UDP, SNMP, Telnet, SNTP, HTTP, SMTP
5. LED: Power, Status, LAN 10/100 Link
6. Miscellaneous: Real-Time-Clock, Reset button
7. Firmware upgrading: Network Upgrade and Serial Upgrade
8. System Security: Provides IP-based filtering & password protection
9. Approvals: CE, FCC Class B
- c. SNMP Operating Systems Supported
 1. Microsoft Windows XP/2003, 7, 8, 10
 2. Novell 4.x thru 6.x
 3. Solaris (x86 version) 2.6/2.7/2.8
 4. Solaris (Sparc version) 7/8/9/10
 5. Linux-derivatives OS (Kernel 2.x or later).
7. Serviceability, Reliability, Maintainability, and Warranty
 - a. Mean-Time-Between-Failure (MTBF) for UPS shall be 75,000 hours.
 - b. Mean-Time-To-Replace or Repair (MTTR) for both Electronics and Battery System shall be 15 minutes or less each.
 - c. The UPS shall include a manufacturer's warranty covering defects for a minimum of three years (5 years for the external batteries) from the date of final equipment acceptance. The warranty must include provisions for providing a replacement UPS within 10 calendar days of notification for any UPS found to be defective during the warranty period at no cost to the maintaining agency.

B. Communications

Wireless shall consist of installing a Wireless Network Communications Link with all necessary hardware in accordance with the plans and standard drawings to provide a data link between field devices (i.e. Traffic Signal Controllers).

Each link shall consist of Master ODU (Out Door Unit, Antenna) connected to a data switch within one of the signal cabinets and a Slave ODU connected to a data switch within the other signal cabinet. Each ODU is aligned to face the opposing ODU. The cable length between the ODU and its associated data switch may not exceed 300 feet.

The Wireless Network Communications Link components at each of the linked traffic signal cabinets shall include an ODU, a LPU (Lightning Protection Unit), power supply mounting hardware, and CAT 5e cabling. The ODU is pole mounted per manufacturer's specifications. The LPU and power supply are mounted within the traffic signal cabinet. CAT 5e cable is installed between the ODU and LPU.

For the applicable frequency spectrum of the radios being deployed, perform a spectrum analysis to ensure no competing equipment in the area. Ensure the radio path site survey test is performed using the supplied brand of radio equipment to be deployed. Typically, if the ODUs can be mounted with clear line of sight between them, this is sufficient to ensure proper operation. If this is not possible, it may be determined that a repeater station is necessary to complete the intended link. Provide the test results to the ENGINEER for review and approval. Submit copies of the test results and colored copies of the frequency spectrum scan along with an electronic copy of this information. The ENGINEER will approve final locations of the ODUs and any necessary repeater stations.

Install each ODU in such a manner that avoids conflicts with other utilities (separation distances in accordance with the guidelines of the NESC) and as specified in the ODU manufacturer's recommendations. Secure the ODU mounting hardware to the pole and route the CAT 5E cable such that no strain is placed on the RJ-45 connectors. Align each antenna/radio to be perpendicular to the ground (using bubble level) and to face the opposing radio.

C. Fiber optic cables

Multi-mode type fiber optic cable shall be 50 μm core diameter, with at least 12 fibers per cable unless otherwise specified in the plans. Single-mode type cable shall be between 8-9 μm core diameter, with at least 12 fibers per cable unless otherwise specified. A fiber optic drop cable shall be a minimum of 6 fibers (each type) and be spliced into the trunkline in a splice enclosure either aerially or in a pull box. 50ft. of slack shall be provided, either lashed to a span aerially, or coiled in a pull box for underground installations. Termination panels shall be provided with sufficient size to provide for a neat installation, and enough panel space to accommodate the specified number of fibers for termination. ST connectors shall be used unless otherwise specified. Any necessary jumpers shall be provided for installed equipment.

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.

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 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 Vehicle Detection System (RVDS)

Where specified in the plans, provide radar detectors which are Wavetronix SmartSensor,. Supply detectors which:

1. Have a manufacturer's warranty to be free of defects in materials and workmanship for a period of not less than 2 years.
2. Meet, as a minimum, all applicable sections of the NEMA Standards Publication No. TS2-2003. Where differences occur, this specification shall govern.
3. Are in full compliance with FCC CFR 47, part 15, section 15.249 as an international radiator. The detection unit shall comply with FCC regulations under all specified operating conditions over the life of the unit.
4. Present real-time presence data in up to 10 lanes.
5. Support a minimum of 16 zones and 16 channels with user-selectable zone to channel mapping.
6. Are designed to operate over a voltage range of 9.8 to 28 VDC.
7. Are designed to provide a continuous "fail-safe" (Fail-call) output in the event communication is lost to the unit.
8. Shall detect and report presence in lanes with boundaries as close as 6 ft. and within 140 ft. from the base of the mounting pole.
9. Detect and report presence in lanes within a 90 degree field of view.
10. Are able to detect and report presence in curved lanes and areas with islands and medians.

Each detector shall have a traffic cabinet pre-assembled back plate with the following:

1. AC/DC power conversion
2. Surge protection
3. Terminal blocks for cable landing
4. Communication landing blocks

In addition, the detector shall:

1. Be enclosed in an enclosure classified "f1" for outdoor weatherability in accordance with UL 746C and classified watertight according to NEMA 250 standard.
2. Be able to withstand a drop of 5 ft. without compromising functionality and structural integrity.
3. Have a method for automatically defining traffic lanes, stop bars, and zones without requiring user intervention, and also allowing manual input of the parameters.
4. Maintain accurate detection and reporting in all weather conditions including rain (up to 1" per hour), freezing rain, snow, dust, fog, and changes in temperature and light.

D. Wireless Magnetometer Detection System (WMDS)

When specified in the plans, the equipment shall consist of all items necessary to provide a complete functional wireless magnetometer detection system that process changes to earth magnetic field and provide detection outputs to the traffic signal controller.

WMDS shall be capable of NEMA TS2 operation.

The WMDS shall consist of the following components:

1. In-pavement sensors
2. All wireless communication equipment needed to establish communication links to the controller cabinet.
3. Interface modules compatible with NEMA TS-2 V2.06b cabinet detector rack.
4. Surge protection for the WMDS and system software for set-up and monitoring of the WMDS.

The WMDS shall be capable of the following:

1. Detecting a variety of vehicle types including motorcycles, automobiles and large trucks. The system must allow the user to select sensitivity levels that adjust the amount of hysteresis to the magnetic field needed to achieve contact closure to the assigned detector channel. Magnetometer sensitivity level adjustments must allow for different levels of vehicle detection.
2. The ability to configure presence, pulse, extend and delay outputs.
3. WMDS equipment failure such as: the sensor, communications link, access point radio, repeater radio (if used) or interface module, shall result in constant vehicle call "fault state" on the affected detector channel to the traffic controller.
4. Detection accuracy must be comparable to properly operating inductive loops.
5. Provide real-time vehicle detection (within 150 milliseconds (ms) of vehicle arrival). Once detection is achieved by the sensor, the traffic controller must receive contact closure to the assigned detector channel within the 150 ms time frame.
6. The in-pavement sensor must operate on batteries without the need for underground power or communication cable connections to the unit.
7. The average operating life span of the sensor under battery power must be a minimum of 10 years.
8. The interface module must provide 2 or 4 detector channels. Sensors must be assignable to the available detector channels on the interface module using software provided with the WMDS.
9. The front face of the module shall identify detector channel 1 and detector channel 2. Each must use an LED to indicate contact closure on the channel. When vehicle detection is achieved, the LED will be on and contact closure applied to the detector channel. During periods of no vehicle detection the LEDs will be in an off state and no contact closure will be applied to the detector channel.
10. The interface module will use an LED indication to indicate a "fault state" with the WMDS. When the fault state is active contact closure will be applied to the appropriate detector channel.

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.

730.30 (Reserved)**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, grommets 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.

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

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.