

CITY OF MEMPHIS – STANDARD CONSTRUCTION SPECIFICATIONS

SECTION 02890 TRAFFIC SIGNALS

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PART 1 – GENERAL PROVISIONS

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SECTION 101 – SCOPE

101.01 SCOPE

This work shall consist of furnishing and installing all necessary materials and equipment to provide new traffic signal systems complete and in-place and/or to modify existing traffic signal systems. The work includes earthwork and concrete placement for pole foundations, installation of conduit with required earthwork, erection of signal support poles and span wires or mast arms, installation of signal heads and a controller for each signal system, and installation of all wiring, appurtenances, and auxiliary equipment necessary for the complete installation of the traffic signal system as shown on the Plans or Design Standards and as specified herein or as directed by the Engineer.

SECTION 102 – GENERAL REQUIREMENTS

102.01 GENERAL

All material shall be new unless otherwise indicated in the Plans or specified in the Specifications or other Contract Documents. The signals, controllers, and appurtenances shall be located as shown on the Plans or as directed by the Engineer. All incidental parts which are not shown on the Plans or specified herein or in other Contract Documents and which are necessary to complete the traffic signals or other electrical systems or required for modifying existing systems, shall be furnished and installed as though such parts were shown on the Plans or specified herein. Costs of such incidentals shall be included in bid prices for other items. All systems shall be complete and in operation to the satisfaction of the Engineer at the time of completion of the work.

102.02 REGULATIONS AND CODES

All electrical equipment and materials shall conform to the Standards of the National Electrical Manufacturer's Association (NEMA) or the Radio Manufacturer's Association, whichever is applicable. In addition to the requirements of the Specifications, the Plans, and other Contract Documents, all material and work shall conform to the requirements of the National Electrical Code (NEC); the Standards of the American Society for Testing Materials (ASTM); the American National Standards Institute National Electrical Safety Code (ANSI C-2); the American Standards Association (ASA); U.S. Department of Transportation, Federal Highway Administration Manual on Uniform Traffic Control Devices (MUTCD); Institute of Transportation Engineers (ITE); International Municipal Signal Association, Inc. (IMSA); City of Memphis Design Standard Drawings (Design Standards); and any other Tennessee Department of Transportation standards or City of Memphis ordinance which may apply. Assembly shall be capable of full interface to the City's traffic management system. Should there be any conflict between the above standards and this specification, the specification shall prevail.

102.03 MATERIALS

All materials furnished shall conform to the requirements provided herein, the Plans, Design Standards, and where applicable the appropriate sections of the City of Memphis Standard Specifications or other Contract Documents. If the Contractor proposes to furnish materials or supplies other than those specified, he shall furnish complete descriptive data, including performance capabilities, specifications, and other such data as the City determines necessary to evaluate the substitute items. The City shall accept or reject any substitution which is requested according to these Specifications. The provisions of this substitution of materials shall not relieve the Contractor of the responsibility of meeting the requirements of the Plans and Specifications. All materials must be approved before any installation shall be permitted.

Throughout the entire project, all units of any one pay item shall be of the same manufacturer and model unless otherwise approved by the Engineer.

102.04 CONSTRUCTION

All construction and equipment installations shall comply with the requirements provided herein and with the details shown on the Plans for the type work involved. Responsibilities of the City of Memphis, the Engineer, and the Contractor are defined in the City of Memphis Standard Contract Documents Book.

All construction equipment required for the satisfactory performance of this work shall be on hand and approved by the Engineer before execution of the work shall be permitted to begin.

A. ELECTRICAL INSTALLATIONS

All electrical installations shall comply with all laws, codes, and regulations of the City of Memphis and with the service rules of the Memphis Light, Gas, and Water Division. Also, where not in conflict with such laws, codes, regulations, and rules, the electrical work shall comply with the requirements of the ANSI C-2.

All metallic conduit and the installed electrical equipment shall be grounded in accordance with the NEC, these Specifications, and the Plans. The effectiveness of the grounding shall be determined by measuring the resistance from the point of attachment of the grounding wire to the equipment or conduit to a convenient underground water line with an approved 0 to 50 ohm megger. Where a water line is not available, an auxiliary ground test method approved by the NEC shall be used with the required resistance reading.

B. BONDING AND GROUNDING

All metallic cable sheaths, cable shields, conduit (both metal and PVC), transformer cases, span wires, cabinets, and metal poles and pedestals shall be made mechanically and electrically secure to form a continuous system and shall be effectively grounded. Grounding of conduit and neutral shall be accomplished as required under the NEC, except that grounding conductors shall be #6 AWG or approved equal, as shown in the Plans and Design Standards. Exposed grounding conductors shall be enclosed in 1/2 inch diameter rigid galvanized steel conduit riser and shall be bonded to the ground rod with a copper clad ground clamp.

Bonding and grounding jumpers shall be #10 AWG solid copper wire with green insulation. Grounding conductors which ground electrodes to the signal system or the utility system neutral shall be bare stranded or braided copper wire of not less than the same cross-sectional areas as #6 AWG. Ground electrodes shall be one-piece lengths of copper weld ground rod not less than 8 feet in length and 5/8 inch in diameter, installed in accordance with the NEC and Plans or Design Standards.

C. EXCAVATION, CONSTRUCTION, AND IMPROVEMENTS

The excavations required for the installation of conduit, foundations, and other items shall be coordinated with other improvements and performed in such a manner as to cause the least possible damage to the existing streets, sidewalks, and other improvements. The trenches shall not be excavated wider than necessary for the proper installation of the electrical equipment and foundations. Excavating shall not be performed until immediately before installation of conduit and other items. The material from the excavation shall be placed in a position where the least disruption and obstruction to vehicular and pedestrian traffic shall be realized and the least interference with the surface drainage will occur.

The excavations shall be backfilled and compacted to at least the density of the surrounding material. All surplus excavation material shall be removed and disposed of by the Contractor outside of the highway right-of-way, in accordance with the provisions of Sections 02315, 02330, and 02335 of these Specifications, or as directed by the Engineer.

Excavations, after backfilling, shall be kept well filled and maintained 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, all equipment and other obstructions shall be removed from the portion of the roadway to be used by public traffic.

Excavation in the street or highway shall be performed in such a manner that not more than one traffic lane shall be restricted in either direction at anytime. Traffic signal installation work shall be scheduled so no part of the roadway is closed to traffic between the hours of 7-9 a.m. and 4-6 p.m., Monday through Friday unless approved otherwise by the Engineer. Construction signing shall be incorporated in accordance with the provisions of Section 01551 of these Specifications.

D. REPLACING REMOVED, BROKEN, OR DAMAGED IMPROVEMENTS

Improvements such as sidewalks, driveways, curbs, gutters, Portland cement concrete and asphalt concrete pavement, bituminous surfacing, base material, and any other improvements removed, broken, or damaged by the Contractor and not a part of the installation shall be replaced or reconstructed in kind according to the requirements of these Specifications without cost to the City of Memphis.

Whenever a part of a square of slab of existing concrete sidewalk or driveway is broken or damaged, the entire square or slab shall be removed and reconstructed as specified above.

E. CONCRETE PLACEMENT

Concrete operations (foundations, sidewalks, curb, and gutter, and pavement) shall not be permitted when in the opinion of the Engineer the weather or other conditions are in any way unsuitable. Concrete placement and curing shall conform to the requirements of these City of Memphis and TDOT Standard Specifications. Any concrete damaged by the weather or otherwise unacceptable to the Engineer shall be removed and replaced without additional compensation.

F. REMOVAL, RELOCATION, AND INSTALLATION OF TRAFFIC CONTROL FACILITIES

All new signals installed at previously unsignalized locations are required to flash for a period of 24 hours before being placed in stop and go operation. Such new signals shall not be placed in the flash operation on a Thursday, Friday, or the day immediately preceding a holiday.

New span mounted signal heads shall have a clearance to the roadway crown as required by the Design Standards. The span wire shall be fastened to the pole as shown in the Design Standards. Span wires shall maintain a sag of not more than five percent after being fully loaded with signal heads, cable, and lashing rods.

New pedestrian and vehicular signals shall be hooded with tied canvas or opaque plastic bags until all work at the intersection has been completed, accepted by the Engineer, and the signals are being turned on for traffic use. Hooded shall mean that the entire signal head shall be covered. At the time of turn-on of the new signal, any previously used signal taken out of service shall be hooded with tied canvas or opaque plastic bags or immediately removed.

Existing traffic control signs pertaining to turn or entry prohibition shall be relocated by the Contractor, as directed by the Engineer, to appropriate positions on relocated existing supports or on the new poles using new stainless steel straps, as required, and without damage to the finish coating of the poles. At intersections where stop signs are replaced by

traffic signals, once the signals are in use the stop signs shall be removed immediately and returned to the City of Memphis.

Utility companies shall be responsible for the relocation and/or removal of their poles and equipment. The poles and equipment to be removed by the Contractor have been generally noted on the Plans; however, it is the intent of the Contract to have the Contractor remove any City owned traffic control related or lighting equipment that is in conflict with the installation of the proposed equipment. All poles and equipment so designated or directed to be removed, including embedded poles, shall be removed in such a manner that the removed poles or equipment shall not be damaged. Poles shall be cleaned of any concrete foundation material. Any damage due to negligence on the part of the Contractor because of lack of proper care of equipment shall be cause for the Engineer to order its replacement. The cost of such replacement shall be borne fully by the Contractor without extra compensation.

Removed equipment or materials shall not be reused by the Contractor unless specifically noted on the Plans or ordered by the Engineer. The Contractor shall remove, transport, and place the removed equipment in storage at a facility designated by the Engineer, and all costs incidental thereto shall not be paid for separately but shall be included in the bid price for related items of work. The removed items shall remain the property of the City of Memphis and a receipt shall be obtained from the City on delivery.

G. POWER SUPPLY

The Memphis Light, Gas & Water Division (MLG&W) shall provide an electrical secondary service drop for each cabinet. The Contractor shall coordinate with MLG&W for the service drop and make the connection from the drop to the cabinet panel terminal as specified herein.

H. PLACING SIGNAL IN SERVICE.

Following completion of all construction required by the Plans and Specifications and all tests, checks, and inspection are satisfied, the City shall place the signal in service. The Contractor shall be present when the signal is placed in service.

I. MAINTENANCE OF TRAFFIC.

Traffic disruption and delay shall be kept to a minimum, and traffic operations shall be maintained through the project area for the length of the Contract in accordance with Section 01140 of these specifications. The Engineer may direct special efforts during certain phases of work to insure compliance with the approved construction schedule. The waiver of restriction, or the imposition of additional restrictions in critical areas of work and traffic flow, may be granted or established by the City.

The Contractor shall be responsible for providing and maintaining adequate safety lights and barricades to protect the public and must maintain access to abutting property. Such protective work shall be done in conformity with applicable portions of Section 01551 of these Specifications.

The Contractor shall be required to have police personnel present to direct traffic during signal turn-on if so directed by the Engineer.

102.05 PAINTING

All metal parts, fittings, signal heads except polycarbonate type, posts, pedestals, standards, and cabinets shall be prepared and painted according to these Specifications, except new galvanized poles, aluminum pedestals, and galvanized or aluminum hardware shall not be painted.

In general, the following materials and equipment require finishing:

- New signal heads except plastic composition type, terminal compartments and framework, push-button housings, cabinets (except aluminum), and guard parts shall be painted.
- New standards, posts, and pedestals shall be painted unless they are galvanized or aluminum or unless otherwise specified on the Plans.
- Existing equipment and materials to be relocated and existing equipment altered in place shall be repainted, unless otherwise specified or approved.

A. Paint Material

Types of paint to be used shall be as follows:

1. Primer

- Chromate aluminum oxide coating process - shall meet or exceed Government Specifications MIL-C-5541.
- Epan Oxide baking primer - shall meet or exceed Government Specifications TT-P-636.
- Zinc Chromate primer - shall meet or exceed Government Specifications P-753.
- Iron Oxide - shall meet or exceed Government Specifications TT-P-63.

2. Enamel

- Gloss (yellow or green) - shall be a high gloss alkyd enamel for exterior use and shall meet or exceed Federal Specifications TTC-595 Gloss Yellow or Green No. 1310. Color shall be standard Traffic Signal Yellow or Green. Color chips shall be furnished upon request.
- Lusterless (Black) - shall be lusterless over baked black enamel meeting or exceeding Federal Specifications TT-E-489.
- Alkyd Area Black Synthetic Baking Enamel with minimum gloss reflectance and shall meet or exceed the performance requirements of MIL-E-5557 Enamel Heat Resisting Glyceryl Phthalic, Type 4, Instrument Black.
- Aluminum Zinc Rust-Inhibitive--shall meet or exceed Federal Specifications TT-P-1561A.

3. Substitutions

These specifications are not intended to specifically prohibit the use of paints of similar character but different composition or the use of polycarbonate signal heads and mounting brackets of equal end product color. Substitute products must be equivalent to

specified paints for all qualitative requirements applicable to their use. Substitute products must be approved by the Engineer before application; however, approval of a product shall not relieve the Contractor of his obligations outlined in these Specifications.

B. Preparation and Finishing

1. New Equipment

The preparation and finishing of new equipment shall be as follows:

- Standards, posts, pedestals, and any other galvanized surface to be painted shall be cleaned and coated with the approved primer best suited for the surface.
- If an approved prime coat has been applied by the manufacturer and is in good condition, additional primer application by the Contractor, other than for repairs, shall not be required.
- When specified to be painted, standards and posts shall have at least two coats of Traffic Paint applied as follows:
 - Mast arms and standards with bracket mounted signals shall be painted in their entirety, except that polycarbonate signals and brackets shall be omitted and only the standards painted.
 - Pedestrian push-button posts, steel pedestals for cabinets, and standards with top mounted signals, including left turn signals, shall be painted from the base to the top of the post.
- Steel controller cabinets shall have a finish on all surfaces, both interior and exterior, consisting of a minimum of one coat of zinc chromate primer on all surfaces and two coats of a high grade aluminum paint, unless otherwise shown on the Plans.
- All signal heads, signal head mountings, and pedestrian push-button housings shall have one or more coats of primer followed by two coats of Traffic Signal Yellow except polycarbonate type which shall present the equivalent color.
- Louvers as specified, interior and exterior of signal hoods, and fronts and backs of back plates shall have one or more coats of primer followed by two coats of Lusterless Black enamel, except polycarbonate type. All factory enameled equipment and materials shall be examined for damaged paint after installation, and such damaged surfaces shall be repainted to the satisfaction of the Engineer. Factory applied enamel finish in good condition and of appropriate color shall be acceptable.

2. Existing Equipment and Materials

Existing equipment and materials to be repainted, whether remaining in place or to be relocated, shall be cleaned of all rust, scale, grease, dirt, and poorly bonded paint by any method satisfactory to the Engineer. Immediately after cleaning, all bare metal shall be primed as appropriate, or as specified for new material. A finish coat shall then be applied over newly primed areas followed by one or more finishing coats over the entire surface.

Blast cleaning of galvanized metal surfaces in good condition, as determined by the Engineer, shall not be permitted.

3. Painting Procedures

102.05 Painting

All paint coats may be applied either by hand brushing or by approved spraying machines in the hands of skilled operators, except that no spraying shall be done at the job site. The work shall be done in a neat and skillful manner, and the Engineer reserves the right to require the use of brushes for the application of paint should the work done by the paint spraying machine prove unsatisfactory or objectionable, as determined by the Engineer.

The thickness of each paint coat shall be limited to that which will result in uniform drying throughout the film. Skips, thin areas, or other deficiencies in any one coat of paint shall be corrected to the satisfaction of the Engineer before succeeding coat is applied.

The final coat shall present a smooth surface, uniform in color, free of runs, sags, or excessive brush marks.

SECTION 103 – TESTS AND INSPECTION

103.01 GENERAL TESTING REQUIREMENTS

The Contractor shall be responsible for the installation tests, demonstration of the functioning system, and checks of all hardware.

The Engineer reserves the right to examine and test any and all materials furnished and/or installed by the Contractor for this project to determine if they meet the requirements of the Plans and of the specifications. If any material used in the construction of this project does not meet these requirements, the Contractor shall replace such defective parts and material at no cost to the City. Rejected equipment may be offered again by the Contractor for re-testing provided all non-compliance has been corrected and the equipment has been pre-tested by the Contractor.

Testing of Contractor-furnished and installed hardware and equipment shall be conducted as described below. All tests specified herein shall be successfully conducted prior to Final Acceptance of the Project. All test equipment shall be provided by the Contractor unless otherwise provided herein. The Contractor shall perform the tests and document the test results. When the tests are completed, whether successfully or not, the test results shall be furnished to the Engineer. All test documentation forms shall be submitted to the Engineer for approval.

No separate payment shall be made for any testing or documentation, all costs of which shall be included in the amount bid for other pay items.

The times and dates of tests shall be approved by the Engineer. The Contractor shall conduct all tests in the presence of the Engineer or his authorized representative. Unless otherwise approved by the Engineer, testing shall take place only on weekdays which are official working days of the City and during normal working hours of the City.

103.02 TEST EQUIPMENT

If called for in the Plans or other Contract Documents, the Contractor shall furnish one or more items of the following test and support equipment. Each item furnished shall be new as of the start of the project but may be used by the Contractor to perform testing and/or training required in these specifications. At the completion of the project, each such item shall become the property of the City. At that time, each item of furnished test equipment shall be in working condition.

A. Controller Tester

This tester shall be housed in a luggage-type case made of aluminum or similar material. The unit shall plug into a standard 120 VAC outlet.

Harnesses shall be provided to mate with the standard NEMA A, B, and C MS-type connectors and any other connectors on the controllers supplied by the Contractor. Test switches shall be provided to test all inputs, and indicator lights shall be provided to test all outputs of the controllers provided by the Contractor. This shall include preemption inputs and outputs, and special functions. The unit shall have a cycle generator which has adjustable settings from a minimum range of 40 to 240 seconds. The unit shall also provide a power interrupt test adjustable from 0.1 to 1.1 seconds. An instruction manual shall be provided to explain all recommended test procedures.

B. PROM Burner/Duplicator

The PROM burner/duplicator shall permit the user to read, test, or copy every type of PROM used on any other piece of equipment provided by the Contractor. The PROM burner/duplication shall interface to a microcomputer. An instruction manual shall be provided to explain each operation.

C. Test Cabinet/Controller

Each test cabinet/controller shall be an 8-phase cabinet/controller, base-mounted. Each test cabinet shall include a conflict monitor and full compliment of rack-mounted detector amplifiers and load switches. The controller shall have an OTR/LT.

Each test cabinet shall have a heavy duty aluminum dolly base with heavy duty lockable casters. The base shall accommodate a fully equipped type of base-mounted cabinet/controller. A pole or pedestal shall be attached to the base to support a display panel, which shall be located either above or beside the cabinet convenient for use by maintenance personnel. The panel, which shall depict an 8-phase intersection, shall have all indicators and switches on the front, and shall have a suitable aluminum enclosure. The color of the panel and dolly shall be coordinated with other equipment and shall be subject to the approval of the Engineer. The panel shall be fully labeled.

1. Indicators

The panel shall contain indicators to display the outputs of all the cabinet's traffic signal load switches. Red, yellow, and green indicators shall be used to display the outputs of the traffic signal load switches. In addition, indicators shall be provided for four (4) pedestrian displays and four (4) special functions.

2. Controls

The panel shall be equipped with controls which are connected to simulate all of the inputs, for test purposes, to the controller which are not already accommodated by switches in the controller cabinet. The panel shall contain a thumb-wheel switch for the selection of the communications address to be assigned to the cabinet.

3. Harnesses

The panel shall be connected to the controller cabinet by means of harnesses. To the extent possible, such connections shall be accomplished by connecting the harnesses between the controller harnesses and the controller with suitable connectors. The harnesses shall be concealed in the pedestal or pipe supporting the panel and shall enter the cabinet from the bottom.

D. Fiber Optic Test Equipment

1. Hand-Held Optical Power Meter

The hand-held optical power meter shall provide overall continuity and attenuation testing of the fiber optic communications plant. The optical power meter shall be a lightweight, compact unit weighing less than one (1) pound and measuring less than six (6) inches x four (4) inches x two (2) inches in size. The unit shall be supplied with an instruction manual, shall not require extensive training, and shall include the following easy-to-use features:

- Interchangeable connector adapters,

- Automatic measurement range selection,
- Power measurements in Watts or Decibels,
- Selectable measurements of absolute or relative power levels, and
- Audible test tones for "no-look" verification of user-programmed measurement levels.

The optical power meter shall be calibrated to perform certification testing in compliance with TIA/EIA-568A at the 850, 1300, 1310, and the 1550 nanometer wavelengths. The power meter shall feature a lighted display which is readable both in direct sunlight and at night. The power meter display shall include a minimum of a four-digit power level indication with an auto-ranging units indication including dB, dBm or mW, uW, and nW. The unit also shall have "out-of-range" and "low battery" indicators. The unit shall measure and display optical power levels from a minimum of +10 to -60 dBm to a 0.01 resolution in the dB and dBm display ranges. The unit also shall measure and display optical wattage levels from a minimum of +10 mW to 1 nW to a 0.01 resolution in the mW, uW, and nW display ranges. The optical power meter accuracy shall be ± 10 percent or better throughout its measurement range.

The optical power meter shall, without degradation of performance, withstand a storage temperature from a minimum of -18°C (0°F) to $+74^{\circ}\text{C}$ ($+165^{\circ}\text{F}$) and an operating temperature from a minimum of 0°C ($+32^{\circ}\text{F}$) to $+50^{\circ}\text{C}$ ($+122^{\circ}\text{F}$) at 0 to 95 percent relative humidity. The power meter shall feature a built-in, rechargeable power supply and shall be provided with a 115 ± 10 % VAC charger/adaptor. The power supply shall be fully rechargeable in six (6) hours or less and provide a minimum of nine (9) hours of continuous use when fully charged.

The optical power meter shall be provided with a carrying case and an interchangeable connector/adaptor which, as a minimum, is ST-compatible.

2. Hand-Held Optical Light Source

The hand-held optical light source unit shall provide calibrated test signals for use in the overall continuity and attenuation testing of the fiber optic communications plant. The optical light source unit shall be a lightweight, compact unit weighing less than one (1) pound and measuring less than 6.5 inches x four (4) inches x two (2) inches in size. The unit shall be supplied with an instruction manual, shall not require extensive training, and shall feature simple on/off operation.

The optical light source shall be calibrated to perform certification testing in compliance with TIA/EIA-568A at 1310 ± 20 nanometer wavelength. The unit shall feature stabilized laser diode output maintaining a ± 0.40 dB output operating in a 0°C ($+32^{\circ}\text{F}$) to $+50^{\circ}\text{C}$ ($+122^{\circ}\text{F}$) environment. The light source also shall maintain a minimum of ± 0.10 dB output accuracy over an eight-hour period while operating at $+23^{\circ}\text{C}$ ($+73^{\circ}\text{F}$). The optical light source output power onto a SMFO core shall not be less than -8 dBm with a spectral width of not more than 5 nanometers, RMS. The optical light source shall selectively provide a continuous wave or a 2000 Hz, modulated-wave output.

The optical light source unit shall, without degradation of performance, withstand a storage temperature from a minimum of -23°C (-10°F) to $+74^{\circ}\text{C}$ ($+165^{\circ}\text{F}$) and an operating temperature from a minimum of 0°C ($+32^{\circ}\text{F}$) to $+50^{\circ}\text{C}$ ($+122^{\circ}\text{F}$) at 0 to 95 percent relative humidity. The unit shall feature a built-in, rechargeable power supply and shall be provided with a 115 ± 10 % VAC charger/adaptor. The unit also shall feature a "low battery" indicator. The power supply shall be fully rechargeable in six (6)

hours or less and provide a minimum of nine (9) hours of continuous use when fully charged.

The optical light source unit shall be provided with a carrying case and an interchangeable connector/adaptor which, as a minimum, is ST-compatible.

3. Hand-Held Visual Fault Finder

The hand-held visual fault finder shall provide visual identification of faulty connectors, poor splices, microbends, fiber breaks, and other sources of high optical power attenuation along FO media. The visual fault finder shall be a lightweight, compact unit weighing less than one (1) pound and measuring less than 6.5 inches x four (4) inches x two (2) inches in size. The unit shall be supplied with an instruction manual, shall not require extensive training, and shall include the following features:

- Highly efficient laser diode operating at short wavelengths
- Continuous wave or 1.5 Hz pulsed-wave output, and
- An automatic turn-off function.

The visual fault finder shall be a labeled, Class II LASER unit operating at 670 ± 20 nanometer wavelengths with an output power from -2 dBm to 0 dBm into a single mode fiber core.

The visual fault finder, without degradation of performance, shall withstand a storage temperature from a minimum of -21°C (-5°F) to $+52^{\circ}\text{C}$ ($+125^{\circ}\text{F}$) and an operating temperature from a minimum of 0°C ($+32^{\circ}\text{F}$) to $+50^{\circ}\text{C}$ ($+122^{\circ}\text{F}$) at 0 to 95 percent relative humidity. The unit shall feature a built-in, rechargeable power supply and shall be provided with a 115 ± 10 % VAC charger/adaptor. The unit also shall feature a "low battery" indicator. The power supply shall be fully rechargeable in fifteen hours or less and provide a minimum of nine (9) hours of continuous use at $+25^{\circ}\text{C}$ ($+77^{\circ}\text{F}$) in the pulsed-wave mode when fully charged.

The optical power meter shall be provided with a carrying case and an interchangeable connector/adaptor which, as a minimum, is ST-compatible.

4. Optical Fiber Cleaver

The fiber cleaver shall be a lightweight, compact unit weighing less than 1.5 pounds and measuring less than 3.5 inches x 3.5 inches x 3 inches in size. The unit shall be supplied with an instruction manual, shall not require extensive training, and shall include a diamond cutting blade with a cutting life of not less than 10,000 cleaves. The cleaver shall accommodate bare fiber diameters from 100 to 140 micrometers at lengths up to 6 millimeters. The fiber cleaver shall produce smooth, flat, fiber end-faces which are less than 1.0° from perpendicular a minimum of 95 percent of the time.

5. Field Test Equipment Transit Case

A hard-shell transit case shall be provided by the Contractor to use and provide protection for the hand-held optical power meter, the hand-held optical light source, and the hand-held visual fault finder defined in this subsection. The transit case shall be inner-lined with shock absorbing foam and shall have compartments for convenient storage of the hand-held components and their associated power chargers/adaptors and connector accessories. The transit case shall have a hard shell which is crush-resistant, moisture-resistant, and dust-resistant. The transit case shall weigh less than eight (8) pounds and measure less than 19 inches x 14 inches x 9 inches in size.

E. Conflict Monitor/Malfunction Management Unit Tester

This tester shall, in an automated manner, fully test and document the testing of all functions performed by each malfunction management unit. This tester shall be furnished with all connectors to mate with the malfunction management unit. An instruction manual shall be provided.

F. Tester to Test the Internal Communications of the New Controllers

This tester shall simulate the range of operating conditions experienced in normal field service. An instruction manual shall be provided. to a microcomputer. An instruction manual shall be provided to explain each operation.

103.03 CIRCUIT TESTS

Prior to completion of the work, the Contractor shall cause the following tests to be made on all traffic signal circuits in the presence of the Engineer. Any fault in any material or in any part of the installation revealed by these tests shall be replaced or repaired by the Contractor in a manner approved by the Engineer, and the same test shall be repeated until no fault appears.

A. Ground Tests

Each circuit shall be tested for grounds in the circuit.

B. Megger Tests

A megger test shall be made 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. The load in amperes of each signal circuit shall be measured at the controller cabinet with a clamp-on ammeter. If the amperage is in excess of the expected lamp load plus minimal transmission losses, the circuit will not be accepted and shall be replaced or corrected by the Contractor at no additional compensation.

C. Functional Tests

A function test shall be performed in which it is demonstrated that each and every part of the system functions as specified or intended herein. Signal circuits shall be "flashed out" from the cabinet terminals to determine that the proper function has been assigned each circuit.

D. Detector Ground Tests

All detector loops and leads shall be tested before and after they are sealed in the pavement to be sure there are no shorts to ground in the system and to assure that the loop plus lead-in inductance is within the operating range of the detector, all according to the Standards on loop installation.

103.04 INSPECTION

All work and materials to be performed or furnished under these specifications shall be subject to observation and inspection by the Engineer according to the Contract Document Book. Request for an Engineer or Inspector in connection with work under these Specifications shall be made by the Contractor at least twenty-four (24) hours before the services thereof shall be required.

103.05 MILL TEST REPORT AND CERTIFICATION

Mill Test Reports or Certifications of Specifications for Materials and Design shall be required for all materials incorporated into the work. The following shall be supplied by the Contractor prior to acceptance of the materials:

- "Mill Test Reports" (M.T.R.) for MAJOR structural items only, as noted in Table 103-1, shall include both physical and chemical descriptions of the material as supplied to the fabricator. When physical properties are altered during the fabrication, M.T.R. covering chemical composition shall be supplemented by certified test reports indicating the physical properties of this material after fabrication.
- Certification of conformance to the Specifications for all remaining material not covered by M.T.R. as noted in Table 103-1.
- Certification that all welding was performed by operators qualified as follows: Steel welders to AWS and aluminum welders to ASME.
- Certification of conformance to the Specification for the design of all components not completely dimensioned and detailed in the Design Standards.

Table 103-1 Mill Test Report and Certification of Conformance Requirements

Component Materials	M.T.R.	Certification
Tubes for arms and poles	X	
Base castings	X	
Anchor Bolts	X	
Pole tops, miscellaneous fittings and hardware		X
Fabricated or cast-type arm connections		X
Galvanizing		X
Signal cable and wire		X
Loop Sealant		X
Concrete	X	

103.06 "AS BUILT" PLANS FOR TRAFFIC SIGNAL INSTALLATIONS

Upon completion of the work, and prior to final inspection and acceptance, the Contractor shall submit to the Engineer two (2) copies of "As Built" or corrected Plans on mylar showing in detail all construction changes, including location and depth of conduit. The Contractor shall also furnish all literature and drawings which are received with the equipment to be installed and which pertain to the engineering installation, operation, warranty, and maintenance of that equipment.

SECTION 104 – GUARANTEES**104.01 GUARANTEES**

The Traffic Signal System(s) installed under these Specifications, including all equipment, parts, and appurtenances in connection therewith shall be guaranteed to the City by the Contractor according to the requirements of the Contract Document Book. Upon completion of the project, warranties or guarantees on equipment and materials that are offered by the manufacturers as normal trade practice and have not expired shall be turned over by the Contractor to the City.

Unless any special guarantees or warranties specified in the Contract Documents or this specification, the Contractor shall furnish a written guarantee that all work executed under the contract shall be free from defects of materials and workmanship for a period of one year from date of acceptance of work by the Owner. This shall be understood to mean the replacement or correction of such defective work and material, together with the correction of damage to other work, occasioned by the defect, at the Contractor's expense. Where guarantees and/or warranties are written in the specification (or offered by the manufacturer at no additional cost) for a longer period than one year, such longer terms shall apply. A manufacturer's warranty shall not relieve the contractor from his/her full responsibilities under guarantees and/or warranties called for in these specifications.

SECTION 105 – MEASUREMENT AND PAYMENT**105.01 MEASUREMENT**

Each accepted installed item relating to traffic signal installation shall be measured as described herein. Items which are incidental construction required for the installation of a traffic signal shall not be measured and shall be considered incidental to the work. Construction which is in addition to that required for the installation of a traffic signal shall be measured according to the respective section of these Specifications. Items of equipment and material designated or required for removal shall not be measured, and such removals shall be considered incidental to the work. Any other item for installation not measured herein shall not be measured and shall be considered incidental to the work.

105.02 PAYMENT

Payment for accepted work, measured as provided herein, shall be made at appropriate contract unit prices which shall be payment in full for all labor and materials required for a complete and operable installation. Payment shall be made for quantities as shown on the Plans unless the work shown on the Plans is changed by the Engineer or a field measurement is requested by the Contractor, in which case payment shall be for the approved quantities as changed or for the approved field measured quantities.

Payment for all work under this specification shall be made under the pay items listed at the end of each subsection. Unless noted otherwise, the payment schedule shall be as follows:

Stage of Construction	Partial Payment Schedule
Stockpiled / Equipment order delivery	100% invoice or 60% of unit price, whichever is less
Completion of field installation	80% of unit price
Final acceptance	100%

PART 2 – CONTROLLERS AND CABINETS

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SECTION 201 – TRAFFIC SIGNAL CONTROLLERS

201.01 DESCRIPTION

This subsection describes the general and specific construction and operating requirements, design requirements, controller interfaces, physical standards, functional standards, and coordination standards of new controllers to be furnished by the Contractor.

The control equipment described herein is to be capable of being used in operating traffic signals as part of a coordinated system. The controller shall consist of an electrically operated traffic control device, which shall function continuously and unattended at the locations shown in the Plans, to assign vehicle and pedestrian right-of-way by illuminating standard signals in accordance with a prescribed timing program. The signal display operation shall conform to the sequence charts and the phase diagrams included on the Plans.

201.02 GENERAL REQUIREMENTS

Each model of new traffic signal controller furnished by the Contractor shall be a proven controller and not a pre-production prototype.

A. Standards

The controller and associated equipment shall, at a minimum, comply with the latest edition of NEMA Standard TS 2-2003 - Traffic Control Assemblies with NTCIP Requirements (NEMA TS-2), the National Transportation Communications for ITS Protocol (NTCIP), and the Joint NEMA/AASHTO/ITE Advanced Transportation Controller (ATC) Standard; and that Standard is hereby made a part of this Specification. The controller shall be interchangeable with any other controller meeting the NEMA TS-2, NTCIP, and ATC standards. All requirements, functions, operational modes, and features required by this specification, which are not required by NEMA, shall be incorporated in such a manner as to retain compliance with NEMA. Where a conflict should arise between NEMA and this Specification, this Specification shall prevail. In the event of the aforementioned conflict, the Contractor shall list on a separate sheet, accompanying his bid, any and all areas of conflict, describing each conflict and referencing the appropriate sections of this specification and NEMA for each conflict.

B. Traffic Management System

The City of Memphis currently uses a traffic management system to monitor and control the various traffic control devices in operation. All traffic signal controllers shall be capable of communication with the City's traffic management system computer software by either fiber-optic, direct hardwire, or remote telephone modem.

201.03 MATERIAL AND COMPONENT

The controller shall be of modular design with an internal power supply all mounted in a suitable sheet metal enclosure or injection molded high impact polycarbonate enclosure. The chassis shall be designed for easy access to the printed circuit boards. All pin connectors shall be front mounted. The design shall allow for easy removal or replacement of all modules without the use of special tools.

The controller circuitry shall consist of a high threshold solid-state digital electronic design. The circuit components shall be standard production types that are typically available from industrial electronic supply houses. The circuit and component design life under continuous duty operation shall not be less than ten years. All controllers shall employ high quality solid-state, modular electronic construction designed for continuous unattended operation. No electro-mechanical devices such as camshafts, rotary stepping line switches, lightning discharge tubes, or vacuum or gaseous tubes shall be used for internal or external auxiliary circuitry.

The controller shall have a time of Day (TOD) clock with hours, minutes, seconds, month, year, and automatic daylight savings time adjustment. TOD may be implemented in the CPU via electronic circuitry, operating system software, or a combination of the two. During power failures, the TOD clock shall be powered by STANDBY voltage from the power supply.

A. Standard NEMA Configurations

Two Input/Output configurations shall be provided:

- NEMA TS-2 Type 1 for serial connection to cabinet Bus Interface Unit, and
- NEMA TS-2 Type 2 for direct parallel connection to load switches and detectors

B. Power Supply

The control unit shall have a self-contained power supply to operate the controller and all auxiliary equipment. The power supply shall operate from an electric service line with input voltage from 95 to 135 volts, 60 Hertz, and develop stabilized controller voltages for continuous controller operation with interval timing remaining within specified tolerances. The power supply shall be separately and independently fuse protected for both the 120 VAC input and 24 VDC output with easily accessible fuses. Internal fuses are not permitted. DC output for external circuitry shall be rated at a minimum of 0.5 amps and capable of direct short circuit without internal damage to the power supply. All components of the power supply shall be amply de-rated with respect to heat dissipating capacity so that any extreme ambient temperature and applied voltage shall result in neither a material shortening of component life nor a severe deterioration of operational characteristics. The power supply shall be capable of operating the controller when expanded to its maximum capabilities complete with all auxiliary equipment. No auxiliary or external power supplies are permitted.

All controller input and output logic levels shall be a nominal zero volts (logic ground) for the true state and nominal +24 volts for the false state.

Line Frequency Reference signal shall be generated by a crystal oscillator, which shall synchronize to the 60-Hz VAC incoming power line at 120 and 300 degrees. A continuous square wave signal shall be +5 VDC amplitude, 8.333 ms half-cycle pulse duration, and 50 +/- 1% duty cycle. The Line Frequency Reference shall compensate for missing pulses and line noise during normal operation. The Line Frequency Reference shall continue through 500 ms power interruptions.

Standby voltage via a super capacitor for backup power during loss of service voltage shall be provided. The super capacitor shall have a minimum of 15-farad nominal size. No batteries of any type are allowed.

C. Keyboard and Display

In addition to NEMA requirements, the Keyboard and Display shall provide the following:

- If a removable keyboard is equipped, keyboard shall be removable by pulling off without use of tools
- Emulation of terminal per Joint NEMA/AASHTO/ITE ATC Standard
- Key quantity and function per Joint NEMA/AASHTO/ITE ATC Standard
- Liquid Crystal Display (LCD) with 16 lines of 40 characters minimum
- LCD contrast adjustment accomplished via the keypad, no contrast knob allowed.
- Light-emitting diode backlight for the LCD.
- Audible electronic bell.

All input data shall be user-programmable by means of the keyboard and LCD display. All internal time settings shall be programmed via a keypad and stored in EPROM memory. Programming shall be facilitated by the use of menu driven displays in English terms. Data entry and interrogation of the controller shall be simplified by listing instructions in English on the display so that codes or reference manuals are not required.

D. Specific Design Requirements

The controller shall conform to requirements of NEMA "Environmental Standards for Test Procedures." No cabinet surge protection or line filters shall be considered in providing the required transient protection.

Digital timing utilizing the 60 Hertz frequency of the electrical service line as a counting reference shall be used for all intervals. Any interval shall not deviate more than 0.100 seconds from its true time setting.

The controller shall have one and only one set of master digital clocks to time all intervals of all phases. Separate clocks associated with and/or located on individual phase boards are prohibited.

All controllers shall be provided capable of coordinated control. Any phase of a multi-phase controller shall be capable of being the coordinated phase with any or all timing plans.

The control unit enclosure shall bear a name plate plaque with an engraved identifying serial number, model number, and manufacturing date code.

The control unit shall be furnished consistent with a standard model designation and registration and shall be completely interchangeable with other units of the same model and type, as well as with other controllers NEMA compliant.

E. Communications Interface

At a minimum, the following built-in communications ports shall be provided by the controller on front panel:

- A 10 Base-T or faster Ethernet network interface card (RJ-45 connector) for TCP/IP communications.
- A SDLC port for communications to other cabinet devices.
- A EIA/TIA-232-E 25-pin connector for RS-232 serial communications with a computer for uploading, downloading, or upgrading the controller software.

Each controller furnished by the Contractor shall have an internal communications transceiver which shall receive system commands and data from the central system and transmit local intersection status data, database, and system detector data to the central system that support the following protocols:

- TCP/IP
- NTCIP Level 2 as defined by Section 3.3.6 of NEMA TS2

At a minimum, the communications transceiver shall fully support the following functions:

- Downloading and uploading of the entire local intersection database
- Updating the controller firmware
- Transmitting the status of the following to the central system for monitoring:
 - All vehicular signal indications for each active phase and green, yellow, and red indications for a minimum of four (4) overlaps.
 - All pedestrian indications for a minimum of four (4) active phases. WALK, flashing DONT WALK, and steady DONT WALK shall be monitored.
 - Vehicle and pedestrian actuations for each active phase.
 - Timing plan in effect.
 - Cycle countdown.
 - Status of all local special functions, including a "door-open" alarm.
 - Operational status of the intersection (in coordination, in transition, free operation, flash, local manual control or preempted).
- Receiving from the central system command data including the following:
 - Timing plan commands.
 - Local special function commands (minimum of four).
 - Coordinated or free mode.
 - Request for local data response.
 - System clock update

F. Software Updates

The Contractor shall furnish a certification from the controller manufacturer that the controller software shall be updated as revisions are available. One (1) copy of the latest computer system software for an IBM-compatible microcomputer shall be furnished by the Contractor. The certification shall assure that this copy shall be continually updated by the controller manufacturer so that both the traffic controllers and the computer are operating on compatible software. The certification shall state that this software update service shall be provided at no future cost to the City.

G. Internal Fiber Optic Transceiver (Port 3, Optional)

The internal fiber optic transceiver (OTR) is not required, unless specifically called for on the Plans and Bid Documents.

1. Functional Requirements

The OTR shall either be line repeating (OTR/RP) or line terminating (OTR-LT) as required for the application called for on the Plans. The OTR in the last controller of a multi-dropped optical string shall be line terminating. The OTRs in all other controllers shall be repeating. Each such OTR shall be compatible with the OTRs at the associated central control facility or field communications hub. The multi-dropped communications between the central control apparatus and the controllers shall be accomplished over single-mode (or multi-mode, if required by Plans and Special Provisions of the project specifications) optical fiber at either the 850 nanometer (nm) or the 1310 nm wavelength. The associated central OTRs shall: Convert RS-232 electrical signals into a downlink optical signal which is compatible with the OTRs that are integral to the controllers; and convert the uplink optical signals from the OTRs in the controllers into a RS-232 electrical signal for interface with the central control apparatus.

2. Electrical Interfaces

- Power - The OTR/RP shall be compatible with and operate from its host traffic controller's internal power supply. OTR/RP circuitry shall be designed to operate with voltage fluctuations of $\pm 15\%$ from nominal. Where over or under voltage conditions exist out of the operating range of the OTR/RP, circuitry shall protect electronics from damage. The OTR/RP shall automatically recover from an over or under voltage condition when the input power returns to normal operating range.
- Electrical Signal Interface - The OTR/RP shall interconnect within the controller and shall provide full duplex asynchronous data transmission.
- Grounding Provisions and Lightning Protection - There shall be no internal connection between signal ground and chassis ground. The OTR/RP design shall protect the electronics from lightning.

3. Optical Interfaces

Connectors shall be LC-compatible, or compatible with the type of connectors used by existing upstream or downstream signal controllers or master controllers.

The optical interface to the OTR/RP shall be Single-mode fiber (or Multi-mode if required by Plans and Special Provision of specifications) using LC connectors. Female LC connectors shall be provided on the front panel of the controller as follows:

- Transmit uplink
- Transmit downlink
- Receive from uplink
- Receive from downlink

A total of four (4) fiber optic LC interconnections are required. All OTR/RPs shall have compatible communications specifications. When two or more OTR/RPs are interconnected by a fiber optic cable, it shall conform to the following specifications:

Type:	Single-mode	Multi-mode
Core Diameter:	8.3 \pm 0.5 microns	62.5 \pm 3.0 microns
Cladding Diameter:	125.0 \pm 1.0 microns	125.0 \pm 2.0 microns
Operating Wavelength:	850 or 1310 nanometers	

201.04 Functional Requirements – Local Intersection Controller

The data rate of the OTR/RP link shall be automatically adaptable to an attached RS-232 electrical signal interface to a minimum of 19.2 Kbps.

The link loss budget between any two OTR/RPs shall not exceed 14 dB while the two communications devices are operated within environmental and power input variations specifications stated in this document.

The optical repeating process shall not add signal distortion nor optical noise which would compromise the link performance. The receiving OTR/RPs shall provide electrical interfaces to all attached controllers with a bit error of no greater than 1 in 10⁹ bits.

OTR/RP shall be modular in design and easily accessible for maintenance. The following indicators shall be provided on the front panel of the controller to show OTR/RP communications channel activity:

- Transmit Data Optical Channel 1 (TD-1)
- Receive Data Optical Channel 1 (RD-1)
- Transmit Data Optical Channel 2 (TD-2)
- Receive Data Optical Channel 2 (RD-2)

4. Miscellaneous Requirements

The OTR/RP is required to be inter-changeable between traffic controllers. For this reason, the OTR/RP shall conform to the standard mounting and interconnection provisions within the controller.

Connectors shall be located on the OTR/RP for convenient cable attachments. Strain reliefs shall be included on all cables provided with the OTR/RP.

Construction and materials selection for the OTR/RP shall prevent fungus growth and cathodic action. Flame retardant materials shall be utilized in the construction of electronics.

All connectors and indicators shall be marked. All replaceable components shall be marked and all markings shall conform to the supplied documentation, including schematics and parts lists. The OTR/RP external markings shall include the product name, model number, part number, serial number, manufacturer's name and manufacturer's address.

The OTR/RP shall conform to performance specification when operated within the environments specified in NEMA Section 2.

No cooling air flow shall be required. Units shall be shipped with protective covers over all connectors.

The OTR/RP shall have a Mean Time between Communications Failure of 43,800 hours when operated as a pair, to a 95% confidence level.

The OTR/RP shall comply with FCC Class A requirements.

201.04 FUNCTIONAL REQUIREMENTS – LOCAL INTERSECTION CONTROLLER

Each new controller furnished by the Contractor shall be fully capable of providing, as a minimum, all standard NEMA phase sequences and all phase sequences shown on the Plans. The local controllers, in combination with the central software or field master controllers, shall provide for time-based coordination of each of these required phase sequences and for the

201.04 Functional Requirements – Local Intersection Controller

independent programming of each odd- numbered phase (i.e., 1, 3, 5 and 7) to be either leading or lagging with respect to its corresponding even-numbered phase (i.e., 2, 4, 6 and 8).

In addition to NEMA requirements, the controller shall provide the following capabilities at a minimum:

- 16 Vehicle Phases
- 16 Pedestrian Phases
- 4 Timing Rings
- 16 Overlaps
- 80 Detectors
- Per-phase features:
 - Extended flashing pedestrian clearance
 - Actuated rest in walk
 - Soft vehicle recall
 - Selective phase omit
 - Conditional service
 - Detector (stretch, delay and switching)
- Per-unit features:
 - Programmed (remote) flash
 - Exclusive pedestrian service
 - Ring configurations (to 4 rings)
 - Start-up flash or all red
 - Remote sequence modifiers (16)
 - Timed trailing overlaps
 - Overlap green/yellow omit
 - Parameter printout
- Coordination features:
 - 4 Dial / 4 Split / 3 Offset
 - 48 traffic patterns
 - 3 offset correction modes
 - Transition cycles
 - Sync monitoring
 - Coordination Modes: Permissive Mode, Permissive Yield Mode, Full Actuated Mode.
- Time base scheduler features:
 - 10 week programs

201.04 Functional Requirements – Local Intersection Controller

- 99 day programs
- 250 event capacity
- Auxiliary special function outputs, minimum of four (4)
- Max II selection per phase TOD
- Phase omit TOD
- Automatic daylight savings time and leap-year adjustment
- Whether or not preemption is required by the intersection's initial operation as called for on the Plans, each new local intersection controller shall provide a minimum of six (6) preemption sequences, each with the following features:
 - Delay and duration (multiple runs)
 - Programmable sequence
 - Programmable flash override
 - Programmable priority
- The programmable sequence feature shall permit the programming of railroad preemption consisting of:
 - Delay before track clearance
 - Track clearance
 - Preemption dwell (which may be either limited sequence or flashing operation)
 - Special sequence of phases to be serviced before return to normal operation
 - The Contractor shall program and make operational all preemption sequences called for in the Plans.
- The controller shall have the ability to assign, modify, and view detector operational parameters of all detector inputs to the controller. Detector operations shall be assigned as follows:
 - All NTCIP detector functionality
 - A standard vehicle detector
 - A standard pedestrian detector
 - A 1-calling vehicle detector where the input shall operate as a vehicle detector that is operational while the phase is not green and the phase is on locking detection.
 - A stop bar detector that shall operate as a vehicle detector which operates normally until it is in its phase green. In the green, the detector is disconnected and does not input to the phase. This feature is to operate in either lock or non-lock operation.
 - A stop bar detector whose input shall operate as a vehicle detector that operates normally when the assigned phase is not green. When a call is detected, it shall be held in green until a gap greater than the Extend Timer setting occurs. The Extend Timer shall begin with the green. If a call is received before the Extend Timer times out, it shall be reset. Timer reset shall continue to occur until a gap is large enough to allow the Extend Timer to time out. Once a time out occurs, the detector shall be disconnected

201.04 Functional Requirements – Local Intersection Controller

until the green terminates. When the extend time setting is zero, a call shall be held in green until a gap occurs. Delay time is to function normally.

- Ability to switch detector actuations to another phase when the assigned phase cannot be serviced normally or is red or yellow and the entered phase is green.
- Delayed actuations, selectable from 0-99.9 sec. in 1/10th sec. increments.
- Extended actuations, selectable from 0-99.9 sec. in 1/10th sec. increments.
- Other special features:
 - Eight (8) system detector/coordination inputs
 - 6 Priority Routines
 - Detector assignments and special detector allocation
 - Standard reports
 - Built-In Diagnostics: MMU Status Display, Cycling Diagnostics, Detector Diagnostics
 - Controller local alarm log. The log shall be accessible from the keyboard. It shall have the ability to store up to 80 alarms with any additional alarms replacing the oldest. The alarms shall be of the following types showing the date and time of occurrences. Alarms shall appear in the order in which they occur.
 - On-line/off-line
 - Power on/off-interrupt
 - Preemptions and user definable alarms
 - Low battery check/replace
 - EPROM write/failure counts
 - Communication Faults
 - Diagnostics
 - Coordination status and Local/Free
 - Software clock adjust
 - Time change remote/keypad
 - Minimum of four (4) special functions
 - Remote "Manual" overrides
 - TBC on loss of communications
 - Adaptive Traffic Control:
 - Adaptive Maximum Routines
 - Adaptive Protected / Permissive Routines
 - Conditional Virtual Split Routines
 - Coordinated Adaptive Split Routines
 - Current status of ring timers, coordination timers, preempt timers, time base, communication, detector diagnostics, intersection, and input/output

201.05 Functional Requirements - Master controller

The controller shall also be capable of receiving, prioritizing, and assigning phasing for traffic signal preemption for emergency vehicles, railroad crossings, and transit facilities.

201.05 FUNCTIONAL REQUIREMENTS - MASTER CONTROLLER

The master controller shall be capable of operating a “closed-loop” traffic signal system that does not have a network connection to a traffic management center. The master controller hardware and software shall combine continuous real-time monitoring and reporting of conditions, system management control, and data collection capabilities. The master controller shall be fully compatible with any existing or proposed local intersection controller software and hardware to be interconnected.

The master controller shall provide a user interface that allows full system access directly on the master controller unit itself and from a traffic management center. The master controller shall support, at a minimum, the following system control capabilities:

- 32 local controllers
- 2 independent traffic control groups
- 64 system detectors
- 48 traffic coordination patterns
- 16 timing plans with cycle length, splits, and offsets
- Priority-based program selection (Manual, remote, time-based, traffic responsive)
- Common group sync reference (crossing arterials)
- Group traffic responsive operation
- Matching program technique (based on V+O)
- Group time-based operation
- 180 Event capacity
- 10 week, 99 day programs
- Group time-based, manual, and remote traffic plans

The master controller shall provide the following system parameter modification and entry capabilities:

- Display/modify field master parameters
- Display/modify all local controller parameters
- Remote timing modification
- Remote system parameter modification and entry

The master controller shall provide the following report generation and system logging options:

- System data reporting by user request
- Reports output via hard copy
- Reports uploaded to central

- Automatic and continuous alarm logging
- System detector status
- System program changes
- Traffic responsive computations

The master controller shall be capable of sending and receiving communications to local controllers and system detectors using either Ethernet TCP/IP communications protocol or serial-based communications protocol. If the optional fiber optic transceiver is provided on the master controller unit, communications shall be supported using either single-mode or multi-mode fiber optic cable, as noted in the Plans.

201.06 INSTALLATION

Before any new controller is installed in the field, the Contractor shall deliver the controller to the City of Memphis Signal Shop for programming. City personnel will then program the controller with the timing plans furnished by the Engineer. The appropriate communications settings (including the IP address) will be programmed by the City.

The Contractor shall deliver to the City not more than ten (10) controllers in each batch. Each controller shall be clearly labeled as to the intersection for which it is intended.

The Contractor shall allow at least five (5) working days (excluding City holidays) per delivered lot of controllers for the City to perform the required programming and database entry, after which the Contractor shall pick up the controllers and install them at the locations for which they have been programmed. The Contractor shall install the controller in the controller cabinet, making the necessary connections between the controller and the terminal blocks in the controller cabinet.

For local or master controllers connected to an existing or proposed traffic signal system, the Contractor shall fully integrate the new controller with the existing or proposed communications equipment and network. The Contractor shall setup and configure the local intersection at the City's central traffic management software and fully test the communications before acceptance testing.

201.07 TESTING

See **Subsection 211 –Traffic Signal Controller Cabinet** for testing requirements.

201.08 WARRANTY

Signal controllers shall be replaced or repaired by the manufacturer if a controller fails to function as intended due to workmanship or material defects within the first 24 months from the date of being put into field operation at no cost (including shipping) to the City.

201.09 DOCUMENTATION

For each new controller furnished by the Contractor, one hard copy of the user's manual shall be provided by the Contractor and placed in the plastic envelope inside the cabinet. One electronic copy of the user's manual shall be provided by the Contractor to the City.

The Contractor shall provide to the City the following information for each new controller furnished by the Contractor.

- Manufacturer's name, model number, and serial number
- Length of warranty and start date
- MAC address of the Ethernet network interface

201.10 MEASUREMENT AND PAYMENT

Payment at the contract unit price, per each, shall be made for each accepted controller of the type specified. This shall be payment in full for furnishing and installing the controller in the controller cabinet, making all connections inside the controller cabinet as required to render the installation operable, and fully integrating the controllers with existing traffic signal system.

Item Number	Description	Pay Unit
02890-201.01	8-Phase Traffic Signal Controller	EACH
02890-201.02	8-Phase Traffic Signal Controller (With Port 3 Internal Fiber Optic Transceiver)	EACH
02890-201.11	Master Controller	EACH
02890-201.02	Master Controller (With Port 3 Internal Fiber Optic Transceiver)	EACH

SECTION 211 – TRAFFIC SIGNAL CONTROLLER CABINET**211.01 GENERAL**

Three sizes of traffic signal controller cabinets are required by the City of Memphis with the following size and characteristics (**Table 211-1**):

Table 211-1 Controller Cabinet Types

Cabinet Type	Size M	Size P	Size U
Application	Corner with very limited Right-Of-Way	Standard size for base mounted cabinet	Signal with railroad preemption or other critical locations
Maximum outside dimensions	63”H x 36”W x 17”D	56”H x 44”W x 25”D	57”H x 58”W x 26”D
Load Switch Bays	12	16	16
Divided Compartment	No	No	Divided compartment with side door for battery backup system
Pole Mounted	Per Plans or Engineer approval	No	No
Base Mounted	Per Engineer approval	Per Plans	Per Plans
Foundation	Cast on-site	Precast hollow base	Size P foundation with side add-on on-site

Before fabrication of the cabinets is begun, the Contractor shall submit an electronic copy of complete shop drawings of each type of cabinet to be furnished for Engineer’s approval.

211.02 CABINET DESIGN AND CONSTRUCTION**A. General Requirements**

All components used shall be the industrial equivalent of military grade, meeting all the requirements contained herein, and shall, at a minimum, comply with Electronic Industries Association (EIA) Specifications. No component shall be of such design, fabrication, nomenclature, or other identification as to preclude the purchase of said component from any wholesale electronics distributor or from the component manufacturer.

Any electrical component weighting more than two ounces shall be supported firmly by supports other than its own pins or electrical connectors.

All electrical components modules shall be rated to tolerate a temperature range of 100 percent more than the ambient temperature to avoid component degradation, so physical and electrical parameters of the used materials remains operational. All circuits shall be designed for reliability and maximum performance.

211.02 Cabinet Design and Construction

The life expectancy of all components, under 24 hours a day operating conditions in their circuit application, shall not be less than ten (10) years.

All components such as resistors, capacitors, diodes, transistors, and integrated circuits shall be individually replaceable by the service technician.

The equipment shall meet all of its specified performance requirements when the input power is AC power, 60 ± 1 Hz, single phase, 115 volts ± 20 volts. The equipment shall be designed such that the failure of the equipment shall not cause the failure of any other.

B. Cabinet Material and Finishing

All traffic signal controller cabinets shall be fabricated from 0.125"-thick type 5052-H32 cast aluminum or welded sheet aluminum. All welds shall occur on the inside surface of the cabinet to maintain a clean appearance. All surfaces shall be free from weld flash. Welds shall be smooth, neatly formed, free from cracks, blowholes and other irregularities. All sharp edges shall be ground smooth. Sufficient care shall be taken in handling to ensure that scratches are minimized.

Unless otherwise specified, all new controller cabinets shall have an unpainted natural aluminum finish. Where painted cabinets are specified, the exterior shall be degreased and primed with a spray applied iron phosphate coat, equivalent to a four-stage iron phosphate coat prior to painting. The final coat shall consist of a powder coat paint (TGIC or equivalent) applied with a minimum thickness of 2 mils.

C. Power Distribution Panel

All cabinets shall be furnished with a power distribution panel mounted on the lower right hand inside wall when facing the front door opening of the cabinet. This panel shall include the following components:

1. Circuit Breakers

The circuit breaker shall be approved and listed by Underwriter's Laboratories. The operating mechanism shall be enclosed, trip free from operating handle on overload, and trip indicating. Contacts shall be silver alloy enclosed in an arc-quenching chamber. Each field cabinet shall have, as a minimum, a circuit breaker to protect the lamp, vent fan and duplex outlet. In addition, a properly rated equipment circuit breaker(s) shall be provided for the equipment complement shown on these specifications and Plans. Breakers shall have a minimum interrupt capacity of 10,000 amperes.

2. Radio Interference Suppressor

The cabinet shall be equipped with a radio interference filter installed at the electric service line input. The filter shall provide a minimum electrical noise attenuation of 50 decibels over the range of 200 kilohertz to 75 megahertz. The suppressor shall be hermetically sealed in a substantial metal case filled with a suitable insulation compound.

The suppressor terminals shall be nickel-plated brass studs of sufficient external length to provide space for connection of two appropriately sized AWG conductors and shall be mounted so that the terminals cannot be turned in the case. The suppressors shall be designed for operation at 50A, 120/240 Volts, 60 Hertz operation, and shall be approved by UL and EIA.

3. Power Cable Input and Junction Terminals

211.02 Cabinet Design and Construction

Power distribution blocks suitable for use as a power feed and junction points shall be furnished and installed for two and three wire circuits as indicated on the Plans. The line side of each circuit shall be capable of handling the number of different AWG wire sizes as shown on the Plans.

Each field cabinet shall include a fully wired equipment panel to be mounted on the lower rear inside of the wall of the field cabinet. The back panel shall be utilized to distribute and properly interconnect all cabinet wiring related to the specific complement of equipment as indicated on the Plans. Each piece of equipment specified shall have its cable harness properly terminated at terminal boards on the back panel. All functions available at the equipment connector shall be carried in the connector cable harness to a terminal board point on the back panel.

4. Power Outlets

A minimum of four (4) 110VAC standard (not GFCI) receptacles shall be provided on the power panel, protected by the surge suppressors and a circuit breaker.

D. Doors

Cabinets shall have a right-hinged front opening door, which shall include, substantially, the full area of the cabinet front and one (1) auxiliary police door-in-door for access to emergency controls. The main door shall be equipped with a positive hold fast device to secure the door in at least two open positions being approximately 90 degrees open and the other at 120 degrees or more. The hold fast device shall be easily secured and released without the use of tools. Each door shall be furnished with a neoprene rubber door sealing gasket to assure the weatherproof integrity of the cabinet doors when closed. The main cabinet door shall employ two or three heavy duty hinges which shall be welded to or an integrally cast part of the cabinet and door. Hinge pins shall be ¼-inch diameter (minimum) stainless steel. No "piano" hinges or riveted construction shall be acceptable. The police panel door shall employ hinges meeting the above requirements.

The main cabinet door shall have a switch wired to activate "door-open" alarm input into the controller. This alarm shall be active whenever the main door is open.

E. Locks and Keys

The main door shall have a Corbin pin-tumbler cylinder lock conforming to the City of Memphis master key. The Memphis key code shall be furnished to the Contractor after award of contract. The auxiliary police door shall be furnished with a standard police sub-treasury lock. Two (2) keys for each lock shall be provided with each controller cabinet.

F. Fans and Ventilation

All cabinets shall be furnished with a thermostatically operated roof-mounted electric exhaust fan. All cabinets shall have fans rates at 200 cubic feet per minute at 100 degrees F. The fan shall be equipped with long-lasting permanently lubricated bearings for constant unattended operation. The exhaust fan shall be mounted in a rain-tight housing attached to the cabinet top. The thermostat shall have an adjustable turn on at temperatures ranging from 70 to 160 degrees F.

In all cabinets, the inlet ventilation openings shall be located in the lower part of the cabinet door, shall be screened and fitted with a fiberglass, furnace-type replaceable air filter of adequate size and capacity to pass a volume of air equal to or greater than the rated

capacity of the fan. The air filter supplied shall be a type and size which is readily available commercially.

G. Lighting

A LED lighting strip shall be mounted on the inside top of the cabinet near the front edge. The fixture shall be rated 45-watt equivalent and shall be wired to a door activated switch mounted near the top of the door.

H. Laptop Drawer Stand

An aluminum pull-out covered drawer shall be provided to the underside of the second shelf down. The drawer shall have an approximate dimension of 14”D x 16”W, less than 2” thick. The drawer shall have a flip up lid capable of holding the necessary equipment manuals and drawings. Top surface of the drawer shall be flat and have smooth edges. When fully extended, it shall hold a 10 lbs full size laptop securely and stable.

I. Foundation and Mounting Hardware

All base-mounted cabinets shall be installed on a hollow concrete foundation using Contractor-furnished hot dip galvanized bolts, nuts, washers, and template. Precast hollow base shall be used for Size P and Size U cabinets. The hollow base shall have opening slots on all four sides of the base near the bottom edge to allow future 2” or 3” conduit entry.

Pole-mounted cabinets shall be equipped with brackets (two each) for ¾ inch wide stainless steel banding. The Contractor shall attach such cabinets to wood or steel poles using food service grade stainless steel banding which has minimum thickness of 3/16 inch.

J. Cabinet Switches and Police Panel

1. Switches Inside Main Door.

Automatic/Flashing switch: Mounted on the inside of the main cabinet door. Switch shall preempt the normal signal display and initiate the specified flashing display. The controller shall continue to operate during this flashing mode.

2. Police Panel

All cabinets shall be furnished with 2 police compartment accessible through the door-in-door. The back side of the compartment extending into the cabinet shall have all exposed electrical facilities enclosed in a protective housing. The police compartment shall be equipped as follows:

- Signal Power Switch: This switch will remove power from the signal Buss.
- Automatic/Flashing switches: In flashing position, the normal red, yellow, and green signal display shall be preempted for the flashing operation. Upon resuming automatic operation, the controller display shall be in the pre-programmed start-up orientation.
- Normal/Manual switch: When in manual, this switch shall stop the automatic sequence of the controller and hold the existing display until manually advanced into the next interval. When in normal, the automatic control sequence shall continue.
- Push Button and Cord. A miniature panel connector shall be installed for connecting a detachable hand held push button for manual operation. The connector shall be a

211.03 Cabinet Wiring

Canon #WK-3325 or exact equivalent. A quality retractable cord with molded hand held push button with attached connector plug for engaging the connector described above. The retractable cord shall be capable of an extension of 3 feet minimum and shall be stored in the police compartment when not in use.

K. Dimensions and Equipment Locations

All cabinets shall be supplied consistent with the following minimum and maximum dimensions and equipment locations:

- Top shelf positioned to allow 4 inches above controller to top of cabinet and 4 inches on each side of controller to the sides of the cabinet.
- Second shelf-positioned approximately 8 inches below the top shelf to allow for a 6 inch high amplifier with 2 inches of space between top of amplifier and bottom of top shelf.
- Width of cabinet must allow at least 2 inches clearance on each side of the set of amplifiers (where applicable) from the terminal strips mounted on the sides of the cabinet.
- Load switches are to be mounted below the bottom shelf at the left rear of the cabinet. With the relays in their bases, a minimum clearance of 2 inches shall be maintained below the bottom shelf and from the terminal blocks mounted on the sides of the cabinet.
- Field connectors are to be at the bottom rear of the cabinet on horizontal terminal strips. Terminal strip blocks shall be positioned not less than 2 inches nor more than 4 inches from the cabinet bottom.
- Field loop connections are to be made on terminal strips located on the left wall of the cabinet below the bottom shelf.
- Loop amplifier cabinet connections are to be made on terminal strips on the left wall of the cabinet as that of the loop amplifier shelf with connections available for AC+, AC-, logic common, and the appropriate vehicle and pedestrian input to the controller for each module.
- Cabinet power connections are to be made on the right wall of the cabinet below the bottom shelf and 2 to 4 inches above the bottom of the cabinet.

211.03 CABINET WIRING

All cabinet wiring shall be neatly bundled and attached to the sides and back of the cabinet. No stick-on pads shall be acceptable. Wiring must be attached to cabinet wall using screws.

Cabinet wiring shall be provided for the equipment complement as specified on the Plans and these specifications. All field cabinet wiring where connected to terminal strips, switches, radio interference suppressor, etc. shall be identified by the use of insulated pre-printed sleeving slipped over the wire before attachment of the lug or making the connection. The wire markers shall carry the legend in plain words with sufficient details so that a translating sheet shall not be required.

All wires shall be cut to the proper length before assembly. No wires shall be doubled back to take up slack. Wires shall be neatly laced into cables with nylon lacing. Cables shall be secured with nylon cable clamps. The grounded side of the electric service shall be carried throughout the field cabinet without a break.

211.03 Cabinet Wiring

All electrical connections in the field cabinet shall have sufficient clearance between each terminal and the field cabinet to provide an adequate distance to prevent a leakage path or physical contact under stress. Where these distances cannot be maintained, barriers must be provided. All equipment grounds shall run directly and independently to the ground bus. Interconnect cables between components shall be carefully laid such that when the door is closed, it does not press against the cables or force the cables against the various components inside the cabinets. Sufficient length of cable harnesses shall be provided to easily reach the electronic equipment placed anywhere on the shelves.

All wiring containing line voltage AC shall be routed and bundled separately and/or shielded from all low voltage, i.e. control circuits. All conductors and live terminals or parts, which could be hazardous to maintenance personnel, shall be covered with suitable insulating materials.

All conductors used in the cabinet wiring shall be #22 AWG or larger with a minimum of 19 strands. The insulation shall have a minimum thickness of 10 MILS. All wiring containing line voltage shall be a minimum size of #14 AWG.

The Power return (neutral) and equipment ground wiring shall be electrically isolated from each other and the line (hot) wiring by an insulation resistance of at least 10 Megohms when measured at 250 VAC. Return and equipment grounding wiring shall be color-coded white and green respectively.

Terminal strips located on the panels shall be accessible to the extent that it shall not be necessary to remove the electronic equipment from the cabinet to make an inspection or connection.

Terminal blocks shall be two position multiple pole barrier type. Shorting bars shall be provided in each of the positions provided along with an integral marking strip. Terminal blocks shall be so arranged that they shall not upset the entrance, training, and connection of incoming field conductors. All terminals shall be suitably identified by legends permanently affixed and attached to the terminal blocks. Not more than three (3) conductors shall be brought to any one terminal screw. No electrically alive (hot) parts shall extend beyond the protection afforded by the barriers. All terminal blocks shall be located below the shelves.

Power terminal blocks shall be Underwriter's Laboratory approved for 600 volts minimum and shall be suitable for outdoor use. Terminals used for field connections shall secure conductors by means of a nickel or cadmium plated brass binder head screw. Terminals used for internal wiring connections, but not for field connections, shall secure conductors by means of a nickel or cadmium plated brass binder head screw.

A solid copper ground bus bar shall be permanently affixed to the inside surface of a cabinet wall. The point of contact between the ground bus and cabinet wall shall have less than 0.5-ohm resistance. The copper ground bus bar shall have a minimum of 20 connector points, each capable of securing at least one #10 conductor. AC return and equipment ground wiring shall return to the ground bus bar. Where multiple bus bars are used, they shall be bonded to each other with bare stranded #10 copper wire.

Unless otherwise required to accommodate the phase sequence called for on the Plans, cabinets shall be wired for eight (8) vehicular phases and four (4) pedestrian phases with the signal monitor programmed accordingly.

A. Emergency Vehicle Preemption (EVP) Card Rack Harness

Each controller cabinet shall have the required wiring and harness for installing an EVP card rack either as part of the Plans or in future.

B. Pin Connectors

Electrical connections between the control unit and the cabinet wiring harnesses shall be accomplished using one or more "MS" type multiple pin connectors at the controller (NEMA type) and insulated spade wire terminal connectors at the cabinet terminal blocks. The pin connectors and function pin assignments shall be in accordance with the following tables: **Table 211-2 through 211-6.**

All functions developed within the control unit for existing or future expansion phasing up to the maximum capability of the controller shall be available at the cabinet terminals for greatest operational flexibility. All functions and pin assignments required by NEMA shall be provided as a minimum. Additional functions and features, either required by these specifications or offered by the manufacturer, shall be provided through the pin connector on otherwise spare positions.

C. Colors of Signals During Flashing Operation

During flashing operation, the colors of the signals shall be as follows unless otherwise called for on the Plans:

- The signals for major street (phase 2 and 6 for east/west, or phase 4 and 8 for north/south) shall flash yellow (circular face).
- All other signals shall flash red (circular face).
- During flashing operation, all signals facing the same approach shall flash concurrently.

A circuit shall be provided and connected to the conflict monitor to cause the signals to flash when a conflict exists. The flash colors shall be programmed by the Contractor to meet the requirements listed above. Re-programming shall be accomplishable by adjusting wires on the signal terminal points. This process shall require no tools other than a screwdriver.

Table 211-2 Connector A - Alphabetical List of Pin Assignments

PIN	FUNCTION	PIN	FUNCTION
A	Spare 1	n	Test Input A (remote flash)
B	+24V DC External	p	AC+ Control
C	Voltage Monitor Output	q	Spare 1
D	Phase 1 Red Driver	r	Coded Status Bit B Ring 1
E	Phase 1 Don't Walk Driver	s	Phase 1 Green
F	Phase 2 Red Driver	t	Phase 1 Walk
G	Phase 2 Don't Walk	u	Phase 1 Check
H	Phase 2 Ped Clear	v	Phase 2 Pedestrian Omit
J	Phase 2 Walk	w	Omit All Red Clear Ring 1
K	Phase 2 Vehicle Call Detector	x	Red Rest Mode Ring 1
L	Phase 2 Ped Call Detector	y	Spare 3
M	Phase 2 Hold	z	Call to Non-Actuated II
N	Stop Timing Ring 1	AA	Test B
P	Inhibit Max Termination Ring 1	BB	Walk rest Modifier
R	External Start	CC	Coded Status Bit A Ring 1
S	Internal Advance	DD	Phase 1 On
T	Indicator Lamp Control	EE	Phase 1 Ped Omit
U	AC-	FF	Pedestrian Recycle Ring 1
V	Chassis Ground	GG	Max 2 Selection Ring
W	Logic Ground	HH	I/O mode bit C
X	Flashing Logic Output		
Y	Coded Status Bid C Ring 1		
Z	Phase 1 Yellow		
a	Phase 1 Ped Clear		
b	Phase 2 Yellow		
c	Phase 2 Green		
d	Phase 2 Check		
e	Phase 2 On		
f	Phase 1 Vehicle Call Detector		
g	Phase 1 Pedestrian Call Detector		
h	Phase Hold		
i	Force Off Ring 1		
j	Ext Min Recall All Phases		
k	Manual Control Enable		
m	Call to Non-Actuated I		

Table 211-3 Connector B - Alphabetical List of Pin Assignments

PIN	FUNCTION	PIN	FUNCTION
A	Phase 1 Next	n	Phase 8 Ped Omit
B	Spare 1	p	OL. A Yellow Driver
C	Phase 2 Next	q	OL. A Red Driver
D	Phase 3 Green Driver	r	Phase 3 Check
E	Phase 3 Yellow Driver	s	Phase 3 On
F	Phase 3 Red Driver	t	Phase 3 Next
G	Phase 4 Red Driver	u	OL. D Red Driver
H	Phase 4 Ped Clear Driver	V	Spare 4
J	Phase 4 Don't Walk Driver	w	OL. D Green Driver
K	Phase 4 Check	x	Phase 4 Ped Omit
L	Phase 4 Vehicle Call Detector	y	Free (no coordination)
M	Phase 4 Pedestrian Call Detector	z	Max 2 Selection - Ring 2
N	Phase 3 Vehicle Call Detector	AA	OL. A Green Driver
P	Phase 3 Ped Call Detector	BB	OL. B Yellow Driver
R	Phase 3 Omit	CC	OL. B Red Driver
S	Phase 2 Omit	DD	OL. C Red Driver
T	Phase 5 Ped Omit	EE	OL. D Yellow Driver
U	Phase 1 Omit	FF	OL. C Green Driver
V	Ped Recycle Ring 2	GG	OL. B Green Driver
W	Spare 2	HH	OL. C Yellow Driver
X	Spare 3		
Y	Phase 3 Walk Driver		
Z	Phase 3 Ped Clear Driver		
a	Phase 3 Don't Walk Driver		
b	Phase 4 Green Driver		
c	Phase 4 Yellow Driver		
d	Phase 4 Walk Driver		
e	Phase 4 On		
f	Phase 4 Next		
g	Phase 4 Omit		
h	Phase 4 Hold		
i	Phase 3 Hold		
j	Phase 3 Ped Omit		
k	Phase 6 Ped Omit		
m	Phase 7 Ped Omit		

Table 211-4 Connector C - Alphabetical List of Pin Assignments

PIN	FUNCTION	PIN	FUNCTION
A	Coded Status Bit A Ring 2	n	Phase 5 Omit
B	Coded Status Bit B Ring 2	p	Phase 6 Hold
C	Phase 8 Don't Walk Driver	q	Phase 6 Omit
D	Phase 8 Red Driver	r	Phase 7 Omit
E	Phase 7 Yellow Driver	s	Phase 8 Omit
F	Phase 7 Red Driver	t	Phase 8 Veh Call Det
G	Phase 6 Red Driver	u	Red Rest Mode Ring 2
H	Phase 5 Red Driver	v	Omit All Red Ring 2
J	Phase 5 Yellow Driver	w	Phase 8 Ped Clear Driver
K	Phase 5 Ped Clear Driver	x	Phase 8 Green Driver
L	Phase 5 Don't Walk Driver	y	Phase 7 Don't Walk Driver
M	Phase 5 Next	z	Phase 6 Don't Walk Driver
N	Phase 5 On	AA	Phase 6 Ped Clear Driver
P	Phase 5 Veh Call Detector	BB	Phase 6 Check
R	Phase 5 Ped Call Detector	CC	Phase 6 On
S	Phase 6 Veh Call Detector	DD	Phase 6 Next
T	Phase 6 Ped Call Detector	EE	Phase 7 Hold
U	Phase 7 Ped Call Detector	FF	Phase 8 Check
V	Phase 7 Veh Call Detector	GG	Phase 8 On
W	Phase 8 Ped Call Detector	HH	Phase 8 Next
X	Phase 8 Hold	JJ	Phase 7 Walk Driver
Y	Force Off Ring 2	KK	Phase 7 Ped Clear
Z	Stop Timing Ring 2	LL	Phase 6 Walk Driver
a	Inhibit Max Termination Ring 2	MM	Phase 7 Check
b	Spare 1	NN	Phase 7 On
c	Coded Status Bit C Ring 2	PP	Phase 7 Next
d	Phase 8 Walk Driver		
e	Phase 8 Yellow Driver		
f	Phase 7 Green Driver		
g	Phase 6 Green Driver		
h	Phase 6 Yellow Driver		
i	Phase 5 Green Driver		
j	Phase 5 Walk Driver		
k	Phase 5 Check		
m	Phase 5 Hold		

**Table 211-5 Connector D-37 Pin socket AMP # 747315-2
Alphabetical List of Pin Assignments**

PIN	FUNCTION
1	TBC On Line (Sys Detector #1)
2	Dial A (Sys Detector #7)
3	Dial B (Sys Detector # 8)
4	Split A (Sys Detector #5)
5	Split B (Sys Detector #6)
6	Offset 1 (Sys Detector #2)
7	Offset 2 (Sys Detector #3)
8	Offset 3 (Sys Detector #4)
9	Remote Flash
10	Preempt 1
11	Preempt 2
12	Preempt 3
13	Preempt 4
14	Conflict Flash Status
15	Manual Flash Status
16	Alt Sequence A (Sp Status #1)
17	Alt Sequence B (Sp Status #2)
18	Alt Sequence C (Sp Status #3)
19	Alt Sequence D (Sp Status #4)
20	Set Clock (Sp Status #5)
21	Dimmer (Sp Status # 6)
22	Dial A (Sys Out 7)
23	Dial B (Sys Out 8)
24	Split A (Sys Out 5)
25	Split B (Sys Out 6)
26	Offset 1 (Sys Out 2)
27	Offset 2 (Sys Out 3)
28	Offset 3 (Sys Out 4)
29	Flash (Sys Out 1)
30	Auxiliary 1
31	Auxiliary 2 or any Pre-empt
32	Auxiliary 3 or Detector Reset
33	Logic Ground
34	Optional Serial Comm. 1
35	Optional Serial Comm. 1
36	Optional Serial Comm. 2 Reserved-1
37	Optional Serial Comm. 2 Reserved-2

Table 211-6 Connector RS232 - Alphabetical List of Pin Assignments

PIN	FUNCTION
1	Frame Ground (FG)
2	Transmit Data (TD)
3	Receive Data (RD)
4	Request To Send (RTS)
5	Clear To Send (CTS)
6	Not Used
7	Signal Ground (SG)
8	Data Carrier Detect (DCD)
20	Data Terminal Ready (DTR)

211.04 LOAD BAY, SWITCHES, FLASHERS, AND RELAYS

A. Load Bay

Each cabinet shall have a load bay that supports 50A power distribution and is compatible with NEMA TS1 controller and NEMA 12-channel conflict monitor.

For Size M cabinet, the load bay shall have a minimum of 12 load switch positions and 6 flash relay positions. For Size P or Size U cabinets, the load bay shall have 16 load switch positions and 8 flash relay positions.

B. Load Switches

All load switches shall be three-circuit solid-state load switches conforming to NEMA section 5. Indicators on the front panel of the load switch shall indicate the status of the input side of the load switch. These switches shall isolate the 24 V DC signal logic outputs of the controller from the 120 VAC power line and field terminals so as to prevent high energy line transients from entering the controller unit. Each load relay circuit shall optically isolate the field terminal from the controller, shall turn on at zero volts, and be rated at 25 amps output load at 120 VAC (Crydom relay d 1225 or equal). Load switches for vehicular and pedestrian indications shall be interchangeable. Each output shall be driven by a separate controller input. No logic circuitry is permitted in load switches. No reed switches shall be permitted.

Each load switch base shall be identified by phase number and overlap number as applies. Each relay base and power relay base shall be properly identified. No cabinet equipment may obstruct these identifications.

Twelve (12) load switches shall be provided for all type of controller cabinets.

C. Flasher and Flasher Relays

Each cabinet shall be furnished with and wired for a plug-mounted, dual circuit, all solid-state flasher unit. The connector for the flasher is to mate with a Beau S-406-LAB or approved equal. The flasher shall have a duty of at least 50 percent and no more than 60 percent at a flash rate of 1 Hertz. The flasher shall be wired into the cabinet to provide

211.05 Detector Amplifiers

optionally a yellow/red flash display or an all-red flash display. The flasher shall be rated at 25 amperes per circuit at 120 VAC. Each circuit shall use the same type load cube specified for the signal load switch. A heat sink shall be made a part of the flasher body. Two (2) LEDs shall be incorporated into the flasher to indicate circuit actuation. Load cubes shall be hard-wired to the flasher outputs without the use of printed circuit boards. Solid state flasher units shall meet the requirements of section 4D 11 of the MUTCD.

Six flasher relays shall be provided for all type of controller cabinets.

D. Preemption Isolation Relays

At intersections where the Plans call for preemption, an isolation relay shall be provided for each separate preempt input.

Railroad preemption, where called for on the Plans, shall provide fail-safe operation such that removal of voltage from the railroad cabinet-side of the isolation relay shall remove an input to the controller and thereby initiate the railroad preemption sequence.

211.05 DETECTOR AMPLIFIERS

Each controller cabinet shall be supplied with one 6-position detector card rack and harnesses that meet NEMA TS1-1989 R2000 standard.

One rack power supply unit shall be provided as part of the 6-position card rack. The power supply unit shall meet all requirements of the NEMA TS1-1989 R2000 standard. The power supply unit shall provide four independent channels of regulated 24VDC power for the detector rack. A power switch shall be provided on the unit to switch power to all channel outputs. A separate green LED indicator shall be provided to display output status and fuse integrity for each of the four supply outputs. Each output shall be fused for over-current protection. Each output shall also be protected against voltage transients by a 1500 Watt suppressor.

A minimum of four (4) inductive loop detector amplifiers shall be provided for each controller cabinet. Detector amplifiers shall meet the requirements of **Section 401**. Loops located at different approaches of the intersection shall not share the same detector card.

For Size P and Size U controller cabinets, one additional 5-position detector card rack and harnesses shall be provided and wired for future use.

211.06 CONFLICT MONITOR

Each cabinet shall have a 12-channel conflict monitor which meets or exceeds all specifications outlined in Section 6 (Conflict Monitor) of NEMA TS1-1989 R2005. The Signal Monitor shall be capable of monitoring six or twelve channels consisting of a Walk input, Green input, Yellow input, and Red input for each channel. All fault timing shall be computed for each channel individually except for Conflict faults.

A. Monitoring Functions**1. Conflict Monitoring**

The Signal Monitor shall be able to detect the presence of conflicting Green or Yellow or Walk signal voltages on the AC field terminals between two or more non-compatible channels. A Conflict fault (CONFLICT) shall be a latching fault. The Signal Monitor shall

trigger when voltages on any conflicting channels are present for more than 450 ms. The Signal Monitor shall not trigger when voltages on any conflicting channels are present for less than 200 ms. Conflicting signals sensed for more than 200 ms and less than 450 ms may or may not trigger the unit.

2. Red Fail Monitoring

The Signal Monitor shall be able to detect the absence of active signal voltages on the Red and Green and Yellow and Walk AC field terminals. A Red Fail fault (RED FAIL) shall be a latching fault. The Red Fail monitoring function shall be disabled for all selected channels when the Red Enable input is not active. The Signal Monitor shall trigger when active voltages on all inputs of a channel channels are absent for more than 1000 ms. The Signal Monitor shall not trigger when active voltages on all inputs of a channel channels are absent for less than 700 ms.

A Walk Disable function shall be provided which will modify operation of Red Fail and Dual Indication monitoring. If this function is enabled via a front panel DIP switch labeled "WALK DISABLE", the unit shall trigger if it senses the absence of active Green, Yellow, and Red inputs of a channel regardless of the state of the Walk input. Dual Indication faults of Red + Walk shall not trigger the unit.

3. Voltage Monitoring

The Signal Monitor shall trigger when the voltage on the +24V input is below 18 Vdc for more than 200 ms. The Signal Monitor shall not trigger when the voltage on the +24V input is below 18 Vdc for less than 100 ms. A voltage level of +22 Vdc shall be required to prevent the unit from triggering. If the 24V Latch function is enabled via a front panel DIP switch, restoration of the proper voltage levels will not reset the unit. Only a manual reset or external reset will reset the unit. The Signal Monitor shall trigger when the Controller Voltage Monitor (CVM) input level goes False. A CVM Monitor function shall be provided which will sense a CVM fault and cause the unit to trigger. The Signal Monitor shall trigger when the voltage on the CVM input is False for more than 200 ms. The Signal Monitor shall not trigger when the voltage on the CVM input is False for less than 100 ms.

If the CVM Latch function is enabled via a front panel DIP switch, restoration of the CVM input to the True voltage level will not reset the unit. Only a manual reset or external reset will reset the unit.

The Signal Monitor shall provide a front panel DIP switch labeled "CVM LOG DISABLE" which prevents CVM events from being entered into the Previous Fail log.

4. AC Line Brownout Recognition

The Signal Monitor shall be able to detect that the AC Line has fallen below 92 ± 2 Vac for greater than 475 ± 25 ms. This shall force the Output and Start Delay Relay to the de-energized "fault" state and cause the POWER LED to flash at a 2 Hz rate. The unit shall maintain this state until the AC Line voltage rises above 96 ± 2 Vac for greater than 120 ± 25 ms.

5. Dual Indication Monitoring

The Signal Monitor shall be able to detect the presence of active voltage on any combination of field signal inputs of a channel except Green and Walk. A Dual Indication fault shall be a latching fault. This function shall be enabled on a per channel basis using DIP switches mounted on the front panel labeled "SSM". The Dual Indication monitoring

211.06 Conflict Monitor

function shall be disabled for all selected channels when the Red Enable input is not active.

The Signal Monitor shall be able to detect the presence of active voltage on the Yellow and Green field signal inputs of a channel. A GY Dual Indication fault shall be a latching fault. This function shall be enabled with a DIP switch on the front panel labeled "GY ENABLE". When the switch is in the ON position, all channels shall be monitored for simultaneous active Green and Yellow inputs on a channel.

The Signal Monitor shall trigger when multiple inputs are active on a channel for more than 500 ms. The Signal Monitor shall not trigger when multiple inputs are active on a channel for less than 250 ms. Channels with multiple voltages active for more than 250 ms and less than 500 ms may or may not trigger the unit.

A Walk Disable function shall be provided which will modify operation of Red Fail and Dual Indication monitoring. If this function is enabled via a front panel DIP switch labeled "WALK DISABLE", the unit shall not trigger if it senses the Red and Walk signals active.

6. Clearance (Short or Absent Yellow) Monitoring

The Signal Monitor shall be able to detect that a channel has not provided an adequate Yellow Clearance interval during a Green to Yellow to Red sequence. A Clearance failure shall be a latching fault. This function shall be enabled on a per channel basis using DIP switches mounted on the front panel labeled "SSM". The Clearance monitoring function shall be disabled for all selected channels when the Red Enable input is not active.

The Yellow Clearance interval shall be 2.7 seconds +/- 0.1 seconds.

7. Recurrent Pulse Monitoring

The Signal Monitor shall detect Conflict, Red Fail, and Dual Indication faults that result from intermittent or flickering field signal inputs. These recurring pulses shall result in a latching fault with the RP STATUS indicator illuminated along with the resulting Conflict, Red Fail, or Dual Indication indicator.

8. External Watchdog Monitoring

Absence of a logic input transition from the cabinet controller watchdog circuitry for 1500 msec (+_100 msec) shall cause the unit to trigger. The monitor shall remain in the fault mode until the unit is reset by the Reset button or the External Reset input. A Power Failure shall also reset the CVM/WD fault state of the monitor. This function shall be enabled via a front panel DIP switch labeled "WD ENABLE". The EXTERNAL WATCHDOG input shall be wired to connector MSB-S (12 Channel) or MSA-q (6 Channel).

9. Program Card Ajar

When the Programming Card is removed or not seated properly, the Signal Monitor shall force the Output Relay to the de-energized fault state and illuminate the PROGRAM CARD indicator. A reset command from the front panel Reset switch or External Reset input shall be required once the Program Card is in place.

10. Flashing Yellow Arrow Pplt Support

The Signal Monitor shall be designed to monitor an intersection with up to four approaches using the four section Flashing Yellow Arrow (FYA) movement outlined by the NCHRP Research Project 3-54 on Protected/Permissive signal displays with

Flashing Yellow Arrows. Two cabinet configurations shall be supported depending on the number of load switches provided and the capabilities of the Controller Unit. In both modes the Signal Monitor shall be designed to provide the same fault coverage for the FYA approaches as it does for conventional protected left turn phases including Conflict, Red Fail, Dual Indication, and Minimum Yellow Clearance monitoring.

11. Led Signal Threshold Adjust

The MMU shall provide the capability to sense field inputs signals with the following thresholds:

Conflict, Dual Indication Low Threshold Signal Inputs (Green, Yellow, and Red)

No Detect	less than 15 Vrms
Detect	greater than 25 Vrms

Red Fail High Threshold Signal Inputs (Green, Yellow, and Red)

No Detect	less than 50 Vrms
Detect	greater than 70 Vrms

B. Front Panel Control and Indicators

1. LED Indicators

All LED display indicators shall be mounted on the front panel of the Signal Monitor and shall be water clear, T 1 package, Super Bright type LEDs. All LEDs shall be labeled as follows:

- **POWER:** The POWER indicator shall flash at a rate of 2 Hz when the unit has detected a low voltage condition as described in Section 2.3.2.3. It shall illuminate when the AC Line voltage level is restored above the brownout level. The indicator shall extinguish when the AC Line voltage is less than 75 Vrms.
- **DIAGNOSTIC:** The DIAGNOSTIC indicator shall illuminate when an internal diagnostic test has failed. This indicator is intended to inform the service technician of a monitor hardware or firmware failure.
- **FAULT:** The FAULT indicator shall illuminate when the unit has responded to a fault condition and has transferred the Output relay.

2. LCD Indicators

- **CONFLICT:** The CONFLICT indicator shall illuminate when a conflicting proceed signal fault is detected.
- **RED FAIL:** The RED FAIL indicator shall illuminate when an absence of signal is detected on a channel(s). If the Red Enable input is not active, the RE OFF indicator shall illuminate.
- **CVM / WD:** The CVM /WD indicator shall illuminate when a Controller Voltage Monitor fault or External Watchdog fault is detected.
- **24V-2:** The 24V-2 indicator shall illuminate when a 24VDC fault condition on the 24V Monitor input #2 is detected.
- **24V-1:** The 24V-1 indicator shall illuminate when a 24VDC fault condition on the 24V Monitor input #1 is detected.

211.06 Conflict Monitor

- **RP STATUS:** The RP STATUS indicator shall illuminate when a recurrent pulse Conflict, Dual Indication or Red Fail fault is detected on a channel(s).
- **DUAL INDICATION:** The DUAL INDICATION indicator shall illuminate when a Dual Indication or GY Dual Indication fault is detected on a channel(s).
- **CLEARANCE:** The CLEARANCE indicator shall illuminate when the minimum Yellow Clearance time has not been met on a channel(s).
- **Rx:** The Rx indicator shall illuminate when the RS-232 port has received a character.
- **Tx:** The Tx indicator shall illuminate when the RS-232 port has transmitted a character.
- **CHANNEL STATUS:** A separate indicator for each input of each channel shall display all active signals simultaneously. Additionally, one indicator per channel shall be provided which identifies a channel as being involved in an error condition that has triggered the unit.

3. Front Panel Control

- **RESET Button:** A momentary SPST Control switch labeled RESET shall be provided on the unit front panel to reset the monitor circuitry to a non-failed state. A reset command issued from either the front panel button or External Reset input shall be a one-time reset input to prevent the unit from constant reset due to a switch failure or constant external input, and shall cause all LED and LCD indicators to illuminate for 500ms.
- **MODE Button:** A momentary SPST Control switch labeled MODE shall be provided on the unit front panel to control the display mode.
- **INC Button:** A momentary SPST Control switch labeled INC shall be provided on the unit front panel to modify the selected display mode.

C. Electronics1. Internal MPU Watchdog

A microprocessor shall be used for all timing and control functions. Continuing operation of the microprocessor shall be verified by an independent monitor circuit, which shall force the OUTPUT RELAY to the de-energized "fault" state and illuminate the DIAGNOSTIC indicator if a pulse is not received from the microprocessor within a defined period not to exceed 500 ms. This shall be programmable as a latching function and will require a power-down cycle to clear.

2. Ac Input Sampling

High speed sampling techniques shall be used to determine the true RMS value of the AC field inputs. Each AC input shall be sampled at least 32 times per line cycle. The RMS voltage measurement shall be insensitive to phase, frequency, and waveform distortion.

3. Sockets

In the interest of reliability, no sockets shall be allowed for ICs. All embedded programming shall be accomplished using in-circuit techniques or via the front panel communications port.

4. Internal Power Supply

A built-in, high-efficiency switching power supply shall generate all required internal voltages. Failure of the internal power supply to provide proper operating voltages shall force the Output Relay to the de-energized "fault" state and illuminate the DIAGNOSTIC indicator. A user replaceable slow blow fuse shall be provided for the AC Line input. The unit shall be operational over the AC Line voltage range of 75 Vrms to 135 Vrms.

5. Configuration Parameters

All user programmed configuration settings shall be stored in an electrically erasable programmable read-only memory (EEPROM) or front panel DIP switches. Designs using a battery to maintain configuration data shall not be acceptable.

6. Field Terminal Inputs

All 120 Vac field terminal inputs shall provide an input impedance of 150K +_50K ohms and be terminated with a discrete resistor having a power dissipation rating of 0.5 Watts or greater. In the interest of reliability and repair ability, the front panel MS connectors shall not be directly mounted to the printed circuit board. A wire harness of 22 gauge minimum stranded wire shall be used.

7. Communications Ports

An Ethernet port capable of a minimum 10 Mbps operation shall be provided on the front panel. The Ethernet port shall be electrically isolated from the monitor electronics and shall provide a minimum of 1500 Vrms isolation. The connector shall be an RJ-45 eight pin connector.

An HTML based capability shall be provided in the monitor to configure the network parameters of the Ethernet port using a standard HTML browser.

8. Component Specifications

All electrical components used in the unit shall be rated by the component manufacturer to operate beyond the full unit operating temperature range of -34oC to +74oC including the Liquid Crystal displays (LCD).

9. Printed Circuit Boards

All printed circuit boards shall meet the requirements of the NEMA STANDARD TS-1 1989, plus the following requirements to enhance reliability:

- All plated-through holes and exposed circuit traces shall be plated with solder.
- Both sides of the printed circuit board shall be covered with a solder mask material.
- The circuit reference designation for all components and the polarity of all capacitors and diodes shall be clearly marked adjacent to the component. Pin #1 for all integrated circuit packages shall be designated on both sides of all printed circuit boards.
- All electrical mating surfaces shall be gold plated.
- All printed circuit board assemblies shall be coated on both sides with a clear moisture-proof and fungus-proof sealant.
- All components and wire harnesses shall be mounted to the PCB using plated holes. "Piggy back" connections or jumper wires shall not be acceptable.

D. Event Logging Functions

In addition to the normal display mode, it shall be possible to review the previous failure (PF) and AC Line (AC) event logs, Program Card permissive programming, SSM switch programming, and set the Real time clock and calendar using the front panel display.

The Signal Monitor shall be capable of storing in non-volatile memory a minimum of 100 events. Each event shall be marked with the time and date of the event. These events shall consist of fault events, AC Line events, reset events, and configuration change events. The capability to assign a four digit identification number and 30 character description to the unit shall be provided. The event logs shall be uploaded to a PC using the serial port of the Signal Monitor and Windows based software provided by the manufacturer.

Each event log report shall contain the following information:

- Monitor ID#: a four digit (0000-9999) ID number and 30 character description assigned to the monitor.
- Time and Date: time and date of occurrence.
- Event Number: identifies the record number in the log. Event #1 shall be the most recent event.

1. Current Status Report (CS)

The Current Status report shall contain the following information:

- Fault Type: the fault type description.
- Field Status: the current GYRW field status and field RMS voltages if the monitor is not in the fault state, or the latched field status and field RMS voltages and fault channel status at the time of the fault.
- Cabinet Temperature: the current temperature if the monitor is not in the fault state, or the latched temperature at the time of the fault.
- AC Line Voltage: the current AC Line voltage and frequency if the monitor is not in the fault state, or the AC Line voltage and frequency at the time of the fault.
- Control Input Status: the current state and RMS voltage of the Red Enable input if the monitor is not in the fault state, or the status latched at the time of the fault.

2. Previous Fault Report (PF)

The Previous Fault log shall contain the following information:

- Fault Type: the fault type description.
- Field Status: the latched field status with RMS voltages, fault channel status, and RP Detect status at the time of the fault.
- Cabinet Temperature: the latched temperature at the time of the fault.
- AC Line Voltage: the AC Line voltage and frequency at the time of the fault.
- Control Input Status: the latched state with RMS voltage of the Red Enable input at the time of the fault.

3. AC Line Event Report (AC)

The AC Line log shall contain the following information:

- Event Type: describes the type of AC Line event that occurred.
 - Power-up - AC on, monitor performed a cold start
 - Interrupt - AC Line < Brownout level
 - Restore - AC restored from AC brown-out or AC interruption, no cold start
- AC Line Voltage: the AC Line voltage & frequency at the time of the event.

4. Monitor Reset Report (MR)

The Monitor Reset log shall contain the following information:

- The monitor was reset from a fault by the front panel Reset button, or External Reset input, or a non-latched event clear.

5. Configuration Change Report (CF)

The Configuration Change log shall contain the following information:

- The status of all configuration programming including the contents of the Program Card, all configuration DIP switches and option switches.
- Any configuration programming inputs such as 24V Inhibit.
- Configuration Check Value: A unique CRC value

The log shall also indicate which items have been changed since the last log entry.

6. Signal Sequence History Report (SSG)

At a minimum five logs shall be provided that graphically display all field signal and Red Enable states for up to 30 seconds prior to the current fault trigger event. The resolution of the display shall be at least 50 milliseconds.

211.07 SURGE PROTECTION

A. Electromechanical Relays

Each 120 VAC electromechanical relay in the cabinet, flash transfer, signal monitor, etc., shall be suppressed with an R.C. circuit (100 OHM/0.1 MFD) across it to ground.

B. AC Service

The cabinet AC service shall be provided with the following surge protection:

- Unit must be a two stage hybrid type.
- The protector shall be provided with terminals as defined below:
 - Main line (AC line first stage terminal)
 - Main neutral (AC neutral input terminal)
 - Equip line in (AC line second stage input terminal, 10 amps)
 - Equip line out (AC line second stage output terminal, 10 amps)
 - Equip neutral out (neutral terminal to protected equipment)
 - GND (earth connection)

211.07 Surge Protection

- The equip line in and equip line out terminals shall be separated by a 200 microhenry (minimum) inductor rated to handle 10 amps AC service.
- The first stage clamp shall be between main line and GND terminals.
- The second stage clamp shall be between equip line out and equip neutral.
- Main neutral and equip neutral out shall be connected together internally and shall have a gas discharge tube rated at 20 kA between main neutral and GND terminals.
- Main line and equip line terminals shall be isolated internally.
- If gas discharge tubes are utilized for the first stage clamps, each tube shall have a minimum of 0.15 OHM follow-current limiters in series.
- Peak clamp voltage: 350 volts at 20 KA. (Voltage shall be measured between equip line out and equip neutral out terminals. Current shall be applied between main line and GND terminals with GND and main neutral terminals externally tied together.)
- Response time: voltage as measured during peak clamp voltage test can never exceed 350 volts.
- Protector shall be epoxy encapsulated in a flame-retardant material.
- Continuous service current -- 10 amps at 120 VAC RMS.

C. Solid-State Load Switches

- Each AC+ signal display terminal shall withstand a 10 kA, (8 x 20 microsecond surge) 5 times without damage.
- Unit response time shall be less than 50 nanoseconds.
- Maximum clamping voltage shall be 395 volts (at 1 mA).
- Unit shall return to a high impedance state following surge.
- Unit shall be epoxy encapsulated in flame retardant material.

D. NEMA 24 VDC Inputs

Each 24 VDC input that leaves main controller cabinet (such as pedestrian detector, remote vehicle detector, logic common, etc.), shall be protected at the cabinet entry point with the following surge protection:

- Unit must be a two stage hybrid type.
- The signal pair must "pass thru" the protector so that the protector has an input lead, and output lead, and a ground connection.
- Peak surge: 4000 amps, 8 x 20 microsecond waveform.
- Number of occurrences: 25 times minimum at 2000 amps. (8 x 20 microsecond). Protector shall be operative after this test.
- Unit first stage shall be a two element gas discharge tube rated at 5 kA (8 x 20 microseconds).
- Unit second stage shall be 1500 watt silicon avalanche device with a clamp voltage of 45 volts max. at 2000 amps.

- Unit shall be epoxy encapsulated.

E. Loop Detectors

Each loop detector input circuit (at cabinet entry point) shall be equipped with the following surge protection:

- Unit shall be a three terminal device capable of protecting the detector against differential surges (between the loop leads), and against common mode surges (between leads and ground).
- Unit shall withstand six 400 amp (8 x 20 microsecond) differential mode surges and six 1000 amp (8 x 20 microsecond) common mode surges.
- Unit shall clamp both common mode and differential mode surges at 35 volts maximum in less than 40 nanoseconds.
- Differential (between loop leads) capacitance of the protector shall be less than 50 microfarads.
- Unit shall be epoxy encapsulated.

F. Data Communication Interconnect

Each external data communications pair must be protected at the cabinet entry point with the following surge protection:

- Unit must be a two stage series hybrid type.
- The signal pair must "pass thru" the protector, i.e.: the protector has two input leads, two output leads, and a ground connection.
- Peak surge: 4000 amp, 8 x 20 microsecond waveform.
- Number of occurrences: 25 times minimum at 2000 amps (8 x 20 microsecond). Detector must be operational after this test.
- Unit first stage must be a three element gas discharge tube rated at 10 KA per side (8 x 20 microsecond).
- Unit second stage must be 1500 watt silicon avalanche device with a clamp voltage twice that of the peak to peak operating voltage.
- Unit must be epoxy encapsulated.

G. 120 Volt AC Interconnect

- Unit must withstand a 10KA, (8 x 20 microsecond surge) 25 times.
- Unit response time less than 400 nanoseconds at 10KV/micro-second rise.
- Discharge voltage under 200 volts at 1000 amps.
- Operate on line voltage 120 VAC RMS single phase.
- Unit must be epoxy encapsulated in flame-retardant material.

211.08 Uninterruptible Power Supply (UPS) System (Optional)

211.08 UNINTERRUPTIBLE POWER SUPPLY (UPS) SYSTEM (OPTIONAL)**A. Stand-Alone UPS Cabinet**

If requested on Plans or Bid Documents, a stand-alone UPS cabinet can be used to house the UPS System. The UPS cabinet shall meet the following requirements:

- Same requirements as defined in **Section 211.02, A through F**, with the exception of a 100 CFM thermostatically regulated cabinet fan.
- Maximum outside dimensions: 56”H x 26”W x 15”D.
- Four (4) flat-top shelves at 12” apart, each capable of supporting a minimum of 125 lbs.
- Shelves shall provide vertical passageway for wiring in the rear of the cabinet on both the left and right side.
- The Cabinet shall include a generator receptacle accessible from the outside of the cabinet with a lockable door.

The stand-alone UPS cabinet shall support the following two mounting options, as requested on Plans:

- Base-mounted: Cabinet shall be installed on a concrete foundation using Contractor-furnished hot dip galvanized bolts, nuts, washers, and template. Concrete foundation is included in this bid item.
- Attached to Existing Cabinet: With prior Engineer’s approval, the stand-alone UPS cabinet shall be attached to the side of an existing Size P cabinet with manufacturer recommended attachment methods and hardware, and properly sealed for a waterproof attachment.

B. Size U Controller Cabinet

If requested on Plans or Bid Documents, a Size U controller cabinet shall be provided to house the UPS system. A Size U cabinet can be requested with or without the UPS system included.

The Size U cabinet shall meet all requirements described in this section. In addition, the Size U cabinet shall include a divided compartment to house a UPS system, allowing for an UPS in the same enclosure for ease of installation. The UPS compartment shall meet all requirements described in **Subsection A** for a stand-alone UPS cabinet.

C. UPS System

A complete UPS system shall be provided if requested on Plans or Bid Documents. The UPS system shall consist of a power interface module, a UPS unit, a generator receptacle, and a set of UPS batteries. For traffic signal cabinets, the UPS system shall be compatible with the two cabinet housing options described in **Subsection A and B** above. For other cabinets such as school flasher, radar detection system, or HAWK pedestrian signal, the UPS system shall be compatible with the cabinet housing options described in the respective sections of this specification.

The UPS system shall be provided with the following three options as requested on Plans and Bid Documents:

- Option A:

211.08 Uninterruptible Power Supply (UPS) System (Optional)

- Power output capacity: 400 Watts / 560 VA
- Minimum backup time: 2 hours at 100% load, 4 hours at 50% load.
- Option B:
 - Power output capacity: 875 Watts / 1,250 VA
 - Minimum backup time: 2 hours at 100% load, 4 hours at 50% load.
- Option C:
 - Power handling capacity: 1,400 Watts / 2,000 VA
 - Minimum backup time: 1 hour at 100% load, 3.5 hours at 50% load.

The UPS system shall meet NEMA TS2 environmental requirements. In the event of utility power outage, the UPS system shall keep the traffic signal running for 8 hours.

The UPS system shall meet the following additional requirements:

1. Power Interface Module

The power interface module shall be designed and manufactured to interface cabinet utility power to the UPS system and to control the output utility power within the cabinet. The PIM's primary element is a magnetic contactor that is controlled by the UPS system. The UPS constantly monitors utility power and when available, feeds that power through the PIM, to the utility input of the UPS.

The UPS operates in two distinct modes, a Standby Mode and an On-line Mode. In the Standby Mode when the utility power fails, the PIM will automatically switch the UPS generated power to power the traffic cabinet. In the Online Mode, conditioned, regenerated power is supplied to the cabinet via the UPS inverter. In the event of utility failure, the inverter will seamlessly switch (no measurable delay) from utility power to battery power. Additionally, should the UPS inverter ever fail the PIM will automatically by pass the inverter and switch utility power to the cabinet.

The PIM shall use magnetic contactor to control system power. The PIM shall be mounted on a back or side panel of the UPS compartment or cabinet. The PIM shall include a watertight receptacle accessible from outside the cabinet for generator hookup.

The PIM shall have a by-pass switch which allows hot swapping of entire UPS without disturbing intersection operations.

2. UPS Unit

The UPS Unit shall include the following features and minimum requirements:

- General requirements
 - Provides ON-LINE conditioned, re-manufactured power for cabinet equipment protection. Output electrical properties:
 - Voltage: 120 VAC +3%
 - Frequency: 50 or 60 Hz
 - Total Harmonic Distortion (THD): 4.0% max
 - Crest Factor Ratio (Non-linear Load and <5% THD) Typical:
 - @50% Load: Up to 4.8:1

211.08 Uninterruptible Power Supply (UPS) System (Optional)

- @75% Load: Up to 3.2:1
 - @100% Load: Up to 2.4:1
 - Dynamic Response: +/- 4% for 100% step order change;
0.5ms recovery time
 - Overload: 110% for 10 sec; 200% for 0.05 sec
- UPS protection for input/output short circuit; Input/Output overload; Excessive battery discharge
- Options to allow full signal operation for short power interruptions and flash operation for longer interruptions or low battery
- Fully compatible with police panel operation and allows complete shutdown during emergencies
- All internal calibrations shall be digital with no potentiometer to set or fail
- Microprocessor controlled
- Rugged, military grade inverter designed for 24 hour, 7 day, 365 days a year operation
- Built-in TVSS (surge suppression)
- Automatic periodic self testing
- Battery System
 - Sophisticated battery management for recharging and protection
 - Temperature compensated battery charging
 - Battery run-time counter
 - Periodic battery testing checks for: Battery condition; Battery charge; Battery status; Battery temperature
 - Fool proof battery connector system allows safe, tool-less installation even in dark or low-light conditions
 - Optional “quick charge” battery charge
- User Interface
 - All configuration can be accomplished from local keypad, no laptop necessary
 - 4 line front panel LCD display of battery, power system, and UPS system status; UPS information; and event logs
 - 8 programmable relays with 16 assignable status conditions to set or reset relays
 - Alarm monitoring and logging functions for the following:
 - Input bad
 - Output bad
 - Temperature
 - Overload
 - General alarm

- Standard Ethernet (TCP/IP) communications interface for remote monitoring and configuration, including remote monitoring software
- Web-based network interface allows monitoring with common web browsers
- Reliability
 - MTBF: Inverter > 100,000 hours; System > 150,000 hours

3. UPS Battery

Batteries shall be specifically designed for outdoor use with the following requirements:

- UL 924 and UL 1989 certified
- Absorbed Glass Mat (AGM) and Valve Regulated Lead Acid (VRLA) battery technology
- Copolymer Polypropylene case and cover, sealed, maintenance free
- 12 VDC
- Amp Hour Capacity (20 hour rate): 41 Amp/Hour minimum
- Maximum weight: 50 lbs
- Maximum dimensions: 10”L x 6”W x 10”H
- Minimum run time (77°F, full charge) at 875 Watts: 2.5 Hours

211.09 FIBER DISTRIBUTION BOX

Each controller cabinet shall be supplied with one Fiber Optic Termination Unit which meets the requirements of **Section 811.06.B**.

211.10 CABINET MONITORING UNIT

Each controller cabinet shall be supplied with one remotely managed cabinet monitoring unit that meets the following minimum requirements:

- Powered by 120 VAC power source
- Operating temperature range: - 40°C to + 80° C (-40°F to 176°F)
- Humidity range: 5-95%, non-condensing
- Dimension: 17.5”W x 1.75”H x 7.5”D, standard 19-inch rack mount 1U
- Analog inputs: 8 (4 as 120VAC/12-28VDC selectable, 4 as 12-28VDC only)
- Digital inputs: 8 (4 as 120VAC/12-28VDC selectable, 4 as 12-28VDC only)
- Digital outputs: 10 (2 as NO/NC Relay, 8 as 24VDC ground true)
- Outlets: NEMA 5-15 (4 x 120V, remotely switchable rated 15A total load)
- Integral battery back-up for power failure reporting
- Real time clock
- GPS enabled and ability to self-locate

- Built-in Ethernet Port (10/100 Base-T)
- Cellular modem included to provide internet connectivity with cloud-based management software. No cellular modem connection cost for the life-time of the unit
- Compatible with City's existing cloud based remote management and monitoring system
- Cloud based management software shall provide web-based user interface and shall support the following functions:
 - Display monitoring unit locations on map based on units' GPS self-locating data
 - Remotely switch power outlets with immediate effect
 - If selected, continuously monitoring the following real-time status in cabinet and report failure via email and text messages:
 - Flash or normal intersection operation
 - Power failure
 - Cabinet door status
 - Detector errors
 - UPS power, battery voltage, and charge status
 - GPS unit status
 - Network infrastructure device status
 - Role based and password protected user accounts with device management responsibilities defined by system administrator
 - Cloud based management software shall be free-of-charge to the City for the life-time of all cabinet monitoring units installed

211.11 WARRANTY

All components of the controller cabinet shall be replaced or repaired by the manufacturer if it fails to function as intended due to workmanship or material defects within the first 24 months (60 months for all surge protection components) from the date of being put into field operation at no cost (including shipping) to the City.

211.12 DOCUMENTATION

Contractor shall provide detailed technical circuit description and circuit schematic information and detailed parts list applicable to the operations and maintenance of the controller, signal conflict monitor, loop detectors, vehicle preemption equipment, and associated auxiliary equipment. Cabinet wiring diagrams with interconnection details, schematics, and maintenance techniques shall be furnished. Information in manual form shall include a materials guide which shall contain the replacement part numbers and description of all components used. All solid-state devices shall be listed by their generic number or in lieu of this, a complete cross-index from manufacturers' numbers to generic number shall be provided and shall be identified on all printed circuit boards or other mounting locations. Parts lists shall be itemized with the respective chassis, module, or circuit wherein parts may be found. A total listing of parts without grouping shall be unacceptable. Schematic circuit drawings shall be furnished that are slow to fade when exposed to sunlight over long periods of time. A developed and fixed printing

process, or one of the forms of printing by actual ink transfer, shall be acceptable. Blueline prints and sepias are not acceptable.

Two (2) copies of all the above information shall be provided with each piece of equipment in the cabinet. In addition, two (2) copies of a cabinet wiring diagram, including all auxiliary equipment, shall be supplied with each cabinet. In addition, a photo mylar master of a cabinet wiring diagram including all auxiliary equipment shall be supplied with each control cabinet type. A clear, re-sealable plastic envelope shall be attached with screws to the inside of each cabinet door for storage of the cabinet wiring prints. This envelope shall be mounted so as to avoid restriction of the circulation of air into and out of the cabinet.

The Contractor shall provide to the City the following information for each new cabinet component furnished by the Contractor.

- Manufacturer's name, model number, and serial number
- Length of warranty and start date
- MAC address of the Ethernet network interface for conflict monitor and UPS control unit.

211.13 INSTALLATION

Before any new conflict monitor is installed in the field, the Contractor shall deliver the conflict monitor to the City of Memphis Signal Shop for programming. City personnel will then program the conflict monitor with the phasing information furnished by the Engineer. The appropriate communications settings (including the IP address) will be programmed by the City.

For UPS system, the Contractor shall obtain the assigned IP address for the UPS control unit from the City. The Contractor shall install the assigned IP address and configure the UPS system. Integrate with the existing or proposed Ethernet devices in the cabinet as required. Perform all coordination, setup, and configuration to integrate the UPS system with the City's traffic network.

The Contractor shall install the controller cabinet as required by the Plans, Design Standards, and Specifications, providing all other miscellaneous installation materials including grounding wire, copper clad grounding rod, secondary service drop, brackets and banding (if required), and foundations with anchor bolts, nuts, and washers (if required). The controller cabinet shall be completely wired for service. All cabinet work shall be conducted by IMSA certified traffic signal technicians.

Following the Field Tests indicated in **Section 211.13** of these Specifications, the Contractor shall install the controller in the cabinet, making the necessary connections between the controller and the terminal blocks in the cabinet. The Contractor shall also install the detector amplifiers, flasher, monitor, load switches, and make the necessary wiring connections to the terminal blocks.

Foundations (if required) and topping shall be poured monolithically according to the requirements of **Section 601.08** of these Specifications. Anchor bolts and reinforcing steel shall be placed in accordance with the Plans and Design Standards. The bottom shall rest on firm, undisturbed ground and the top shall be formed to present a neat appearance.

211.14 TESTING**A. Initial Testing by Contractor.**

Each new controller and cabinet assembly shall be tested by the Contractor prior to shipment to the project. For the purposes of the test, the timing intervals shall be programmed in a manner that will exercise each phase and overlap color indication (up to the maximum capacity of the cabinet) throughout the test. Each cabinet shall be hooked up to a test lamp assembly which simulates on-street operations and shall operate properly for a minimum of two continuous working days. This 48-hour burn-in test shall, as a minimum, exercise the following equipment: controller; cabinet auxiliary devices; conflict monitor; power supply; and all load switches, and (if applicable) flasher, flash transfer relays, and preemption isolation relays. Such tests shall demonstrate that the equipment has been fabricated, constructed, and wired in a thoroughly workmanlike manner. Cabinet/controller assemblies which fail the 48-hour burn-in shall be repaired and/or replaced and then re-tested.

B. Signal Turn-on Inspection/Testing

Following completion of all construction required by the Plans and Specifications and all stand-alone tests, checks, and inspection for all traffic signal components are satisfied, the City shall conduct a comprehensive signal turn-on inspection before placing the signal in service. The Contractor shall be present during the turn-on inspection. All punch list items identified by the City during the turn-on inspection shall be corrected by the Contractor on-site if possible.

211.15 MEASUREMENT AND PAYMENT

Accepted traffic signal controllers of the type specified shall be measured by the individual traffic signal control unit and cabinet furnished and installed complete in place, per each.

Payment at the contract unit price, per each, shall be made for each accepted cabinet of the type specified. This shall be payment in full for furnishing and installing the controller cabinet, providing the connection of the power service, and for connecting all wires and components inside the controller cabinet as required to render the installation operable, and fully integrating the cabinet components with with the existing traffic signal system.

Item Number	Description	Pay Unit
02890-211.01	Pole-mounted Controller Cabinet (Size M)	EACH
02890-211.11	Base-mounted Controller Cabinet (Size M)	EACH
02890-211.12	Base-mounted Controller Cabinet (Size P)	EACH
02890-211.13	Base-mounted Controller Cabinet (Size U, with UPS System, 875 Watts)	EACH
02890-211.14	Base-mounted Controller Cabinet (Size U, with UPS System, 1400 Watts)	EACH
02890-211.15	Base-mounted Controller Cabinet	EACH

211.15 Measurement and Payment

(Size U, No UPS System)

02890-211.21	Conflict Monitor	EACH
02890-211.22	Load Switch	EACH
02890-211.23	Flasher Relay	EACH
02890-211.24	5-Position Card Rack	EACH
02890-211.25	6-Position Card Rack	EACH
02890-211.26	Surge Protector (120 VAC Power Service)	EACH
02890-211.27	Surge Protector (120 VAC Loop Detection)	EACH
02890-211.28	Surge Protector (120 VAC Load Relay)	EACH
02890-211.29	Surge Protector (Data/Signal)	EACH
02890-211.30	Cabinet Monitoring Unit	EACH
02890-211.41	Base-mounted Standalone UPS Cabinet (with UPS System, 875 Watts)	EACH
02890-211.42	Base-mounted Standalone UPS Cabinet (with UPS System, 1400 Watts)	EACH
02890-211.43	UPS Cabinet Attached to Existing Cabinet (with UPS System, 875 Watts)	EACH
02890-211.44	UPS Cabinet Attached to Existing Cabinet (with UPS System, 1400 Watts)	EACH
02890-211.51	UPS System (400 Watts)	EACH
02890-211.52	UPS System (875 Watts)	EACH
02890-211.53	UPS System (1400 Watts)	EACH
02890-211.54	UPS Power Interface Module	EACH
02890-211.55	UPS Control Unit (400 Watts)	EACH
02890-211.56	UPS Control Unit (875 Watts)	EACH
02890-211.57	UPS Control Unit (1400 Watts)	EACH
02890-211.58	UPS Battery	EACH

SECTION 221 – HUB CABINET

221.01 MATERIAL AND DESIGN

This Section describes the specifications and requirements for field hub cabinets used for housing Ethernet hub switches and fiber optic termination units at site locations specified in the Plans. Hub cabinets shall meet all requirements in **Section 211.02.A through 211.02.I**, unless described otherwise below. Hub cabinets shall meet the following additional requirements:

- Hub cabinets shall be base-mounted Model 170/2070 style traffic controller cabinet.
- Hub cabinet shall have full size front and rear doors that meets the requirements in **Section 211.02.D**, with no police door and door-open alarm switch required.
- Standard EIA 19" cage rack with a minimum of 30 rack units (RU) space shall be provided for front and back equipment mounting.
- The maximum outside dimensions (exclusive of mounting flanges) shall not exceed 64 inches in height, 24 inches in width, and 30 inches in depth.

221.02 FIBER OPTIC TERMINATION UNIT

Each hub cabinet shall be supplied with one Fiber Optic Termination Unit which meets the requirements of **Section 811.06.A**.

221.03 WARRANTY

All components of the hub cabinet shall be replaced or repaired by the manufacturer if it fails to function as intended due to workmanship or material defects within the first 24 months (60 months for all surge protection components) from the date of being put into field operation at no cost (including shipping) to the City.

221.04 DOCUMENTATION

The Contractor shall furnish two (2) copies of the cabinet wiring diagrams with interconnection details, schematics, and maintenance techniques to the City.

The Contractor shall provide to the City the following information for each new cabinet component furnished by the Contractor.

- Manufacturer's name, model number, and serial number
- Length of warranty and start date

221.05 INSTALLATION

The Contractor shall install the hub cabinet as required by the Plans, Design Standards, and Specifications, providing all other miscellaneous installation materials including grounding wire, copper clad grounding rod, secondary service drop, brackets and banding (if required), and foundations with anchor bolts, nuts, and washers (if required). The controller cabinet shall be completely wired for service. All cabinet work shall be conducted by IMSA certified traffic signal technicians.

221.06 Measurement and Payment

The Contractor shall install the fiber optic termination unit in the cabinet in accordance with **Section 811.08**.

221.06 MEASUREMENT AND PAYMENT

Accepted hub cabinet shall be measured by the individual cabinet furnished and installed complete in place, per each. Payment at the contract unit price, per each, shall be made for each accepted cabinet. This shall be payment in full for furnishing and installing the hub cabinet, the fiber optic termination unit for the hub cabinet, providing the connection of the power service, and for connecting all wires and components inside the cabinet as required to render the installation operable, and fully integrating the cabinet components with the existing traffic signal system.

Item Number	Description	Pay Unit
02890-221.01	Hub Cabinet	EACH

SECTION 231 – RADAR DETECTION SYSTEM (RDS) CABINET**231.01 GENERAL**

This section specifies the minimum requirements for primary and secondary RDS cabinets. A primary RDS cabinet is the RDS cabinet with utility power service and housing the fiber optic communications system (fiber termination and Ethernet switches). A secondary RDS cabinet is the RDS cabinet serving as a secondary RDS unit across the street from the primary RDS cabinet and unit, as shown on Plans. A secondary RDS cabinet provides the EIA RS232 interface and surge protection for the secondary RDS unit.

231.02 MATERIALS AND CONSTRUCTION**A. General**

- Cabinets shall be of a battery compartment design.
- Provide a cabinet intended for outdoor use with a minimum NEMA 3R rating.
- The cabinet enclosure shall be manufactured from 0.125-inch aluminum.
- Provide a cabinet enclosure with a maximum dimensions of 26 inches (H) by 16 inches (W) by 14 inches (D).
- Provide electrical system and components with UL-listings.
- Terminal blocks and component terminals shall be nickel-plated copper, copper alloy, or brass.
- Terminal blocks shall have voltage and current ratings greater than the ratings of the wires that are terminated, be able to terminate wires from #8 AWG to #4 AWG wiring, and shall be assembled into housing enclosures such that all exposed surfaces are touch-safe. Conductor fastening screws shall be captive. Terminal block housings shall be colored as follows:
 - 120 VAC line/hot: black
 - 120 VAC neutral: white
 - 24 VDC positive: red
 - TCP/IP Ethernet communications: blue
 - Ground: green or green/yellow
- The cabinet shall be intended for strapped pole-mounting; provide all mounting hardware necessary including 3/4" stainless steel mounting straps.
- Cabinet door shall reveal the entire front opening of the cabinet for accessibility. The hinge shall be a piano hinge with stainless steel pin and installed on the right side of cabinet.
- Provide door locks for all cabinet doors. Provide one key with each cabinet.
- Include a single-piece 0.125-inch aluminum back panel covering no less than 90% of the cabinet back wall. Back panel shall be affixed to the enclosure with threaded fasteners and shall be removable from the enclosure with hand tools only and without requirement

231.02 Materials and Construction

to remove the cabinet door, mounting straps, or any other components other than communications or device wiring.

- Provide on the back panel a grounding lug capable of terminating #6 AWG wire and directly bonded to the back panel.
- Provide a remote RDS communications wiring module that includes the following:
 - Strain relief brackets for the RDS cable(s) and the RDS unit harness cables
 - Parallel-connection single-stage surge suppressors for the RS-232/CAT5 data signal for the RDS units with integral or separate terminals for a minimum of two RDS cables and connection wiring to the RDS local/remote communications disconnect module.
 - Parallel-connection zero-power dissipation surge suppressor for the 12-24VDC power supply for the RDS units with integral or separate terminals for a minimum of two RDS cables and two RDS unit harness cables.
 - Local/remote communications disconnect module for the RS-232 data signal that includes the following:
 - Terminal facilities for one remote RDS cable connection from the surge suppressor, bus-connected to two separate local/remote disconnect switches, one for each RDS unit that simultaneously makes/breaks all of the RS-232/CAT5 signal lines for a given RDS unit.
 - Separate terminal facilities for each of the RDS unit harness cables on the local side of the local/remote disconnect switch.
 - Separate DB9 connectors with gold-plated pins/sockets and shell for each of the RDS units, bus-connected with the RDS unit harness cable terminals on the local side of the local/remote disconnect switches. Provide protective covers for DB9 connectors.
 - Provision for installing RS-232/CAT5 terminating resistors on the terminals on the remote side of the local/remote disconnect switch. Provide terminating resistors at cabinet locations in accordance with the RDS manufacturer's recommendations.
 - Alternately, provide two separate local/remote communications disconnect modules, one per RDS unit, with jumper wiring between the remote side terminals of the two modules.
 - Connection/jumper wiring between the surge suppressors and the local/remote communications disconnect module(s) shall be of the same conductor size, type, and insulation color as in the RDS cable.
- Provide a voltage label on all cabinets or enclosures in accordance with the NEC labeling requirements. Voltage labels shall meet the following minimum requirements:
 - Labels shall be flat black lettering on a reflective yellow background. Lettering shall be a minimum of 1 inch in height.
 - Labels shall be manufactured from pre-coated adhesive backed reflective sheeting material meeting the minimum requirements of AASHTO M268 Type 1.
 - Labels shall include the voltages entering the cabinet and shall be one continuous adhesive sheet. Examples are "120VAC" or "24VDC".

231.03 Solar Panel and Power System

- Labels shall be installed on all cabinet doors.
- Provide surge suppressors based on the RDS manufacturer's recommendations.
- Cabinet wiring diagrams with inter-connection details and schematics shall be provided to the City.

B. Primary RDS Cabinet

- The primary RDS cabinet shall have one center mount shelf.
- The primary RDS cabinet shall provide a minimum of one ventilation louver on at least two sides. Any louver opening greater than 3/16 inch in any dimension shall be screened to prevent insect entry.
- All primary RDS cabinets shall be furnished with a thermostatically operated roof-mounted electric exhaust fan. All cabinets shall have fans rates at 200 cubic feet per minute at 100 degrees F. The fan shall be equipped with long-lasting permanently lubricated bearings for constant unattended operation. The exhaust fan shall be mounted in a rain-tight housing attached to the cabinet top. The thermostat shall have an adjustable turn on at temperatures ranging from 70 to 160 degrees F.
- In all primary RDS cabinets, the inlet ventilation openings shall be located in the lower part of the cabinet door, shall be screened and fitted with a fiberglass, furnace-type replaceable air filter of adequate size and capacity to pass a volume of air equal to or greater than the rated capacity of the fan. The air filter supplied shall be a type and size which is readily available commercially.
- Provide cabinet ID labels on all cabinets inside and outside. Labels shall meet the following minimum requirements:
 - Labels shall be flat black lettering on a white background. Lettering shall be a minimum of 1/2 inch in height for inside the cabinet door, and 1 inch in height for outside the cabinet door.
 - Labels shall be manufactured from pre-coated adhesive backed reflective sheeting material meeting the minimum requirements of AASHTO M268 Type 1.
 - The cabinet ID labels shall be one continuous adhesive sheet. Contact City of Memphis Traffic Signal Maintenance Department for cabinet ID and wording.
 - Inside the cabinet, cabinet ID sticker shall be installed on the inside of the cabinet door. The cabinet ID sticker shall be printed on labeling tape using labeling machine.
 - Outside the cabinet, the Contractor shall use pre-made mailbox letters/numbers. The cabinet ID sticker shall be installed on the outside, lower-left corner of the cabinet door.

231.03 SOLAR PANEL AND POWER SYSTEM

If a solar powered RDS cabinet is specified on Plans, the cabinet shall also include the solar panel and power system with a solar controller and batteries.

A. Solar Panel

The solar panel shall be of U-frame design with the following minimum requirements:

- Power rating: 80 W
- Wired for 12 Volt operation: 12V
- Voltage at rated power: 16.8V
- Current at rated power: 4.75A
- Short-Circuit current: 5.17A
- Open-Circuit voltage: 21.0V
- Maximum physical size: 58”L x 20”W x 2”D
- Rain-tight 4x4 inch rear mount junction box with ½ inch conduit knockout
- 20 year warranty
- Able to withstand winds up to 120 mph

The solar panel shall be mounted using hardware compatible with the panel module and meeting the following requirements:

- Designed for top-of-pole mount and complete with all hardware, couplings, and U-bolts necessary for top-of-pole mount design
- Designed to attach one solar panel horizontally to the top of a 4 inch SCH40 pole (pole has a 4.5 inch outside diameter)
- All bolt and nuts to be galvanized or stainless steel
- Able to withstand winds up to 120 mph

B. Solar Controller

The Solar Controller / Charge Regulator shall meet the following minimum requirements:

- Have a digital LCD meter display
- LED’s shall indicate battery status and faults
- Tropicalization: conformal coating, stainless steel fasteners & anodized aluminum heat sink
- No switching or measurement in the grounded leg
- 100% solid state
- Current compensated low voltage disconnect (LVD)
- Rated solar input (Amps): 15A
- Rated load (Amps): 15A
- Capable of 25% overloads
- Remote battery voltage sense terminals
- Lightning and transient surge protection:
 - Pulse power rating: 1500 watts
 - Maximum response time: 5 nano seconds

- Other electronic protection features:
 - Short-circuit and overload – Solar and Load
 - Reverse polarity
 - Reverse current at night
 - High voltage and temperature disconnect
 - Loads protected from voltage spikes
 - Automatic recovery with all protections
- Battery voltage setpoints (for sealed battery):
 - Regulation Voltage: 14.2V
 - Load Disconnect: 11.4V
 - Load Reconnect: 12.6V
- Temperature Compensation (mV/C): -30mV
- Accuracy: 40mV
- Self-Consumption: 22 mA
- Charge algorithm: PWM, constant voltage
- Operating temperatures range: - 40°C to + 60°C
- 5 year warranty

C. Battery

The battery shall be Absorbed Glass Mat (AGM) design with the following minimum requirements:

- 100 Amp Hour, 12 VDC
- Sealed design
- Maximum size: 12”L x 7”W x 10”H (to the top of terminal)
- Maximum weight: 70 lbs

231.04 INSTALLATION

Install and configure cabinets as shown in the Plans or Design Standards, including installations and dimensions given for pole-mounting in relationship to the surrounding grade.

Bond all cabinets to the pole grounding lug with minimum #6 AWG stranded copper bare or green-insulated cabinet grounding wire.

Do not install electrical service or electronic devices in the cabinet or connect to the cabinet until ground testing for the pole or structure has been successfully completed and accepted, and the cabinet ground connection has been installed.

231.05 TESTING

The Contractor shall perform a Stand-alone Acceptance Test (SAT) after field installation is complete, including, but not limited to, all field devices to be installed in or connected to that given cabinet. A SAT for a given equipment cabinet shall only be performed in conjunction with the SAT for all devices installed in or connected to that given cabinet. The SAT shall include the following at a minimum:

- Visual inspection of installation.
- Inspection of cabinet documentation.
- Functional test of all cabinet equipment, including circuit breaker, receptacles, fan and thermostat, and lights and door switches.
- Measurement of DC power supply operating under full load.

Additional testing requirements for RDS system is defined in **Section 431**. Submit all test results documentation to the Engineer within 14 days of completion of the tests.

231.06 MEASUREMENT AND PAYMENT

RDS cabinets will be measured in units of each and paid for at the contract price per each. The price bid shall include furnishing and installing the equipment cabinet and all related material and equipment specified in the Plans and these Specifications, and all labor, system integration, testing, system documentation and miscellaneous materials necessary for a complete and accepted installation. The unit price shall also include but is not limited to, the cabinet and all interior materials, mounting hardware, protection bollards, external conduit entrances including conduit bodies and nipples, electrical service and pole grounding terminations. This price shall be full compensation for all labor, tools, materials, equipment and incidentals necessary to complete the work.

Item Number	Description	Pay Unit
02890-231.01	RDS Cabinet (Primary)	EACH
02890-231.02	RDS Cabinet (Primary, Solar Power)	EACH
02890-231.03	RDS Cabinet (Secondary)	EACH

SECTION 241 – SCHOOL FLASHER ASSEMBLY**241.01 GENERAL**

This section specifies the minimum requirements for a school flasher assembly. The assembly shall have the following options:

- Power options: 110VAC power service, or solar powered
- Sign options: Standard S5-1 speed limit sign, or programmable speed limit sign

241.02 SCHOOL FLASHER CABINET AND COMPONENTS

The school flasher cabinet shall include the cabinet, one solid state flasher, one programmable time switch module, and any necessary auxiliary equipment and mounting hardware. All solid-state devices used to power and run the school flasher operation shall be listed by their generic name and meet or exceed the following component specifications:

A. Cabinet

School flasher cabinet shall meet the following minimum requirements:

- Fabricated from 0.125"-thick cast aluminum or welded sheet aluminum. All welds shall occur on the inside surface of the cabinet to maintain a clean appearance. Cabinets shall have an unpainted natural aluminum finish.
- NEMA 3R rated for outdoor use
- 2 – Battery compartment design with one center mount shelf and one removable back panel for component mounting.
- Maximum outside dimensions: 26"H x 16"W x 15"D inches.
- Cabinet door shall have a piano hinge with stainless steel pin installed on the right side of cabinet.
- Cabinet door shall be furnished with a neoprene rubber sealing gasket to assure the weather proof integrity of the cabinet when closed.
- Cabinet door shall have a standard police lock. The lock shall have a cover plate for the keyhole. One (1) key for each lock shall be provided with each cabinet.
- Cabinet shall be furnished with all necessary brackets, bolts and mounting hardware for mounting to a 4 inch metal pole (outside diameter 4.5 inch), unless otherwise specified on Plans.
- Each cabinet shall be wired complete with fuses and necessary wiring harnesses. All wiring harnesses and wiring connections shall be brought out to a terminal strip.
- The cabinet shall have three fuses. One ten Amp fuse for the solar panel, one ten Amp fuse for the battery, and one four Amp fuse for the LED outputs.
- Cabinet wiring diagrams with inter-connection details and schematics shall be provided to the City.

241.02 School Flasher Cabinet And Components

B. Solid State Flasher

School flasher cabinet shall have a solid state flasher that meets the following minimum requirements:

- Flash rate - 60 flashes per minute
- Input voltage of 11.4 – 30 VDC (2 terminals)
- Two outputs of 12 VDC (4 terminals)
- Capable of switching 5 amps @ 12 VDC
- Input and output terminals ¼ male quick connect
- Epoxy encapsulated construction
- Operating temperatures range: - 20°C to + 75° C
- 50% ON/OFF timing cycle shall continue as long as there is 12 VDC

C. Remotely Managed Timer Switch

School flasher cabinet shall include a remotely managed timer switch unit that meets the following minimum requirements:

- Dual powered by either a 120 VAC or 16-30 VDC power source. Both options must be available on the unit.
- Operating temperatures range: - 30°C to + 74° C
- Humidity range: 5-95%, non-condensing
- Maximum Dimension: 9" x 6" x 2.5"
- Analog inputs for AC power, solar batteries, and temperature
- Digital inputs for beacon status and door open switch
- Digital outputs for two beacon circuits
- Battery backed memory that retains program data
- Real time clock
- GPS enabled and ability to self-locate
- Cellular modem included to provide internet connectivity with cloud-based management software. No cellular modem connection cost for the life-time of the timer switch.
- Allow local manual overriding of the switch
- Compatible with City's existing cloud based school flasher remote management and monitoring system
- Cloud based management software shall provide web-based user interface and shall support the following functions:
 - Display school flasher locations on map based on timer's GPS self-locating data
 - Make schedule changes or manually activate one or all beacons from PC or smartphone with immediate effect

241.03 Solar Panel and Power System

- Monitor beacon lamps current and battery status, report failure via email and text messages
- Program, save, and print annual programs per timer unit
- Support 36 alternate program schedules and exception periods per unit used to suspend operations or run a different program schedule during holidays and/or special occasions
- Role based and password protected user accounts with device management responsibilities defined by system administrator
- Cloud based management software shall be free-of-charge to the City for the life-time of all remotely managed timer switch installed

241.03 SOLAR PANEL AND POWER SYSTEM

If a solar powered school flasher assembly is specified on Plans, the school flasher cabinet shall also include the solar panel and power system. The solar panel and power system shall include the solar panel, a solar controller, and a battery.

A. Solar Panel

The solar panel shall be of U-frame design with the following minimum requirements:

- Power rating: 80 W
- Wired for 12 Volt operation: 12V
- Voltage at rated power: 16.8V
- Current at rated power: 4.75A
- Short-Circuit current: 5.17A
- Open-Circuit voltage: 21.0V
- Maximum physical size: 58”L x 20”W x 2”D
- Rain-tight 4x4 inch rear mount junction box with ½ inch conduit knockout
- 20 year warranty
- Able to withstand winds to 120 mph

The solar panel shall be mounted using hardware compatible with the panel module and meets the following requirements:

- Designed for top-of-pole mount and complete with all hardware, couplings, and U-bolts necessary for top-of-pole mount design
- Designed to attach one solar panel horizontally to the top of a 4 inch SCH40 pole (pole has a 4.5 inch outside diameter)
- All bolt and nuts to be galvanized or stainless steel
- Able to withstand winds to 120 mph

B. Solar Controller

The Solar Controller / Charge Regulator shall meet the following minimum requirements:

- Have a digital LCD meter display
- LED's shall indicate battery status and faults
- Tropicalization: conformal coating, stainless steel fasteners & anodized aluminum heat sink
- No switching or measurement in the grounded leg
- 100% solid state
- Current compensated low voltage disconnect (LVD)
- Rated solar input (Amps): 15A
- Rated load (Amps): 15A
- Capable of 25% overloads
- Remote battery voltage sense terminals
- Lightning and transient surge protection:
 - Pulse power rating: 1500 watts
 - Maximum response time: 5 nano seconds
- Other electronic protection features:
 - Short-circuit and overload – Solar and Load
 - Reverse polarity
 - Reverse current at night
 - High voltage and temperature disconnect
 - Loads protected from voltage spikes
 - Automatic recovery with all protections
- Battery voltage setpoints (for sealed battery):
 - Regulation Voltage: 14.2V
 - Load Disconnect: 11.4V
 - Load Reconnect: 12.6V
- Temperature Compensation (mV/C): -30mV
- Accuracy: 40mV
- Self-Consumption: 22 mA
- Charge algorithm: PWM, constant voltage
- Operating temperatures range: - 40°C to + 60°C
- 5 year warranty

C. Battery

The battery shall be Absorbed Glass Mat (AGM) design with the following minimum requirements:

- 100 Amp Hour, 12 VDC
- Sealed design
- Maximum size: 12”L x 7”W x 10”H (to the top of terminal)
- Maximum weight: 70 lbs

241.04 SIGN AND SIGNAL HEAD ASSEMBLY

The sign and signal head assembly shall include the school zone speed limit sign (standard or programmable) and the flashing signals. All signal head assembly for school flasher shall be in conformance with the Plans, **Section 501** of this specification, and the following additional requirements:

A. Signal Head Assembly with Standard Speed Limit Sign

If a standard MUTCD S5-1 school speed limit sign is specified on Plans, the signal head assembly shall consist of two standard yellow 12” polycarbonate signal housings for the yellow flashing signals.

Two yellow circular 12” LED signal modules shall be used for the optical system within the provided signal housings. LED signal modules shall meet the specifications defined in Section 501.05. LED signal modules shall be low voltage 12 VDC.

B. Signal head Assembly with Programmable Speed Limit Module

If a programmable speed limit module is specified on Plans or Bid Documents, the signal head assembly shall consist of a standard three-section yellow 12” polycarbonate signal housings for the yellow flashing signals. The door and visor for the programmable speed limit module (middle section housing) shall have a standard 12” black pedestrian door with black visor.

Two yellow circular 12” LED signal modules shall be used for the optical system within the provided top and bottom signal housings. LED signal modules shall meet the specifications defined in Section 501.05. LED signal modules shall be low voltage 12 VDC.

The programmable speed limit module shall be used for the lighted MPH number within the provided middle section housing. The programmable speed limit module shall meet the following requirements:

- 12VDC
- Operating temperature range: - 40°C to + 74°C
- Quick connect terminals with spade/tab adapters
- RF immunity 10V/M, 80MHz to 1GHz
- Housing size: 12” x 12”
- Symbol color: Portland Orange
- Typical luminance (cd/m²) : 1,400
- Dominant wavelength (nm): 605
- Ability to display speed limit from 10 to 35 with 5 mph interval, easily programmable by setting a group of dip switches

241.05 MEASUREMENT AND PAYMENT

Accepted school flasher assembly of the type specified shall be measured by the individual school flasher assembly furnished and installed complete in place, per each.

Payment at the contract unit price, per each, shall be made for each accepted school flasher assembly of the type specified. This shall be payment in full for furnishing and installing the cabinet, solar panel and power system, and school speed limit sign, providing the connection of the power service, and for connecting all wires and components as required to render the installation operable.

Item Number	Description	Pay Unit
02890-241.01	School Flasher Assembly (Solar Power, Programmable Speed Limit Sign)	EACH
02890-241.02	School Flasher Assembly (Solar Power, Standard Speed Limit Sign)	EACH
02890-241.03	School Flasher Assembly (110VAC Power, Programmable Speed Limit Sign)	EACH
02890-241.04	School Flasher Assembly (110VAC Power, Standard Speed Limit Sign)	EACH
02890-241.05	Remotely Managed School Flasher Timer Switch	EACH
02890-241.11	School Flasher Cabinet (with Flasher and Timer)	EACH
02890-241.12	School Flasher Sign and Signal Head Assembly (Standard School Speed Limit Sign)	EACH
02890-241.13	School Flasher Sign and Signal Head Assembly (Programmable School Speed Limit Sign)	EACH
02890-241.14	School Flasher Solar Panel and Power System Unit (with Battery)	EACH

SECTION 251 – PEDESTRIAN HYBRID BEACON (HAWK) ASSEMBLY

251.01 GENERAL

This section specifies the minimum requirements for a pedestrian hybrid beacon (HAWK) assembly. The assembly shall have the following options:

- Cabinet options: Pole mount or base mount
- Power options: Standard power or solar power

251.02 CABINET AND COMPONENTS

The HAWK pedestrian signal control assembly shall include the following components:

- Traffic signal controller as specified in Section 201
- Cabinet shall be Size M traffic signal cabinet
- Standard card rack with power supply
- 12-channel conflict monitor
- Flasher and flashing relays
- Appropriate number of Load switches
- LED cabinet light
- 400 Watt UPS System with four batteries

Cabinet and its components described above shall meet the minimum requirements specified in **Section 211**.

251.03 SOLAR PANEL AND POWER SYSTEM

If a solar powered HAWK signal assembly is specified on Plans, the cabinet shall also include the solar panel and power system, which includes the solar panel, a solar controller, and batteries.

A. Solar Panel

The solar panel shall be of U-frame design with the following minimum requirements:

- Power rating: 80 W
- Wired for 12 Volt operation: 12V
- Voltage at rated power: 16.8V
- Current at rated power: 4.75A
- Short-Circuit current: 5.17A
- Open-Circuit voltage: 21.0V
- Maximum physical size: 58”L x 20”W x 2”D
- Rain-tight 4x4 inch rear mount junction box with ½ inch conduit knockout

- 20 year warranty
- Able to withstand winds up to 120 mph

The solar panel shall be mounted using hardware compatible with the panel module and meets the following requirements:

- Designed for top-of-pole mount and complete with all hardware, couplings, and U-bolts necessary for top-of-pole mount design
- Designed to attach one solar panel horizontally to the top of a 4 inch SCH40 pole (pole has a 4.5 inch outside diameter)
- All bolt and nuts to be galvanized or stainless steel
- Able to withstand winds up to 120 mph

B. Solar Controller

The Solar Controller / Charge Regulator shall meet the following minimum requirements:

- Have a digital LCD meter display
- LED's shall indicate battery status and faults
- Tropicalization: conformal coating, stainless steel fasteners & anodized aluminum heat sink
- No switching or measurement in the grounded leg
- 100% solid state
- Current compensated low voltage disconnect (LVD)
- Rated solar input (Amps): 15A
- Rated load (Amps): 15A
- Capable of 25% overloads
- Remote battery voltage sense terminals
- Lightning and transient surge protection:
 - Pulse power rating: 1500 watts
 - Maximum response time: 5 nano seconds
- Other electronic protection features:
 - Short-circuit and overload – Solar and Load
 - Reverse polarity
 - Reverse current at night
 - High voltage and temperature disconnect
 - Loads protected from voltage spikes
 - Automatic recovery with all protections
- Battery voltage setpoints (for sealed battery):
 - Regulation Voltage: 14.2V

- Load Disconnect: 11.4V
- Load Reconnect: 12.6V
- Temperature Compensation (mV/C): -30mV
- Accuracy: 40mV
- Self-Consumption: 22 mA
- Charge algorithm: PWM, constant voltage
- Operating temperatures range: - 40°C to + 60°C
- 5 year warranty

251.04 MEASUREMENT AND PAYMENT

Accepted HAWK pedestrian signal control assembly of the type specified shall be measured by the individual HAWK assembly furnished and installed complete in place, per each.

Payment at the contract unit price, per each, shall be made for each accepted HAWK assembly of the type specified. This shall be payment in full for furnishing and installing the cabinet, controller, solar panel and power system, providing the connection of the power service, and for connecting all wires and components as required to render the installation operable.

Item Number	Description	Pay Unit
02890-251.01	Pedestrian Hybrid Beacon (HAWK) Assembly (110VAC Power, Base Mount Cabinet)	EACH
02890-251.02	Pedestrian Hybrid Beacon (HAWK) Assembly (Solar Power, Base Mount Cabinet)	EACH
02890-251.03	Pedestrian Hybrid Beacon (HAWK) Assembly (110VAC Power, Pole Mount Cabinet)	EACH
02890-251.04	Pedestrian Hybrid Beacon (HAWK) Assembly (Solar Power, Pole Mount Cabinet)	EACH

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SECTION 301 – ETHERNET SWITCHES**301.01 GENERAL**

This subsection details furnishing and installing ruggedized Ethernet cabinet switches that are manufactured to be installed in traffic signal cabinets. Four types of Ethernet switches are required by the City of Memphis with the following key characteristics (**Table 301-1**):

Table 301-1 Type of Ethernet Switches

Switch Type	Edge Switch (100Mb Edge Ports)	Edge Switch (Gigabit Edge Ports)	Edge Switch (Gigabit Edge Ports, Detector Rack Card)	Hub Switch
Application	Edge switch, in traffic signal controller cabinet			Backbone device, in hub cabinet
Routing Capabilities	Layer 2			Layer 3 hardware forwarding
Switching Bandwidth	5 Gbps	16 Gbps	16 Gbps	88 Gbps
Pluggable Ports (1000X SFP)	2 x (1000LX SFP single mode LC 10km)			20 x (1000LX SFP single mode LC 10km); 4 x (1000LX SFP single mode LC 25km);
Fixed Ports	8 x (10/100BaseTX)	6 x (10/100/1000Bas eTX)	6 x (10/100/1000Bas eTX)	1 x 10/100/1000Bas eTX management port
Key Protocols Required	VLAN (802.1Q), RSTP (802.1w), RADIUS and 802.1X			VLAN (802.1Q), RSTP (802.1w), RADIUS and 802.1X, OSPF
Mounting Options	Shelf or DIN-rail	Shelf or DIN-rail	Plug into vehicle detector card rack	Rack (19")

301.02 SWITCH PORT CONFIGURATION

All fiber optical ports shall be standard slots accepting Gigabit SFP ports. SFP port link distance specified below is the minimum required. Each fiber optical SFP port shall functionally support the upstream/downstream link distances required in the plans if they exceed the minimum.

A. Edge Switch (with 100Mbit Edge Ports)

- Minimum RJ-45 10/100Base TX Ports: 8
- Minimum (Single-mode or Multi-mode) Fiber optic ports 1000Base LX (Single-mode) or 1000Base-SX (multi-mode) (LC connectors, rated transmission distance 10 km): 2

B. Edge Switch (with Gigabit Edge Ports, shelf or card options)

- Minimum RJ-45 10/100/1000Base TX Ports: 6
- Minimum (Single-mode or Multi-mode) Fiber optic ports 1000Base LX (Single-mode) or 1000Base-SX (multi-mode) (LC connectors, rated transmission distance 10 km): 2

C. Hub Switch

- Minimum RJ-45 10/100/1000Base TX Ports: 1 (Switch management port)
- Minimum (Single-mode or Multi-mode) Fiber optic ports 1000Base LX (Single-mode) or 1000Base-SX (multi-mode) (LC connectors, rated transmission distance 10 km): 20
- Minimum (Single-mode or Multi-mode) Fiber optic ports 1000Base LX (Single-mode) or 1000Base-SX (multi-mode) (LC connectors, rated transmission distance 25 km): 4

301.03 PHYSICAL AND ELECTRICAL

All switches shall have no fans for cooling and comply with NEMA TS2 environmental requirements.

A. Edge Switch (Stand Alone Types)

- Maximum dimension: 9"H x 4"W x 7"D
- Maximum weight: 4.0 lbs
- Maximum power consumption: 10 W
- Enclosure: IP-30 galvanized steel enclosure
- Mounting: DIN-rail or shelf mounted
- 100-240 VAC internal power supply. External power supply unit is not acceptable.

B. Edge Switch (Detector Card Form Factor)

- Fully compatible with a standard NEMA detector card rack
- Maximum Weight: 4.0 lbs
- Maximum power consumption: 15 W
- 9-36 VDC power input from detector card rack

C. Hub Switch

- Fully scalable modular design with a minimum of 4 switch/processor/power modules. Each switch modules shall be field replaceable and upgradable.
- Maximum dimension: 4RU

- Maximum weight: 50.0 lbs
- Maximum power consumption: 100 W
- Enclosure ingress protection: IP-40
- Mounting: standard 19" rack mounted
- 100-240 VAC internal power supply, with the option for dual redundant power supply modules.

D. SFP Transceiver Modules/Ports

The contractor shall submit detailed product specifications of the SFP ports for Engineer's approval. If the submitted SFP ports are not manufactured by the switch manufacturer, the Contractor shall demonstrate that the submitted SFP ports:

- Have a rated operating temperature range of -40° to +85°C,
- Have equal features, performance ratings, regulatory approvals, and warranty as the switch manufacturer's counterpart, and
- Are fully compatible with the receiving switch.

301.04 SWITCH FEATURES

All switches shall have the following minimum switch properties and features:

- Switching method: Store & Forward
- Switching latency: 10.5 us
- Priority Queues: 4
- Port rate limiting: 128kbps, 256, 512, 4, 8Mbps
- No head of line blocking
- Provide auto negotiation and MDI/MDIX crossover capability
- Support half-duplex or full-duplex
- Equipped with LED indicators for power, fault, Link/Activity for each port

All switches shall support the following network management features:

- HTTP graphical web-based
- SNMP v1, v2c, v3
- Telnet, VT100
- Command Line Interface (CLI)

All switches shall support the following network security features:

- Enable/disable ports
- MAC based port security
- Port based network access control (802.1x)

301.05 Standards Compliance and Approvals

- Radius authentication with 802.1x
- VLAN (802.1Q)
- SNMP v1/v2c/v3

A. Edge Switch

All edge switches shall have a minimum MAC address table size for 8K MAC addresses. Edge switches with 100Mb edge ports shall have a minimum switching bandwidth of 5 Gbps. Edge switches with Gigabit edge ports shall have a minimum switching bandwidth of 16 Gbps.

B. Hub Switch

All hub switches shall have the following additional properties:

- Switching bandwidth of 80 Gbps.
- MAC address table size: 96K MAC addresses

All hub switches shall provide layer 3 hardware level switching at wire speed and support the following layer 3 switch features:

- DHCP
- VRRP
- PIM-SM
- Firewall
- OSPF
- BGP
- RIP v1/v2
- Traffic Prioritization

All switches shall be fully compatible with City's existing traffic networking scheme and protocols, existing core, hub, and edge switches, existing servers and traffic management and monitoring software.

301.05 STANDARDS COMPLIANCE AND APPROVALS**A. IEEE Compliance**

- 802.3-10BaseT
- 802.3u-100BaseTX, 100BaseFX
- 802.3x-Flow Control
- 802.3z-1000BaseLX
- 802.3ab-1000BaseTX
- 802.3ad-Link Aggregation
- 802.1d-MAC Bridges

301.05 Standards Compliance and Approvals

- 802.1d-Spanning Tree Protocol
- 802.1p-Class of Service
- 802.1Q-VLAN Tagging
- 802.1w-Rapid Spanning Tree Protocol
- 802.1x-Port Based Network Access Control
- 802.1Q-2005-MSTP

B. IETF RFC Compliance

- RFC768-UDP
- RFC783-TFTP
- RFC791-IP
- RFC792-ICMP
- RFC793-TCP
- RFC826-ARP
- RFC854-Telnet
- RFC894-IP over Ethernet
- RFC1112-IGMP v1
- RFC1519-CIDR
- RFC1541-DHCP (client)
- RFC2030-SNTP
- RFC2068-HTTP
- RFC2236-IGMP v2
- RFC2284-EAP
- RFC2475-Differentiated Services
- RFC2865-Radius
- RFC3414-SNMPv3-USM
- RFC3415-SNMPv3-VACM

C. Environmental Compliance

- NEMA TS 2 Traffic Control Equipment

D. Regulatory Approvals

- Emissions: FCC Part 15 (Class A), EN55022 (CISPR22 Class A)
- Safety: cCSAus (Compliant with CSA C22.2 No. 60950, UL 60950, EN60950)
- Laser Eye Safety (FDA/CDRH): Complies with 21 CFR Chapter1, Subchapter J.

301.06 WARRANTY

All switches shall be replaced or repaired by the manufacturer if a switch fails to function as intended due to workmanship or material defects within the first 60 months from the date of being put into field operation at no cost (including shipping) to the City.

301.07 INSTALLATION

The Contractor shall furnish and install one switch at each location called for on the Plans. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer's recommendations and standard practices.

Plug in the switch's power adaptor to an empty 120V electric service outlet inside the cabinet. If there is only one empty outlet in the cabinet before the installation, the contractor is responsible for adding one new duplex outlet in the cabinet.

The Contractor shall integrate with single-mode or multi-mode fiber optic drop cables in the cabinet installed or previously installed by others.

The Contractor shall obtain Ethernet Switch Configuration Guidelines and the assigned IP address from the City. The Contractor shall install the assigned IP address and configure the device in accordance with these guidelines. Integrate with the existing or proposed Ethernet devices in the cabinet as required. Integrate with the upstream hub switches as required. Perform all coordination, setup, and configuration to integrate the switch with the City's traffic network.

301.08 TESTING

With the presence of the City traffic signal maintenance staff and the project inspectors, the Contractor shall demonstrate the following:

- Ability to communicate successfully and reliably with the switch's management interface via HTTP protocol from the cabinet edge switch, the hub switch, and the TMC workstation.
- All configuration parameters are in accordance with the City's Configuration Guidelines.
- Ability to communicate successfully and reliably with all attached Ethernet devices using respective central software from the cabinet edge switch, the hub switch, and the TMC workstation.

301.09 DOCUMENTATION

One electronic copy of the serial device server's Operations and Maintenance Manuals shall be provided to the City. The Contractor shall provide to the City the following information for each new switch furnished by the Contractor.

- Manufacturer's name, model number, and serial number
- Length of warranty and start date
- MAC address of the Ethernet network interface

301.10 MEASUREMENT AND PAYMENT

Payment at the contract unit price, per each, shall be made for each furnished, installed, and accepted switch of the type specified. Each such item shall include the switch, its integration into the field cabinet, its grounding and electrical isolation, its integration with the fiber optic cable, its configuration and setup, its addressing, documentation and integration into the traffic signal system fiber optic network, all mounting accessories, all cabling necessary for communications and power, connectors, all mounting brackets, mounting hardware, power cords, delivery of all required software, factory certification, and testing.

Item Number	Description	Pay Unit
02890-301.01	Ethernet Edge Switch (100Mb Edge Ports, Single Mode SFPs)	EACH
02890-301.02	Ethernet Edge Switch (Gigabit Edge Ports, Single Mode SFPs)	EACH
02890-301.03	Ethernet Edge Switch (Gigabit Edge Ports, Single Mode SFPs, Detector Card Form Factor)	EACH
02890-301.04	Ethernet Edge Switch (Description)	EACH
02890-301.05	Ethernet Edge Switch (Description)	EACH
02890-301.06	Ethernet Edge Switch (Description)	EACH
02890-301.11	Ethernet Hub Switch (Single Mode SFPs)	EACH
02890-301.12	Ethernet Hub Switch (Description)	EACH
02890-301.21	SFP Module (Single Mode, LC, 10Km)	EACH
02890-301.22	SFP Module (Single Mode, LC, 25Km)	EACH
02890-301.23	SFP Module (Description)	EACH

SECTION 302 – POWER OVER ETHERNET (POE) INJECTOR**302.01 GENERAL**

The Power Over Ethernet (POE) injector shall be a midspan power source to provide POE connection for CCTV cameras or other POE capable devices. The POE injector shall have the option to be installed either inside a traffic signal cabinet or externally on traffic signal poles. The POE injector shall meet the following minimum requirements:

- Input power: 100 – 240 VAC, 50 – 60 Hz
- Output power: 55 VDC, rated 60 Watts maximum
- Operating temperature range: -40°C to +60°C
- Operating humidity: 5% - 90%
- Built in Ethernet and AC surge protection
- Built in short circuit, over current, and over voltage protection
- Compatible with 10/100/1000 Mbps Ethernet data network
- Compatible with all network devices that are IEEE 802.3af or 802.3at complaint
- Automatically detect POE and High POE-enabled devices and supply inline power
- For pole mount option, the casing shall be IP66/NEMA 4X rated for water and dust proof
- Maximum dimension: 9 in. x 6 in. x 3 in; Maximum weight: 3 lbs
- Minimum warranty: 1 year

302.02 INSTALLATION

For in-cabinet installation, the POE injector shall be DIN rail mounted, or securely mounted on the front lip of the top shelf at the far right side of the cabinet. POE injector shall be properly grounded to the cabinet rail. For pole mount option, the casing shall be securely strapped to the pole with ¾" stainless steel bands and properly grounded per manufacturer's recommendations.

302.03 MEASUREMENT AND PAYMENT

Accepted POE injectors shall be measured per each complete furnished and installed unit. Payment at the contract unit price shall be made for each accepted POE injector. This shall be payment in full for furnishing and installing each injector including mounting, wiring, and any necessary materials for a complete, tested, and operable installation.

Item Number	Description	Pay Unit
02890-302.01	POE Injector (In Cabinet)	EACH
02890-302.02	POE Injector (Pole Mounted)	EACH

SECTION 303 – WIRELESS ETHERNET DEVICES

303.01 GENERAL

This section details furnishing and installing Wireless Ethernet Devices that provides high-speed broadband wireless solutions to bridge gaps in the wired connections of the City's existing traffic signal system communications network.

For Point-to-Point (PTP) wireless bridges, a pair of bridge units shall provide point-to-point Ethernet communication between two locations specified on the Plans. For Point-to-Multipoint (PMP) wireless devices, the base station unit shall serve as a central unit and shall communicate with multiple subscriber units at locations specified on the Plans.

The Wireless Ethernet Devices shall be compatible with all existing Ethernet edge and hub switches currently deployed in the City of Memphis.

303.02 PHYSICAL AND ELECTRICAL

- Enclosure: IP-67 outdoor rated metal enclosure
- Antenna: Minimum 15 dBi integrated antenna, or multiple integrated/external antennas required to achieve optimal performance according to manufacturer's recommendations
- Maximum outside dimension: 16"H x 16"W x 16"D
- Maximum weight: 17.0 lbs
- Maximum power consumption: 25 Watts
- Operating temperature range: -40°C to +55°C
- Operating humidity: 5% - 90%
- Designed to withstand 100 mph wind loading

The bridge unit shall be powered by a Power Over Ethernet (POE) injector and power supply unit that complies with the specifications in **Section 302**.

303.03 FEATURES

All devices shall have the following minimum properties and features:

- Orthogonal Frequency Division Multiplexing (OFDM) along with 2x2 MIMO 26 dBm high power radio
- Does not require Line-of-sight
- Meets the transmitting distance required by Plans or Bid Documents with a reliable minimum data throughput of 100 Mbps or required by Plans or Bid Documents
- Radio frequency: 4.9 to 5.9 GHz
- No radio frequency or software license fees required
- Flexible channel width of 5, 10, 20, and 40 MHz

- Capability to analyze frequency bands for interference and select a relatively low interference channel
- Data Interface: RJ45, 10/100/1000 Mbps auto-negotiation Ethernet with POE
- AES-CCM 128 bit encryption
- Radius based Authentication with 802.1x
- VLAN support (802.1Q)
- Network management features supported: HTTP, Telnet, SSH, SSL, SNMPv1v2v3

303.04 INSTALLATION

Wireless Ethernet Devices shall be installed according to the manufacturer's requirements and recommendations. Additional installation requirements are provided below. If these additional requirements conflict with manufacturer's recommendations, the contractor shall obtain approval from the Engineer or the City for alternative installation methods.

A. Installation of the Unit:

The unit shall be mounted with two 3/4" minimum width steel straps.

For mast arm poles, mount the enclosure between the pole mounted signal display and the mast arm. If this space is not available, contact the City or the Engineer to determine an alternative mounting location.

For steel strain poles or wood poles, mount the enclosure immediately below the tether wire. If space is restricted below the tether wire, mount the enclosure immediately above the tether wire.

B. Cable installation and routing from the enclosure to the cabinet:

1. For steel strain poles or mast arm poles:
 - Drill cable entrance hole into steel pole and install 3/4" seal flex conduit from the enclosure to the cable entrance hole on pole. Use liquid-tight connectors at both ends of the seal flex conduit.
 - Install Ethernet cable inside the seal flex conduit from the enclosure into the steel pole.
 - The cable shall enter the cabinet using an existing elbow or conduit (for pole-mounted cabinets) or through underground conduit routed from the pole base to the cabinet (for base-mounted cabinets).
2. For wood poles with an existing conduit riser with adequate space:
 - Install a new 2" steel conduit riser with weather head from the detector enclosure mounting location to top of the pole.
 - Install a seal flex conduit to connect the bottom of the riser and the detector enclosure. Use liquid-tight connectors at both ends of the seal flex conduit.
 - Install proposed Ethernet cable from the detector enclosure to top of pole through the new 2" riser.

- Install proposed Ethernet cable from the weather head of the new riser to the existing weather head of the existing steel conduit.
 - Enter cabinet using the existing steel conduit riser.
3. For wood poles with no existing riser or space for the proposed cable:
- For pole mounted cabinet, install a new 2" steel conduit riser from bottom of the pole mounted cabinet to the bottom of the detector enclosure. Install 2" elbow or conduit to enter the cabinet from bottom.
 - For base-mounted cabinet, install a new 2" steel conduit riser from pole base to the bottom of the detector enclosure. Install new 2" underground conduit to enter the cabinet base.
 - Install a seal flex conduit from the top of the new riser to the detector enclosure. Use liquid-tight connectors at both ends of the seal flex conduit.
 - Enter cabinet using the new riser and conduit.

C. Inside the controller cabinet:

- Securely mount the POE injector on the front lip of the top shelf at the far right side of the cabinet. POE injector shall be properly grounded to the cabinet rail.
- Coil 10 feet of the entering Ethernet cable at the bottom of the cabinet.
- Plug in the POE injector power adaptor to an empty outlet. If there is only one empty outlet in the cabinet before the installation, the contractor is responsible for adding one new duplex outlet in the cabinet.

D. Configuration:

The Contractor shall obtain an IP address from the City for each Wireless Ethernet Device installed. The Contractor shall configure the unit according to manufacturer's recommendations and fully integrate the unit with the City's existing Ethernet network and traffic management servers located in Memphis City Hall.

303.05 WARRANTY

All units shall be replaced or repaired by the manufacturer if a switch fails to function as intended due to workmanship or material defects within the first 24 months from the date of final acceptance at no cost (including shipping) to the City.

303.06 TESTING

The Contractor shall demonstrate the following in the presence of the City traffic signal maintenance staff and the project inspectors:

- Ability to communicate successfully and reliably with the switch's management interface via HTTP protocol from the cabinet edge switch, the hub switch, and the TMC workstation.
- All configuration parameters are in accordance with the City's Configuration Guidelines.

303.07 Documentation

- Ability to communicate successfully and reliably with all attached Ethernet devices using respective central software from the cabinet edge switch, the hub switch, and the TMC workstation.

303.07 DOCUMENTATION

One electronic copy of the Wireless Ethernet Device Operations and Maintenance Manuals shall be provided to the City. The Contractor shall provide to the City the following information for each new bridge unit furnished by the Contractor.

- Manufacturer's name, model number, and serial number
- Length of warranty and start date
- MAC address of the Ethernet network interface

303.08 MEASUREMENT AND PAYMENT

Payment at the contract unit price, per each, shall be made for each furnished, installed, and accepted Wireless Ethernet Device. Each such item shall include furnishing and installing the radio unit; POE injector; integration into the field cabinet; grounding and electrical isolation; configuration and setup; addressing, documentation and integration with the existing Ethernet switches, firewall, and servers; all mounting accessories; all cabling necessary for communications and power; connectors; all mounting brackets; mounting hardware; power cords; delivery of all required software; factory certification, and testing.

Item Number	Description	Pay Unit
02890-303.01	Wireless Ethernet Device (PTP Bridge, 100Mbps Throughput)	EACH
02890-303.02	Wireless Ethernet Device (PTP Bridge, 300Mbps Throughput)	EACH
02890-303.03	Wireless Ethernet Device (PTP Bridge, 400Mbps Throughput)	EACH
02890-303.04	Wireless Ethernet Device (PTP Bridge, 800Mbps Bandwidth)	EACH
02890-303.05	Wireless Ethernet Device (PTP Bridge, ____ Mbps Throughput)	EACH
02890-303.11	Wireless Ethernet Device (PMP Base Station, 100Mbps Throughput)	EACH
02890-303.12	Wireless Ethernet Device (PMP Base Station, 300Mbps Throughput)	EACH
02890-303.13	Wireless Ethernet Device (PMP Base Station, 400Mbps Throughput)	EACH

Section 303 – Wireless Ethernet Devices

303.08 Measurement and Payment

02890-303.14	Wireless Ethernet Device (PMP Base Station, 800Mbps Throughput)	EACH
02890-303.15	Wireless Ethernet Device (PMP Base Station, ____ Mbps Throughput)	EACH
02890-303.21	Wireless Ethernet Device (PMP Subscriber Unit, 100Mbps Throughput)	EACH
02890-303.21	Wireless Ethernet Device (PMP Subscriber Unit, 300Mbps Throughput)	EACH
02890-303.21	Wireless Ethernet Device (PMP Subscriber Unit, 400Mbps Throughput)	EACH
02890-303.21	Wireless Ethernet Device (PMP Subscriber Unit, 800Mbps Throughput)	EACH
02890-303.21	Wireless Ethernet Device (PMP Subscriber Unit, ____ Mbps Throughput)	EACH

SECTION 311 – SERIAL DEVICE SERVERS

311.01 GENERAL

This section specifies the minimum requirements for furnishing and installing serial device servers that are manufactured to be installed in traffic signal controller cabinets. The serial device servers shall be installed and integrated into field cabinets at locations shown on the plans. The serial device server, also commonly referred to as a terminal server or port server device, shall provide the Ethernet (TCP/IP) communications interface between the central server computers and the RS-232 equipped traffic signal controller or conflict monitors.

311.02 PHYSICAL AND ENVIRONMENTAL

The minimum physical and environmental requirements include:

- Each Terminal Server shall have the following ports:
 - Network Ethernet Port: Minimum one (1) 10/100 Mbps RJ-45.
 - Serial Data Interfaces: Two (2) RJ-45 ports.
- Operate in a temperature range of -35°C to 74°C.
- Operate in relative humidity of 5% to 95% non-condensing.
- Ethernet isolation: 1500VAC min per IEEE 802.3/ANSI +3.263
- Serial port protection (ESD): +15 kV air 6 AP and +8 kV contact discharge per IEC 100-4-2
- Maximum Dimensions: 6"W x 5"D x 2"H.
- Provide external markings - all connectors, indicators, and replaceable components shall be permanently marked and traceable to the supplied documentation, including schematics and parts list. The external markings shall include the product function name, model number, serial number and manufacturer's name.
- Terminal Servers shall be shelf mountable or DIN-Rail mountable. Other mounting options may be submitted for review and approval by the Engineer.

311.03 POWER SUPPLY

The minimum electrical/power requirements include:

- 120 VAC, or 9-30VDC @ 0.5 Amps max
- External power supply unit that meets the environmental requirements is acceptable.

311.04 DATA INTERFACE

The minimum data interface requirements include the following:

- The Terminal Server shall support a minimum of two (2) bi-directional serial communication channels over an Ethernet 10/100 Base-TX uplink.
- Each Terminal Server shall have a minimum of two (2) EIA-232/485 Serial interface ports. These ports shall be individually and independently configurable, directly by switching or over the network, to EIA-232/485 mode of operation as defined by the EIA for data format,

311.05 General Features and Capabilities

data rate, and data structure (e.g., the number of bits, parity, stop bits, etc.). Each serial port shall support up to 230 Kbps.

- Each serial port shall support IP addressing, and shall not use proprietary encapsulation methods, which would restrict the use of standards-based virtual COM port connectivity software.
- The equipment shall provide the capability to establish an IP connection directly from a workstation to any device IP address.
- Each Terminal Server shall have an Ethernet Interface (10/100Base-TX protocol, Full/Half-Duplex, Auto Sense (802.3), RJ-45).

311.05 GENERAL FEATURES AND CAPABILITIES

The Terminal Server shall meet the following general requirements:

- 10/100 Base-TX Ethernet port connection
- TCP/IP protocol
- RS-232/485 selectable or programmable serial connections with baud rates up to 230 Kbps
- SNMP compatible
- HTTP remote management and configuration
- Remote TELNET connection and port configuration
- Local configuration port
- ARP-Ping for IP address assignment
- LED status for link and power
- All terminal servers shall be mechanically and electrically interchangeable within the network.

311.06 WARRANTY

All switches shall be replaced or repaired by the manufacturer if a switch fails to function as intended due to workmanship or material defects within the first 60 months from the date of being put into field operation at no cost (including shipping) to the City.

311.07 INSTALLATION

The Contractor shall furnish and install one serial device server at each location called for on the Plans. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer's recommendations and standard practices.

Plug in the serial device server's power adaptor to an empty 120V electric service outlet inside the cabinet. If there is only one empty outlet in the cabinet before the installation, the contractor is responsible for adding one new duplex outlet in the cabinet.

The Contractor shall install all patch cables required to complete the connection between the serial device server and the traffic signal controller port 2 and the serial port on the conflict monitor.

311.08 Testing

The Contractor shall obtain Serial Device Server Configuration Guidelines and the assigned IP address from the City. The Contractor shall install the assigned IP address and configure the device in accordance with these guidelines. Integrate with the existing or proposed Ethernet edge switch as required. Perform all coordination, setup, and configuration to integrate the serial device server with the City's traffic network.

311.08 TESTING

With the presence of the City traffic signal maintenance staff and the project inspectors, the Contractor shall demonstrate the following:

- Ability to communicate successfully and reliably with the serial device server's management interface via HTTP protocol from both the cabinet edge switch and the hub switch.
- All configuration parameters are in accordance with the City's Configuration Guidelines.
- Ability to communicate successfully and reliably with the attached traffic signal controller or conflict monitor using respective central software from the cabinet edge switch and the hub switch.

311.09 DOCUMENTATION

One electronic copy of the serial device server's Operations and Maintenance Manuals shall be provided to the City. The Contractor shall provide to the City the following information for each new item furnished by the Contractor.

- Manufacturer's name, model number, and serial number
- Length of warranty and start date
- MAC address of the Ethernet network interface

311.10 MEASUREMENT AND PAYMENT

Payment at the contract unit price, per each, shall be made for each furnished, installed, and accepted serial device server. Each such item shall include the serial device server, its integration into the field cabinet, its grounding and electrical isolation, its integration with the equipment per Plans, its configuration and setup, its addressing, documentation and integration into the traffic signal system fiber optic network, all mounting accessories, all cabling necessary for communications and power, connectors, all mounting brackets, mounting hardware, power cords, delivery of all required software, factory certification, and testing.

Item Number	Description	Pay Unit
02890-311.01	Serial Device Server	EACH

SECTION 321 – CCTV CAMERA SYSTEM

321.01 GENERAL

This section sets forth the minimum requirements for CCTV Camera System furnished and installed.

The CCTV Camera shall provide unobstructed video images of the roadway, traffic, and other current conditions around a roadside CCTV field site, respond to camera control signals from the operator, and ensure video images can be transmitted to remote locations for observation.

The CCTV Camera System shall consist of one CCTV camera (Dome or Positioner style), wire connectors, mounting extension arm and hardware, software license, installation, configuration, and system integration with the City's central traffic control and monitoring software. Camera style and mounting options are specified on plans.

321.02 CCTV CAMERA

The CCTV cameras shall be Pan-Tilt-Zoom (PTZ), day/night, color IP cameras specifically designed for outdoor video surveillance applications and shall meet the following minimum requirements:

A. Camera Type (Dome or Positioner)

Camera type shall be either Dome or Positioner style as specified on plans. Both type of cameras share the same requirements, except as noted otherwise. Both type of enclosures shall meet IP-66 rating requirements for environmental resistance and tamper proofing.

In general, the cameras shall provide the following features, which are further detailed in the following sections:

- Dome type enclosure camera:

The dome enclosure shall assist in preventing lens fogging and effectively reduce internal temperatures. The enclosure shall minimize glare and provide overexposure protection for the camera when pointed directly at the sun. The dome enclosure shall be constructed in such a way that unrestricted camera views can be obtained at all camera and lens positions. Dome enclosure shall be secured with a mounting plate/attachment designed to withstand a 90 mph sustained wind speed with a 30% gust factor.

- Positioner style camera:

Positioner style camera shall have the camera body attached to the side of the pan/tilt motor drive unit. Camera body shall be equipped with a sun shield, and allow tilting from 90° to - 90°. Positioner style camera shall allow inverted mounting, with camera head mounted upside down. Camera software shall have option to select upright or inverted mounting.

B. General Capabilities and Performance Requirements

Overall CCTV Camera System capabilities and performance requirements include the following:

321.02 CCTV Camera

- CCTV Camera System shall be placed at fixed locations as shown on the plans to provide full coverage for all four legs of the intersection including the mainline travel lanes and sidewalk/shoulders.
- The CCTV Camera System components shall be compatible with each other, be of rugged design, and be suitable for reliable operation when mounted in the configuration as specified and as indicated in the plans.
- Camera enclosures shall be provided pressurized for environmental protection.
- The CCTV Camera System shall be capable of attended and unattended continuous 24 hours per day operation at the sites as shown on the plans.
- The Contractor shall ensure that the installed equipment provides unobstructed video of the roadway, traffic, and other current conditions around a roadside CCTV field site; that it responds to camera control signals from an operator of the system; and that the video images can be transmitted to remote locations interfaced to the system for observation.
- The camera shall be fully compliant with all aspects of Ethernet TCP/IP protocols and produce digital video streams in H.264 and MJPEG format.
- The camera shall operate over wide dynamic light conditions ranging from low light/dusk to full sunlight having day (color)/night (monochrome) switchover and iris control, with user-selectable manual and automatic control capabilities.
- The CCTV Camera System shall be capable of being remotely controlled and programmed.
- The camera shall be mounted together with the zoom lens and integrated into the pan and tilt device within the enclosure forming a totally integrated, easily removable assembly.
- The camera shall be equipped with an auto-iris lens capability compatible with the zoom lens supplied.
- Iris capability shall include a provision for manual override via software.
- The camera shall be capable of auto-focus during zoom-in or zoom-out, with provisions for override via software.
- The capability for local control of pan, tilt, and zoom functions shall be provided at the roadside cabinet using vendor-supplied software installed on a laptop computer.

C. Camera Lens/Sensor

- Camera format: Day/Night (IR cut filter)
- Day/Night modes: Auto, Color, Black/White
- Sensor: 1/2.8" or larger progressive scan digital imaging sensor
- Camera resolution: 1920 x 1080 Full HD 1080p at 30 fps
- Optical Zoom: 30x or greater
- Lens: 4.3 – 4.4 mm to 129 - 132mm
- Electronic-Shutter: dip-switch selectable electronic shutter with speed range from 1/30 of a second (off) to 1/10,000 of a second

- Overexposure protection: The camera shall have built-in circuitry or a protection device to prevent any damage to the camera when pointed at strong light sources, including the sun
- Low light condition imaging
- Scene Illumination Sensitivity at 50 IRE:
 - 1.8 Lux (0.18 fc) @ 1/30 shutter, or better (color mode)
 - 0.02 Lux (0.002 fc) @ 1/4 shutter, or better (mono mode)
- Aspect ratios supported: 4:3 and 16:9
- Wide dynamic range (WDR) operation with manual override option
- White Balance (Auto/Manual)
- Electronic image stabilization
- Automatic focus with manual override
- Iris control (Auto/Manual)
- 2D/3D noise reduction

D. Camera Operations

- Pan range: 360° continuous rotation
- Tilt range:
 - Dome style camera: 0° to - 90° or 0° to - 180° or better
 - Positioner-style camera: 90° to - 90° or better
 - Auto-flip at bottom of tilt travel
- Sector/Privacy Zones: 8 minimum
- Positioning to 0.1° accuracy
- Preset Pan speed: 40 deg/sec minimum
- Preset Tilt speed: 40 deg/sec minimum
- Manual Pan speed: 0.1 to 40 deg/sec
- Manual Tilt speed: 0.1 to 40 deg/sec
- Video Tours: 8 minimum
- Presets: 64 minimum
- Built-in Title Generation (Camera ID, and Preset Titles, at a minimum)

Each CCTV assembly shall accept status information from PTZ equipment for preset positioning of those components. The CCTV assembly shall accept “go to” preset commands from the test panel and central software, decode the command data, perform error checking, and drive the pan/tilt and zoom lens to the correct preset position. The preset commands will consist of unique values for the desired pan, tilt, zoom, and focus positions.

E. Physical

- Maximum dimensions: 14” long or 12” diameter (without mounting bracket)
- Maximum weight: 15 pounds for Dome style, 22 pounds for Positioner style

F. Environmental

The CCTV camera housing shall be a weather-tight enclosure to protect the camera and other internal components from rain, dust, corrosive elements, and typical conditions found at a roadside environment.

- IP-66 or better enclosure rating for entire camera unit for ingress and water protection.
- Operating Temperature (with POE 60w Max): –22° F to +122° F (–30° C to +50° C)
- The camera shall have a heater, a defroster, and a thermostat to maintain internal temperatures and humidity within the manufacturer’s specifications. Heater/blower units shall be fully functional with POE power at 60w maximum
- Camera housing environmental control shall be provided by nitrogen pressurization with a Schrader Valve for pressurization and purging. The enclosure shall be designed to be pressurized at 5 PSI of dry nitrogen. The notation “CAUTION – PRESSURIZED” shall be permanently printed on the rear plate of the enclosure and shall be clearly visible and readable.
- The camera shall be fully assembled, purged, pressurized and tested at the original manufacturing facility and shipped as a complete unit, ready for installation.
- An alarm shall be displayed under low-pressure conditions and displayed on the camera video. The low-pressure alarm shall be on/off selectable by the operator at the TMC.

G. Electrical/Power

The CCTV camera system shall operate using power-over-Ethernet (POE) with power consumption not exceeding 60 watts. All components of the camera shall be fully functional with POE power. Ground loop isolators shall be provided and installed for each CCTV.

- Power consumption < 60 Watts at maximum load
- Power input shall be POE at 60 Watts maximum

H. Communications Standards

The CCTV camera shall support the appropriate NTCIP 1205 communication protocol (version 1.08 or higher), ONVIF Profile S, or approved equal.

I. Networking Standards

- Network Connection: 10/100 Mbps auto-negotiate
- Frame Rate: (30, 15, 7, 4, 2, 1 fps minimum)
- Data Rate: scalable from 64k to 8Mbps per stream
- Built-in Web Server
- Unicast & multicast support

321.03 INSTALLATION and system integration

- Two simultaneous video streams (Dual H.264 and MJPEG):
 - Video 1: H.264 (Main Profile, at minimum)
 - Video 2: H.264 or MJPEG
- Minimum supported protocols: TCP, UDP, IPv4, DNS, DHCP, IGMP, NTP, RTP, RTSP, HTTP, HTTPS, Telnet, ONVIF Profile S

The video camera shall allow for the simultaneous encoding and transmission of the two digital video streams, one in H.264 format (high-resolution) and one in H.264 or MJPEG format (low-resolution). High resolution streams shall allow video bit rates from 1 to 8 Mbps and the low resolution stream shall allow video bit rates from 64 kbps to 2 Mbps. Initially configure these formats for 2.5 Mbps and 384kbps, respectively.

Initially use UDP/IP for video transport and TCP/IP for camera control transport unless otherwise approved by the Engineer.

The camera shall support resolutions of 1080p, 720p, CIF (352 (H) x 240 (V)), and D1 (720 (H) x 480 (V)) at a minimum.

The 10/100BaseTX port shall support half-duplex or full-duplex, provide auto negotiation, and shall be initially configured for full-duplex.

The camera unit shall be remotely manageable using standard network applications via web browser interface administration. Telnet or SNMP monitors shall be provided.

J. Local Storage Recording

The CCTV camera shall have a SD card slot inside the camera allowing continuous video recording on the SD card. A SD card with 32 GB minimum capacity shall be supplied and installed for each CCTV camera system installed.

If no SD card slot is present, the camera firmware/software shall have the capability to record video on a network-attached storage (NAS) device. The storage device shall be portable, have 256 GB minimum capacity, and capable of being attached to the Ethernet switch inside a traffic signal cabinet. The Contractor shall provide two NAS devices to the City and provide training on how to setup local storage recording with provided NAS devices.

321.03 INSTALLATION AND SYSTEM INTEGRATION

All equipment shall be installed according to the manufacturer's recommendations, the plans, and as follows:

- Materials and associated accessories/ adapters shall not be applied contrary to the manufacturer's recommendations and standard practices.
- All materials needed to permanently mount the CCTV camera to the support structure as indicated in the plans shall be provided.
- Furnish and install power, video, and data cables, and any and all ancillary equipment required to provide a complete and fully operational CCTV system site.
- Verify all wiring meets NEC requirements where applicable.

The Contractor shall obtain the IP address information for each CCTV camera from the City. The Contractor shall setup and configure the CCTV camera for remote control and monitoring by the City's Video Management Software. If no video management software is present, the Contractor shall setup camera icons and IP address hyperlinks on the system map of the City's TACTICS central software for each CCTV camera installed.

321.04 TRAINING

Upon completion of the work and at a time approved by the Engineer, the Contractor shall provide training by a qualified instructor to City personnel in the proper operation and maintenance of the equipment. City personnel shall receive training comparable to the equipment manufacturer's factory training for each new type of camera equipment that has not previously been installed within the region. The contractor shall provide a minimum of two training sessions that provide a minimum of two hours of instruction each for device operation and maintenance for each CCTV camera model.

321.05 WARRANTY

The CCTV Camera System shall be replaced or repaired by the manufacturer if any component fails to function as intended due to workmanship or material defects within the first 36 months from the date of being put into field operation at no cost (including shipping) to the City.

321.06 DOCUMENTATION

One electronic copy of the system's Operations and Maintenance Manuals shall be provided to the City. The Contractor shall provide to the City the following information for each new item furnished by the Contractor.

- Manufacturer's name, model number, and serial number
- Length of warranty and start date
- MAC address of the camera's Ethernet network interface

321.07 TESTING

A. Initial Testing by Contractor

Each piece of equipment that is required to provide the fully functioning CCTV camera system as called for on the plans shall be tested prior to shipment to the project and installed in the field.

B. Field Acceptance Testing

The following items will be checked by the City of Memphis at each CCTV site:

- Verify that physical construction has been completed in accordance with plans and specifications.
- Verify the quality and tightness of ground and surge protector connections.
- Verify proper voltages for all power supplies and related power circuits.
- Verify all connections, including correct installation of communication and power cables.

321.08 Measurement and Payment

- Verify video image is present and free from over-saturation and any other image defect in both color and monochrome mode.
- Verify the network connection to the CCTV camera through ping and telnet session from a remote PC.
- Verify support of unicast, multicast, SAP, and QoS.
- Verify that the video signal from the camera is present and of consistent quality at all connection points between the camera, the cabinet, and any video conversion/communication devices therein.
- Exercise pan, tilt, zoom, and focus in all directions and execute a minimum of three other unique programming commands to ensure that the communication link between the cabinet and the camera is functioning properly.
- Verify the local recording function works properly, and recorded images can be downloaded from SD card in camera or from the storage device attached to the Ethernet switch in local signal controller cabinet.

C. System Acceptance Testing

The following items will be checked by the City of Memphis at the City Hall TMC and the Traffic Signal Maintenance Department (collectively, the TMC):

- Verify that camera can be controlled remotely from the TMC and responds to the designated site ID and addressing that were configured by the Contractor.
- Exercise pan-tilt-zoom, and focus controls from the TMC software to confirm communication protocol compatibility.
- Exercise preset locations to verify character titling and responsiveness.
- Check digital streaming reception/ compatibility with TMC software.
- Conduct recording functions and download locally recorded videos to TMC

The Contractor shall be responsible for field fine tuning the CCTV Camera System within four weeks of final acceptance of the project, if requested by the City of Memphis. This field fine tuning shall include modifying system settings and/or identifying potential issues with equipment and replacing the equipment if it is determined to be malfunctioning.

321.08 MEASUREMENT AND PAYMENT

CCTV Camera will be measured in units of each and will be paid for at the contract unit price per each. This price shall include furnishing and installing the CCTV camera, mounting arms, fittings, miscellaneous cabling, testing, operational software package(s) and firmware(s), supplies, support, training, shop drawings, documentation, and all materials, tools, labor, equipment and incidentals necessary to complete the work. Seventy percent of the unit price will be paid upon successful completion of the Field Acceptance Testing. Thirty Percent of the unit price will be paid upon successful completion of the System Acceptance Testing.

Item Number	Description	Pay Unit
02890-321.01	CCTV Camera (Dome Type)	EACH

02890-321.02 CCTV Camera (Positioner Type)

EACH

SECTION 322 – CCTV POLE

322.01 MATERIAL

This work shall consist of furnishing and installing CCTV poles with foundations. Pole length shall be determined by Contractor to maintain specified mounting height as indicated on the plans or as directed by the Engineer. All work and materials shall be in accordance with the TDOT Standard Specifications for Road and Bridge Construction. The poles supplied shall be standard TDOT luminaire poles. Installation and materials shall comply with Section 714 and 917 of the TDOT Standard Specifications.

The Contractor shall supply poles as specified on the plans and install as shown on the plans. CCTV Pole shall consist of, but not limited to a pole, anchor bolts, breakaway base, base plate, ground rod array, communication and power conduit to nearest pull box, grounding conduit, spare conduit, and foundation as shown in plans.

322.02 INSTALLATION

CCTV poles shall be installed as indicated on the plans and shall conform to the following requirements:

- All poles shall be installed in accordance with the National Electric Safety Code and ASSHTO.
- Foundations:
 - The Contractor shall submit a design for pole foundations that has been sealed by a registered Professional Engineer.
 - The foundation design shall adhere to the prescribed loading and wind deflection as specified in TDOT Standards Specification.
 - The foundations shall be constructed in accordance with the TDOT Standard Specifications and shall adhere to the approved shop drawings for the loading specified.
 - If soil conditions require the use of any shoring, casings, or sonotube for proper installation of the foundations, the cost of the shoring, casings or sonotube shall be included in the cost of the pole and foundation.
- The dimensions and reinforcing steel shall be in accordance with the requirements of specifications.
- Cast-in-place concrete pole foundation shall cure a minimum of seven days before any load is applied to the foundation.
- A minimum of one 2 inch spare conduit shall be installed in all pole foundations as shown in the plans Typical Details. Spare conduits in pole foundations shall be sealed with blank duct plugs.
- Grounding System
 - The Contractor shall supply and install a grounding system with ground rod array at the base of all poles as shown on the plans.
 - The ground rod array system shall be connected to the pole through an appropriate ground clamp.
 - A #6 AWG copper stranded bonding wire shall be installed between the pole and the field cabinet providing a common ground system for each site.
 - All ground bonding wires shall be unspliced.

322.03 Measurement and Payment

The installation method for the CCTV poles and cameras shall be such that the camera can be rotated as needed around the pole for optimum placement.

322.03 MEASUREMENT AND PAYMENT

CCTV pole will be measured in units of each and paid for at the contract price of each. The price bid shall include but is not limited to a street light standard pole, breakaway base, foundation, and conduit inside foundation. This price shall be full compensation for all labor, tools, materials, equipment and incidentals necessary to complete the work.

Item Number	Description	Pay Unit
02890-322.01	CCTV Pole (Steel, 35' Mounting Height, with Foundation)	EACH

SECTION 323 – CABINET MODIFICATION**323.01 GENERAL**

This work shall consist of modifying existing traffic signal cabinets at locations specified on the plans to provide surge protection for CCTV and video detection equipment.

One duplex power outlet shall be added to the cabinet power panel, next to the existing power outlets or as specified by the City.

One CCTV and video detection surge protection panel shall be added to existing cabinet. This panel shall provide communications cable termination blocks and surge protection for the proposed CCTV camera, one future Ethernet communication device, and four future video detection cameras. Surge protectors shall conform to the requirements of City of Memphis Traffic Signal Specifications or as approved by the City. This panel shall be mounted on the left side above the first shelf of the controller cabinet.

For cabinets with existing video detection surge protection panels, the contractor may modify the existing panel to allow two Ethernet communication cable entries and surge protection for the CCTV camera.

323.02 MEASUREMENT AND PAYMENT

Cabinet modifications will be measured in units of each and paid for at the contract price of each. The price bid shall include but is not limited to furnishing and installation of the duplex power outlet and CCTV and video detection surge protection panel. This price shall be full compensation for all labor, tools, materials, equipment and incidentals necessary to complete the work.

Item Number	Description	Pay Unit
02890-323.01	Modify Cabinet (Power and Camera Surge Protection)	EACH

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SECTION 401 – INDUCTIVE LOOP VEHICLE DETECTOR

401.01 GENERAL

Inductive loop vehicle detector includes the following components and steps:

- Saw cut pavement
- Install inductive loop lead wire in saw cut and seal with loop sealant
- Splice inductive loop lead wire with two-conductor loop lead-in cable at roadside pullbox
- Install loop lead-in wire from roadside pullbox to controller cabinet
- Install and configure inductive loop detector amplifier on detector card rack

Material and installation requirements for loop wire and loop lead-in cable are specified in **Section 801**.

This section defines the minimum requirements for furnishing and installing Inductive Loop Vehicle Detector Amplifiers (detector) only.

- The detector shall be in full compliance with all applicable requirements in NEMA TS 1-1989 and TS2-2003.
- The detector shall be microprocessor controlled, self-tuning and fully digital. The detector shall be configured as a rack mounted printed circuit board (PCB) for insertion into a NEMA TS1 or TS2 card rack.
- Each detector unit shall include four complete detector channels.
- Detector units shall have optical outputs for interface with existing or new solid state controllers and computer systems.
- The detector shall be equipped with a multi-line Liquid Crystal Display (LCD) display, toggle switches, and a menu driven user interface. The detector shall allow user to setup and change all detector functions from the device front panel.

401.02 PHYSICAL AND ELECTRICAL

All detectors shall comply with NEMA TS2 environmental requirements.

- Fully compatible with a standard NEMA detector card rack
- Width shall not exceed one card slot
- Maximum power consumption: 15 W
- 12-24 VDC power supply from detector card rack, 175 mA maximum
- DC Inputs:
 - True (low): Less than 8 VDC
 - False (high): Greater than 16 VDC
- Optically Isolated Outputs:
 - True (low, 50 mA): Less than 1.5 VDC

- False (high): Greater than 16 VDC
- Maximum Current: 100 mA

401.03 FRONT PANEL USER INTERFACE

A. Front Panel Control

At least two high-reliability front panel toggle switches for each channel shall be provided. The switches can be used to select operational and display settings. One switch can be used to accept the setting displayed and to move to the next menu item or go back to the previously displayed screen. The second switch shall allow user to move through each selected menu.

The toggle switches shall be spring loaded and designed for the traffic signal cabinet environment.

B. Display Interface

A multi-line LCD shall be provided with a white LED backlight. The backlight is energized when any switch is actuated and remains on for 1 hour after the last switch actuation. The LCD screen shall have the ability to automatically adjust contrast to compensate for temperature changes.

All four detection channels shall be displayed and setup simultaneously.

The user interface shall use plain English prompts to describe functions and parameters without the need of a user's manual or a code dictionary sheet.

C. Front Panel LED Indicators

Each channel shall include two, wide angle, high visibility LED indicators. A red LED to display channel detect output status (output state and also the status of the delay and extension timers) plus a yellow LED to display loop fault monitor diagnostics (open loop, shorted loop, $\pm 25\%$ inductance change).

The red DETECT LED indicators shall repetitively cycle on at:

- Solid on for vehicle detection
- 2 Hz flash rate during Delay timing.
- 4 Hz flash rate during Extension timing.
- During fault detection the red channel detect indicators shall provide a steady indication in either pulse or presence mode.

The yellow FAULT LED indicators shall repetitively cycle on for:

- One long pulse and one flash to indicate open loop.
- One long pulse and two flashes to indicate shorted loop.
- One long pulse and three flashes to indicate $\pm 25\%$ change of inductance.

In addition, the LED shall let the user know at a glance that there is a current fault or a previous fault has occurred (intermittent) and could require attention:

- When both the FAULT and the DETECT LEDs are flashing, it is a current fault.

- If just the FAULT LED is flashing, the detector has returned and resumed normal operation.

401.04 FUNCTIONAL REQUIREMENTS

A. Basic Functions

The detector shall detect all vehicles over multiple turn loops installed in asphalt or concrete pavement and/or multiple loops that may be connected in series, parallel, or series/parallel, with lead-in/homerun lengths from 50 feet to over 1,000 feet.

Each channel of the sensor unit shall automatically self-tune to any loop and lead-in inductance from 20 to 2500 microhenries within 4 seconds after application or interruption of supply voltage. Channel outputs shall display calls for a period of less than 4 seconds after which detection shall be normal. Units shall also track changes in loop/lead-in electrical characteristics, as might reasonably be expected to occur in undamaged loops, properly installed in sound pavement, without producing false indications or changes in sensitivity.

Each detector channel shall output a (failsafe) continuous, non-resettable indication and output in the event of a broken (open) circuit. Previous open loop/lead-in connections shall be held in memory for recall and verification via a front panel open loop test switch.

Each channel shall continue to operate with poor quality loop systems ($Q \geq 2$) including those that have a single point short to ground.

B. Loop Frequency

The unit shall provide 8 loop frequency level settings for per channel. The LCD screen shall display the actual loop frequency to help avoid interference which may occur when loops connected to different detectors are located adjacent to one another. One of eight (8) settings (in the range of 20 to 60 kilohertz) may be selected for each channel via the user interface.

The unit shall be capable of displaying a frequency stability graph on its LVD screen to help user analyze each channel's frequency level to ensure proper selection.

The detector shall include an option to enable a (50 Hz or 60 Hz) filter to insure reliable detection thresholds in power-line-noise environments.

C. Sensitivity

Detector units shall employ a constant ΔL threshold that shall respond to vehicle generated changes of inductance and provide a relatively constant, predictable response to small motor vehicles without having to change sensitivity selections despite increased series added inductance.

The detector shall provide twenty (20) selectable sensitivity levels per channel. Sensitivity level can be selected from the user interface menu. The detector shall have the capability to display a pie graph per channel which assists in determining the optimum sensitivity setting by showing the change in inductance caused by traffic moving over the loop.

D. Detection Mode

For each channel, the following four modes of operation shall be provided and are user selectable via the menu:

1. Presence

In presence mode, a choice of short, long, or user defined presence can be selected. On the expiration of short or long presence time a detect CALL will be reset. In user defined mode, the detect CALL can be selected to reset on timer expiration or at the next End-Of-Green (EOG) signal after the expiration of the timer. The green signal is applied to the Timer Control input via the edge card connector.

2. Pulse

In Pulse mode, a 125 ms \pm 25ms width pulse shall be output for each vehicle entering the loop. Pulse mode selection shall reset (Clear) presence indications on individual channels.

3. Turn Queue

The turn queue mode, or “3rd Car” mode, mode shall be supported for Protected / Permissive left turn situations. “3rd Car” mode links ch. 1 and 2 together, and links ch. 3 and 4 together.

4. Directional Logic

Directional Logic mode shall be provided for applications in freeway ramps for wrong way detection and left turn lanes where other movements in the intersection tend to clip the detection zone of the left turn lane. Directional logic mode links ch. 1 and 2 together, and links ch. 3 and 4 together.

E. Channel Output Control

Each channel shall have one of three output options to choose from in the Setup menu; OFF, ON, or CALL:

- Off: channel output is set continuously in the No Call state regardless of the presence or absence of vehicles over the loop.
- On: channel output is enabled.
- Call: channel output is continuously in the Call state regardless of the presence or absence of vehicles over the loop.

F. Delay and/or Extension Time

The detector shall provide delay and/or extension timing capability of the detection output for each channel.

Delay time shall be selectable in 0 to 300 seconds in 1 second increments. Call Delay time shall start counting down when a vehicle enters the loop detection area.

Extension time shall be selectable in 0 to 60 seconds in 1 second increments. Call Extension time starts counting down when the last vehicle clears the loop detection zone. The Extension timer shall provide the following options: Extend Always Mode, Extend On-Green Mode, Extend Disconnect, and Extension Plus

G. Loop Fault Monitoring

The detector shall continuously check the integrity of the loop. The detector shall be able to detect open circuit loops, shorted loops, or sudden changes in inductance exceeding 25% of the nominal inductance. If a fault is detected, each type of fault shall be identified by a different LED flash sequence. The LCD display shall also display the type of fault condition during the fault state. If the fault condition is removed, the LCD "Fault" indication and the LED indicators will return to normal operation.

H. Event Log

The detector shall store the last 25 events on a per channel basis for diagnosing intermittent faults. The event log shall include elapsed time since the event occurred. The following types of loop fault shall be recorded:

- Short
- Open
- 25% or greater change of inductance
- Power Loss

A channel reset shall not clear the Event Log from memory. The user interface menu shall provide options to clear the Event Log memory.

I. Channel Labels

The detector user interface shall allow user to label each channel of detection using up to five characters or numbers. Channel labels shall be displayed on the LCD home screen.

401.05 WARRANTY

Detector card shall be replaced or repaired by the manufacturer if it fails to function as intended due to workmanship or material defects within the first 24 months from the date of being put into field operation at no cost (including shipping) to the City.

401.06 INSTALLATION

The Contractor shall install at a minimum one detector card per intersection approach. Loops located at different approaches of the intersection shall not be connected to the same detector card.

The Contractor shall label each channel in the menu with the approach name (EB/WB/NB/SB) and loop location (Front/Back).

401.07 TESTING

With the presence of the City traffic signal maintenance staff and the project inspectors, the Contractor shall demonstrate the following:

- Ability to detect vehicles successfully and reliably for each detection channel.
- All configuration parameters are in accordance with the City's Configuration Guidelines.

- Channels are labeled clearly to indicate the approach (EB/WB/NB/SB) and location (Front/Back).

401.08 DOCUMENTATION

One electronic copy of the detector card's Operations and Maintenance Manuals shall be provided to the City. The Contractor shall provide to the City the following information for each new card furnished by the Contractor.

- Manufacturer's name, model number, and serial number
- Length of warranty and start date

401.09 MEASUREMENT AND PAYMENT

Accepted vehicle detector amplifiers, including inductive loop detectors of all sizes and shapes, shall be measured by the individual unit furnished and installed complete in place, per each.

Payment at the contract unit price, per each, shall be made for each accepted traffic detector amplifier of the type specified. This shall be payment in full for furnishing and installing the vehicle detector amplifier including mounting and connection to terminals as required to render the signal detection operable.

Item Number	Description	Pay Unit
02890-401.01	Inductive Loop Vehicle Detector Amplifier	EACH

SECTION 402 – VIDEO DETECTION SYSTEM

402.01 GENERAL

This section sets forth the minimum requirements for Video Detection System (VDS) equipment furnished and installed.

The VDS shall consist of up to six video cameras, video detection processors (VDP) capable of processing from one to six video sources, a remote communications module, a monitor, and a mouse.

The system shall include a power supply unit and detector card rack (if not reusing the existing card racks in the controller cabinet). The processor extension modules shall be included in order to have enough detection output channels as called for on the Plans. In addition, if multiple processors / extension modules are used, an integration card should be included so that the operator can then switch to any of the peripheral processors without the need of switching any monitor, communication, or mouse connections.

The system shall include software that detects vehicles in multiple lanes using a video image. Detection zones shall be defined using only an on board video menu and a mouse to place the zones on a video image. Up to 24 detection zones per camera view shall be available. A separate computer shall not be required to program the detection zones.

The VDS shall be able to transmit NTSC or PAL video signals, with minimal degradation, up to 1000 feet under ideal conditions. Adjacent sources of electromagnetic radiation, or the absence of a direct line of sight between transmitter and receiver antennas, may result in video signal degradation.

402.02 VIDEO DETECTION CAMERA

Video detection cameras shall be specifically designed for vehicle detection applications and meet the following minimum requirements:

A. Camera

- Built to detect vehicles in any lighting and weather conditions
- 12x zoom
- Adjustable/auto focus
- Lens Focal length and focus adjustable at the rear of housing for a horizontal field of view ranging from 4.5°tele to 48° wide
- 800 x 500 effective pixels
- 540 TV lines minimum
- Automatic white balance
- >50 dB S/N ratio
- Dynamic range >100 dB at any backlit conditions
- .003 lux capable

- 3D-DNR Noise Reduction
- Heater equipped to enable optimal detection performance in adverse weather conditions
- Ability to setup and configure field of view from the bucket truck or from the traffic signal cabinet

B. Physical

- Maximum dimensions 20" long x 6" diameter (without mounting bracket)
- Maximum weight: 8 pounds, including camera, lens, housing, sunshield, and mounting bracket)

C. Environmental

- Temperature: –31° F to +165° F (–35° C to +74° C)
- Humidity: 0% to 100%
- Vibration: 0.5G, 3 axes, 5-30 Hz
- Shock: 10G in all 3 axes

D. Power

- Standard 115/230 VAC (5W typical, 25W max.) 50/60 Hz
- Heater: Indium Tin Oxide, proportional power

402.03 VDP SYSTEM INTERFACES**A. Video Input**

Each video input shall accept RS170 (NTSC) or CCIR (PAL) signals from an external video source (camera sensor or VCR). The interface connector shall be BNC type and shall be located on the video processing unit. The video input shall have the capability to select 75-ohm or high impedance (Hi-Z) termination. The selection of the video input impedance shall be easily accessible and located near to the video input BNC connector. All inputs shall be clearly labeled on the front panel of the VDP. All cables shall also be clearly labeled denoting which approach the cable is connected to.

B. Video Lock LED

A LED indicator shall be provided to indicate the presence of the video signal. The LED shall illuminate upon valid video synchronization and turn off when the presence of a valid video signal is removed.

C. Video Output

One video output shall be provided. The video output shall be RS170 or CCIR compliant and shall pass through the input video signal. For multi-channel video input configurations, a momentary push-button shall be provided on the front panel to toggle through each input video channel. In the absence of a valid video signal, the channel shall be skipped and the next valid video signal shall be switched. The use of toggle switches is strictly prohibited. The video output shall have the capability to show text and graphical overlays to aid in

system setup. The overlays shall display real-time actuation of detection zones upon vehicle detection or presence. Overlays shall be able to be turned off by the user. Control of the overlays and video switching shall also be provided through the serial communications port. The use of an external device connected to this serial communications port for this communication and switching is prohibited. The video output interface connector shall be BNC type.

D. Serial Communications

A serial communications port shall be provided on the front panel. The serial port shall be compliant with RS232 or RS422 electrical interfaces and shall use a DB9 type connector. The serial communications interface shall allow the user to remotely configure the system and/or to extract calculated vehicle/roadway information. The interface protocol shall be documented or interface software shall be provided. The interface protocol shall support multi-drop or point-to-multipoint communications. Each VDS shall have the capability to be addressable. The use of an external device connected to this serial communications port for this communication and switching is prohibited.

E. Contact Closure Output

Open collector contact closure outputs shall be provided. Four (4) open collector outputs shall be provided for the single or dual channel rack-mount configuration. Additionally, the single channel rack-mount configuration shall allow the use of extension modules to provide two (2) or four (4) additional open collector contact closures. Through the use of multiple extension modules, each camera shall be able to output to a minimum of 24 open collector contact outputs. The actual number supplied shall be as specified. Each open collector output shall be capable of sinking 30 mA at 24 VDC. The open collector output shall be used for vehicle detection indicators as well as discrete outputs for alarm conditions.

F. Detection LEDs

LEDs shall be provided on the front panel. The LEDs shall illuminate when a contact closure output occurs. Video processors shall have a minimum of four (4) LEDs. Extension modules shall have two (2) or four (4) LEDs to indicate detection, depending on the model.

G. Mouse Port

A PS/2 or USB mouse port shall be provided on the front panel of the video processing unit. The mouse port shall not require special mouse software drivers. The mouse port shall be used as part of system setup and configuration. A PS/2 or USB mouse shall be provided per each VDS.

402.04 VDP FUNCTIONAL REQUIREMENTS

Detection zones shall be programmed via an on board menu displayed on a video monitor and a pointing device connected to the VDP. The menu shall facilitate placement of detection zones and setting of zone parameters or to view system parameters. A separate computer shall not be required for programming detection zones or to view system operation.

The VDP shall store up to three different detection zone patterns. The VDP can switch to any one of the three different detection patterns within 1 second of user request via menu selection with the pointing device. The VDP shall detect vehicles in real time as they travel across each detection zone. The VDP shall have an RS232 port for communications with an external

computer. The VDP RS232 port shall be multi-drop capable. The VDP shall accept new detection patterns from an external computer through the RS-232 port when the external computer uses the correct communications protocol for downloading detection patterns. A Windows®-based software designed for local or remote connection and providing video capture, real-time detection indication and detection zone modification capability shall be provided with the system. The VDP shall send its detection patterns to an external computer through the RS-232 port when requested when the external computer uses the correct communications protocol for uploading detection patterns.

The VDP shall default to a safe condition, such as a constant call on each active detection channel, in the event of unacceptable interference with the video signal. The system shall be capable of automatically detecting a low-visibility condition such as fog and respond by placing all defined detection zones in a constant call mode. A user-selected output shall be active during the low-visibility condition that can be used to modify the controller operation if connected to the appropriate controller input modifier(s). The system shall automatically revert to normal detection mode when the low-visibility condition no longer exists.

- Twenty four detection zones per camera configuration shall be supported and each detection zone shall be sizeable to suit the site and the desired vehicle detection region. Placement of detection zones shall be done by using only a mouse, and a graphical interface built into the VDP and displayed on a video monitor, to draw the detection zones on the video image from each video camera. No separate computer or numeric keypad shall be required to program the detection zones.
- The VDP shall provide 4 channels of vehicle presence detection through a standard detector rack edge connector and one or more extension modules. Up to 24 channels of detection shall be available using multiple extension modules. Each extension module shall be self-addressing, based on position in the data chain.
- A single detection zone shall be able to replace multiple inductive loops and the detection zones shall be OR'ed as the default or may be AND'ed together to indicate vehicle presence on a single phase of traffic movement.
- Up to three (3) detection zone patterns shall be saved for each camera within the VDP memory. The VDP's memory shall be non-volatile to prevent data loss during power outages.
- The selection of the detection zone pattern for current use shall be done through a menu. It shall be possible to activate a detection zone pattern from VDP memory and have that detection zone pattern displayed within 1 second of activation.
- When a vehicle is detected crossing a detection zone, the corners of the detection zone shall flash on the video overlay display to confirm the detection of the vehicle.
- Detection shall be at least 98% accurate in good weather conditions, with slight degradation possible under adverse weather conditions (e.g. rain, snow, or fog) which reduce visibility.
- The VDP shall provide dynamic zone reconfiguration (DZR). DZR enables normal operation of existing detection zones when one zone is being added or modified during the setup process. The VDP shall output a constant call on any detector channel corresponding to a zone being modified.
- Detection zones shall be directional to reduce false detections from objects traveling in directions other than the desired direction of travel in the detection area.

402.05 VDP Hardware and mechanical requirements

- Detection zone setup shall not require site specific information such as latitude and longitude to be entered into the system. It shall also not require temporal information such as date and time.
- The VDP shall process the video input from each camera using a separate microprocessor at 30 frames per second.
- The VDP shall output a constant call for each enabled detector output channel if a loss of video signal occurs. The VDP shall output a constant call during the background learning period. Upon system start up (either new detection zones or upon loss of power), all channels of programmed detection shall output a constant call to the controller of at least 15 seconds to ensure safe operation.
- Detection zone outputs shall be configurable to allow the selection of presence, pulse, extend, and delay outputs. Timing parameters of pulse, extend, and delay outputs shall be user definable between 0.1 to 25.0 seconds.
- Up to six detection zones per camera view shall have the capability to count the number of vehicles detected. The count value shall be internally stored for later retrieval through the RS-232 port. The data collection interval shall be user definable in periods of 5, 15, 30 or 60 minutes.

402.05 VDP HARDWARE AND MECHANICAL REQUIREMENTS

The VDP and extension module (EM) shall be specifically designed to mount in a standard 170, 2070, TS-1 and TS-2 detector rack, using the edge connector to obtain power and provide contact closure outputs. No adapters or special racks shall be required to mount the VDP or EM in any of these standard detector racks. Detector rack rewiring shall not be required. Vendor specific racks are only required if called for on the Plans. The EM shall be available, to avoid the need to rewire the detector rack, by enabling the user to plug an extension module into the appropriate slot in the detector rack. The extension module shall be connected to the VDP by a CAT5 cable with modular connectors (same wiring as an Ethernet patch cable), and shall output contact closures in accordance with user selectable channel assignments.

The VDP and EM shall be powered by 12 or 24 VDC. VDP power consumption shall not exceed 300 milliamps at 24 VDC. The EM power consumption shall not exceed 120 milliamps at 24 VDC.

The VDP and EM shall include detector output pin out compatibility with industry standard detector racks.

The front of the VDP shall include one BNC video input connection suitable for RS170 video inputs. The video input shall include a switch selectable 75-ohm or high impedance termination to allow camera video to be routed to other devices, as well as input to the VDP for vehicle detection. Routing of video signals through the back plane (panel?) on the rack mounted configurations is not permissible.

The front of the VDP shall include one BNC video output providing real time video output that can be routed to other devices. For the dual camera rack mount, the video out shall be controlled via the menu button of the front of the faceplate. The use of a toggle switch for this function is prohibited. The video out shall also be directly controlled via software over the RS-232 port. The use of additional hardware for this function is not permitted.

402.06 Power Panel and Surge Protection

The VDP shall operate satisfactorily in a temperature range from -37° C (-35° F) to +74° C (+165° F) and a humidity range from 0% to 95% RH, non-condensing as set forth in NEMA specifications.

The front panel of the VDP shall have a detector test switch to allow the user to place calls on each channel. The test switch shall be able to place either a constant call or a momentary call depending on the position of the switch.

The front face of the VDP shall contain indications, such as LED displays, to enable the user to view real time detections for each channel of detection (up to 8 channels at a time) when the system is operational.

The VDP shall include an RS232 port for serial communications with a remote computer. This port shall be a 9-pin "D" subminiature connector on the front of the VDP.

The VDP shall utilize flash memory technology to enable the loading of modified or enhanced software through the RS232 port and without modifying the VDP hardware.

402.06 POWER PANEL AND SURGE PROTECTION

VDS power and surge protection units shall be mounted on a separate back panel. This back panel shall be mounted to the left side above the first shelf of the controller cabinet.

Surge protection for all cameras shall be in compliance with **Section 211.07**.

402.07 REMOTE COMMUNICATIONS MODULE

A remote communications module in detector card form factor shall be provided with the VDS. The remote access card shall allow the user to view a single quad view video stream or four independent single stream through a single Ethernet TCP/IP connection. The video output shall be MPEG4/H.264 compression format and support 30 frames per second video frame rate.

The remote communications card shall have four (4) VDP extension module input interfaces. The card shall provide one RJ45 Ethernet port, a USB mouse port, and a BNC video output connector.

The remote communications card shall be fully integrated with the VDPs and the Ethernet switch in the cabinet.

402.08 VIDEO/RADAR HYBRID DETECTION SYSTEM (OPTIONAL)

If requested on Plans or Bid Documents, the Contractor shall furnish and install the VDS with a video and radar hybrid detection system. Video detection requirements shall remain the same as described in this section. In addition, the hybrid camera shall include a radar detector with the following features:

- Frequency: 24GHz (K-band)
- Accuracy: Speed 0 to 150 mph \pm 1 mph (240 kph \pm 1.5 kph)
- Tracked objects: Up to 20
- Detection: Across 4 lanes of traffic

- Range: > 600 feet

The hybrid VDS shall also include the corresponding processors and any other required hardware and software to make a complete video/radar hybrid VDS system.

402.09 WARRANTY

The VDS shall be replaced or repaired by the manufacturer if its component fails to function as intended due to workmanship or material defects within the first 36 months from the date of being put into field operation at no cost (including shipping) to the City.

402.10 DOCUMENTATION

One copy of the interface software shall be provided to the City. One electronic copy of the system's Operations and Maintenance Manuals shall be provided to the City. The Contractor shall provide to the City the following information for each new item furnished by the Contractor.

- Manufacturer's name, model number, and serial number
- Length of warranty and start date
- MAC address of the remote communications module's Ethernet network interface

402.11 TESTING

A. Initial Testing By Contractor

Each piece of equipment that is required to provide the fully functioning video detection system as called for on the Plans shall be tested prior to shipment to the project and installed in the field.

B. Testing Performed by the City Prior to Activation

The following items will be checked by the City of Memphis prior to activation of the VDS:

- All appropriate equipment has been installed per this specification and the Plans.
- Cameras located per the Plans.
- Detection zones drawn per the Plans.
- Camera mountings meet minimum height requirements on Plans or Design Standards.
- Detection inputs and cables are correctly labeled.

C. Testing Performed by the City at Activation

The following items will be checked by the City of Memphis at the time of activation of the VDS:

- Wires entering the cabinet are labeled with the associated direction and phase.
- Proper communication is established with each detector.
- Field of view of camera is parallel to the roadway with no horizon.
- Fog zones are drawn for each camera view.

402.12 Measurement and Payment

- Detection zones call proper phases when occupied.

If the remote communications module is installed, Contractor shall demonstrate the following:

- Ability to stream video successfully and reliably according to these specifications via HTTP protocol from the cabinet edge switch, the hub switch, and the TMC workstation.

The Contractor shall be responsible for field fine tuning the VDS within 2 weeks of final acceptance of the project, if requested by the City of Memphis. This field fine tuning shall include modifying system settings and/or identifying potential issues with equipment and replacing the equipment if it is determined to be malfunctioning.

402.12 MEASUREMENT AND PAYMENT

Accepted video detection system shall be measured as one system for a signalized intersection, complete furnished and installed, per each. Alternatively, each VDS component can be measured separately if called for on the plan or the quantity sheet, complete furnished and installed, per each.

If measured by each signalized intersection, payment at the contract unit price, per each, shall be made for each accepted VDS of the type specified. This shall be payment in full for furnishing and installing the video detection cameras, video detection processors, remote communications module, video processor cards, card rack, power supply unit, monitor, mouse, and all other cabling, connections, hardware and software as required to render a fully functional video detection system. Field fine-tuning of the system is included in this item. Removal of existing vehicle detector amplifiers from cabinet is included in this item.

Alternatively, if each VDS component is measured separately as called for on the plan or the quantity sheet, the payment shall be made at the contract unit price, per each, for each accepted VDS component such as cameras, processors, remote communications modules, card racks, power supply unit, monitors, and pointing devices detectors. The price for each component shall include all cabling, connections, installation, configuration, testing, field tuning and other required hardware and software to make the component fully functional.

Item Number	Description	Pay Unit
02890-402.01	Video Detection System	EACH
02890-402.02	Video Detection System (Video/Radar Hybrid System)	EACH
02890-402.11	Video Detection Camera	EACH
02890-402.12	Video Detection Camera (Video/Radar Hybrid Unit)	EACH
02890-402.21	Video Detection Processor (Single Input Channel)	EACH
02890-402.22	Video Detection Processor (Dual Input Channel)	EACH
02890-402.23	Video Detection Processor (Four Input Channel)	EACH
02890-402.24	Video Detection Processor (Single Input Channel, Video/Radar Hybrid System)	EACH

02890-402.25	Video Detection Processor (Dual Input Channel, Video/Radar Hybrid System)	EACH
02890-402.26	Video Detection Processor (Four Input Channel, Video/Radar Hybrid System)	EACH
02890-402.27	Video Detection Card Rack	EACH
02890-402.28	Video Detection Card Rack Power Unit	EACH
02890-402.31	Video Detection Remote Communications Module	EACH
02890-402.32	Video Detection Monitor	EACH
02890-402.33	Video Detection Mouse	EACH

SECTION 411 – PEDESTRIAN PUSH BUTTON

411.01 MATERIAL

Each Pedestrian Push Button Assembly shall be actuated by pushing a corrosion resistant stainless steel plunger at least two inches in diameter. Each push button assembly shall comply with applicable requirements of the Americans with Disabilities Act. The button shall be of the spring return type and cause the closure of a set of internal contacts. Spring shall be a stainless steel wave return spring. The push button/contact assembly shall be screwed into a one-piece, Federal Yellow painted aluminum die cast, cylindrical housing suitable for mounting on a steel pole in conformance with the Plans. The push button assembly shall be constructed and gasketed to prevent accidental shock and provide weatherproof and freeze-proof operation.

The push button assembly shall be replaced or repaired by the manufacturer if it fails to function as intended due to workmanship or material defects within five years from the date of being put into field operation at no cost (including shipping) to the City.

The push button signs shall be R10-3E. The regulatory sign size, color, and legend shall be fully compliant with the latest edition of the MUTCD and Standard Highway Signs Manual. Direction of arrow on signs shall match the push button orientation shown on Plans.

411.02 INSTALLATION

The Contractor shall install pedestrian push buttons and signs according to the pole locations and orientation shown in the Plans. The push buttons shall be wired to the controller in accordance with the Plans. The pedestrian actuated signal sign given in the Plans shall be installed on the pole with each push button.

411.03 MEASUREMENT AND PAYMENT

Accepted pedestrian push buttons shall be measured as one complete furnished and installed unit, per each. Payment, at the contract unit price, shall be made for each accepted pedestrian push button, or pedestrian push button with 15" sign. This shall be payment in full for furnishing and installing each push button assembly including banding or other mounting of the sign and pushbutton, wiring, and any necessary materials for a complete, tested, and operable installation.

Item Number	Description	Pay Unit
02890-411.01	Pedestrian Push Button with 15" Sign	EACH
02890-411.02	Pedestrian Push Button	EACH

SECTION 412 – ACCESSIBLE PEDESTRIAN SIGNAL (APS) SYSTEM**412.01 GENERAL**

The Accessible Pedestrian Signal (APS) system shall consist of one central control unit in cabinet and up to 16 push button stations as specified on Plans.

412.02 PUSH BUTTON STATION

The Push Button Station (PBS) is the pedestrian interface to the proposed APS system. The PBS shall comply with the latest MUTCD standard, providing information and cues by both a vibrating arrow button and audible sounds, making the intersection accessible for all pedestrians. All sounds shall emanate from both the front and the back of the unit. A sunlight-visible red LED illuminates “ON” along with a tactile feedback “bounce” to confirm the button has been pushed. The PBS shall be vandal-resistant and shall include the body which houses the ADA compliant push button, a faceplate (sign), and mounting hardware.

The PBS shall comply with applicable NEMA TS2 environmental requirements for temperature, humidity, mechanical shock and vibration.

- Operating temperature: -34°C (-30°F) to +74°C (+165°F)
- Push button operating force: 3 lbs maximum
- Push button switch operating life: > 20 million operations
- Maximum volume: 100 dB at 1 meter
- PBS Enclosure rating: NEMA Type 4X

By interfacing with the central control unit installed in the traffic signal cabinet, the PBS shall provide the following standard features:

- Operates over a single pair of wires
- All push button stations shall be wired in parallel, individually assignable to any phase
- A minimum of 16 buttons can operate with a single central control unit
- All sounds are synchronized
- Four Locate Tone selectable options
- 14 Walk Sound selectable options, three of them custom options
- Seven Clearance Sound selectable options
- Walk, Clearance and Don't Walk sounds adjust automatically to ambient noise
- Separate ambient response settings for Locate Tone (for quiet ambient conditions)
- Button vibrates during Walk
- Button push confirmed by LED, tactile bounce, and audible “wait” sound
- Extended button push shall boost volume for next Walk and Clearance
- Extended Push Activation Settings: 0-6 second range, .5 second increments

- Ability to select audio messages, change settings, and perform firmware updates wirelessly using iOS or android devices or a Windows PC
- Built in Health/Event logging feature, up to 300 events
- False Walk Detection: Four independent checks

The PBS shall be replaced or repaired by the manufacturer if its component fails to function as intended due to workmanship or material defects within five years from the date of being put into field operation at no cost (including shipping) to the City.

The push button signs shall be R10-3E. The regulatory sign size, color, and legend shall be fully compliant with the latest edition of the MUTCD and Standard Highway Signs Manual. Direction of arrow on signs shall match the push button orientation shown on Plans.

412.03 CENTRAL CONTROL UNIT

The central control unit shall be designed for use with the existing or proposed accessible push button stations (PBS) at the location shown on Plans. The central control unit shall allow connection to a minimum of 16 PBS's. The central control unit shall comply with NEMA TS2 environmental requirements:

- Operating temperature: -34°C (-30°F) to +74°C (+165°F)
- LCD display operating temperature: -20°C (-4°F) to +70°C (+158°F)
- If specified as rack mount option, the unit shall be fully compatible with a standard NEMA detector card rack. Width shall not exceed two card slots.
- If specified as shelf mount option, the unit shall have maximum dimension of 9 in (L) x 3.5 in (W) x 6.5 in (H)
- Ped Walk / Don't Walk Inputs:
 - 0 – 24 VDC (Active Low)
- Ped Outputs:
 - Optically Isolated 36 Volts AC/DC peak
 - 300mA Solid State Fused Contact Closure

The connection for each PBS requires only two wires. All PBS's shall connect in parallel and shall not have a polarity requirement. The control unit front panel shall include a backlit LCD for displaying system status information. Front panel buttons shall be provided for push button setup, placing test calls, and to enable Wi-Fi. The control unit shall allow all setup functions to be performed via Ethernet or Wi-Fi using a PC. The unit shall also support all setup functions using an IOS or Android smartphone or tablet via Wi-Fi. In addition, configuration via Bluetooth shall be supported by pairing with any connected PBS using a PC, Phone, or Tablet. All of the connection options shall provide full access to setup and configuration of both the control unit and all connected PBS's.

Multiple configurations shall be supported, with the ability to change operational features based on time of day. The system shall have internal conflict monitoring and health log data capture that is both downloadable and contains status/fault reporting. Remote Monitoring shall be supported over Ethernet.

412.04 Installation

The central control unit shall be replaced or repaired by the manufacturer if its components fail to function as intended due to workmanship or material defects within three years from the date of being put into field operation at no cost (including shipping) to the City.

412.04 INSTALLATION

The Contractor shall install push button stations according to the pole locations and orientation shown in the Plans. The push button stations shall be wired to the central control unit and the traffic signal controller in accordance with the Plans. The pedestrian actuated signal sign shown in the Plans shall be installed on the pole with each push button station.

412.05 MEASUREMENT AND PAYMENT

Accepted APS push button stations and central control units shall be measured as one complete furnished and installed unit, per each. Payment, at the contract unit price, shall be made for each accepted APS push button station, APS push button station with 15" sign, or APS central control unit. This shall be payment in full for furnishing and installing each assembly including banding or other mounting of the sign and pushbutton, wiring, and any necessary materials for a complete, tested, and operable installation.

Item Number	Description	Pay Unit
02890-412.01	Accessible Pedestrian Signal System	EACH
02890-412.02	APS Push Button Station with 15" Sign	EACH
02890-412.03	APS Push Button Station	EACH
02890-412.04	APS Central Control Unit (Rack Mount)	EACH
02890-412.05	APS Central Control Unit (Shelf Mount)	EACH

SECTION 413 – RECTANGULAR RAPID FLASHING BEACON SYSTEM**413.01 GENERAL**

The Rectangular Rapid Flashing Beacon (RRFB) System shall consist of a self-contained solar engine that houses the charge controller, flash controller, on-board user interface, wireless communications, batteries and solar panel. Each RRFB system shall include up to four RRFB lightbars. The system shall conform to all provisions of the MUTCD, Interim Approval for Optional Use of Pedestrian-Actuated Rectangular Rapid Flashing Beacons at Uncontrolled Marked Crosswalks (IA-21) including WW+S flash pattern. Mounting poles, push buttons, signs and plaques are integral parts of the RRFB system and shall be installed as specified on Plans, but are not included in this item.

413.02 MECHANICAL

The solar engine shall be constructed from aluminum with an integrated solar panel. All batteries and electronics shall be mounted in the controller enclosure, with no external control cabinet or battery cabinet required.

The overall weight of the solar engine, including batteries, shall not exceed 40 lbs (18.2 kg). The solar engine, excluding mounting components, shall not exceed 22" in width, 16" in height, and 5" in depth.

The solar engine shall be supplied with a fixed tilt angle of 45 degrees and shall be able to be oriented toward the equator with no additional mounting hardware. Access to the interior of the solar engine shall be provided by a lid that is hinged on the bottom edge and is fitted with a foam gasket. The lid shall have a lockable latch. The solar engine shall be vented to provide cooling of the battery and electronic system. The vents shall be screened to prevent ingress by insects and debris.

The solar engine shall be furnished with mounting adaptor hardware for banding to 4" diameter or larger round poles.

The lightbar housing and light modules shall conform to all provisions of the MUTCD and FHWA requirements.

Each end of a light bar shall include a side-emitting pedestrian confirmation light composed of a single LED. Users shall have the option of using both confirmation lights for median applications, or covering one confirmation light with an included sticker for side-of-road applications.

The light bar shall be mounted to the post or pole using a separate bracket assembly to facilitate mounting two light bars back-to-back (bi-directional) and to allow the light bar(s) to rotate horizontally for aiming. The light bar bracket shall be constructed from galvanized or stainless steel and shall have both banding and bolting mounting options and shall be able to be mounted to all specified pole types.

The light bar assembly shall open for access to the wiring connections for the LED modules. LED modules shall be rated to NEMA 3R.

The RRFB solar engine and light bars shall be rated to a minimum of NEMA 3R for environmental testing.

413.03 CONFIGURATION

The controller enclosure shall house an on-board user interface that provides on-site configuration adjustment, system status and fault notification.

The flash duration shall be adjustable in-the-field from 5 to 60 seconds in one second increments, 60 to 1,200 seconds in 60-second steps, and 3,600 seconds.

The system shall provide configurable nighttime intensity settings ranging from 10% to 100% of daytime intensity.

The system shall be capable of enabling or disabling ambient brightness auto-adjustment. If enabled, the ambient brightness auto-adjustment shall adjust output to a range between 50% and 100% of daytime intensity.

The User Interface shall provide viewing and/or programming access for the following:

- Activation Duration
- Digital output that is active during the flashing cycle that allows the control of external devices such as crosswalk illumination. Digital output shall be configurable for night operation only or operation day or night
- Radio Channel
- Radio Status
- Night Intensity Setting
- Adjustment for Ambient Daytime Brightness
- Self-Test / BIST (Built-In Self-Test) including the detection of shorts or open circuits in the fixture outputs
- Battery Status – General description and actual battery voltage
- Day or Night Status (as determined by dedicated photosensor not solar panel output)
- Solar Panel Voltage
- Automatic Light Control. If this safety feature is enabled, it allows the RRFB to temporarily reduce the intensity of the light bars to maintain energy equilibrium. The user interface shall report the amount of dimming being applied in the range of 10% to 100%
- Daily activations averaged over 90 days
- Pushbutton detection
- Firmware Version

Activation duration, Night intensity setting and adjustment for ambient daytime brightness shall be automatically broadcast to all RRFBs in the system when changed in one RRFB.

413.04 SOLAR PANEL AND POWER SYSTEM

The following are minimum requirements for the solar power system. The system shall be sized to provide the required power based on the actual location and conditions in which the system will be installed. Solar panel and battery system shall be 12 Volt DC (nominal).

The solar engine shall house one or two sealed valve-regulated AGM lead-acid maintenance-free battery. The battery shall be readily available from multiple suppliers and non-proprietary. Each battery shall be equipped with a minimum 1.5 amp fuse on the positive lead. The battery charging system shall be 3-stage and incorporate temperature-compensation to prevent battery overcharging in hot weather. Batteries, in conjunction with recommended RRFB performance, shall be designed for a demonstrable service life of 5 years. The battery shall be rated for -40° to 140°F (-40° to 60°C). Batteries shall have quick connections to facilitate installation and be readily available from multiple suppliers and non-proprietary. Batteries shall be supported by rubber bumpers and constrained from excessive movement.

The manufacturer shall provide an energy balance worksheet consisting of (Energy In)/(Energy Out), System Array-to-Load (ALR), and System Autonomy calculations. Systems shall be designed to a minimum Array-to-Load (ALR) ratio of 1.2. System autonomy shall be a minimum of 5 days or as recommended by the NASA Atmospheric Data Center for the location.

413.05 OPERATIONAL REQUIREMENTS

The RRFB system operations shall conform to all provisions of the MUTCD, Interim Approval for Optional Use of Pedestrian-Actuated Rectangular Rapid Flashing Beacons at Uncontrolled Marked Crosswalks (IA-21).

The system, including the optional push button with voice message, shall have the capacity to operate 300 20-second activations per day year-round using the applicable peak sun hours insolation available at the installation location. The source of the insolation data shall be the NASA Atmospheric Data Center.

The controller enclosure shall have the capability to activate other solar engines by wireless communications within 500 feet (152 meters). The solar engine shall have a minimum of six unique communication channels that can be configured on-site to avoid activation of nearby systems.

The system shall use a dedicated light sensor to detect night and day states and apply any optionally-enabled intensity adjustments.

All RRFBs in the system shall initiate activation simultaneously within 150 ms of actuation.

If an additional actuation occurs while the system is activated, the flash duration shall reset.

If the RRFB has ceased operation, any subsequent actuation shall activate the RRFB without delay regardless of how recently the RRFB ceased operation.

413.06 WARRANTY

All components of the RRFB system shall be replaced or repaired by the manufacturer if it fails to function as intended due to workmanship or material defects within five years from the date of being put into field operation at no cost (including shipping) to the City.

413.07 MEASUREMENT AND PAYMENT

Accepted RRFB system shall be measured as one complete furnished and installed unit, per each. Payment, at the contract unit price, shall be made for each RRFB system. This shall be payment in full for furnishing and installing each system including banding or other mounting of the components, wiring, and any necessary materials for a complete, tested, and operable installation.

Item Number	Description	Pay Unit
02890-413.01	RRFB System (One Lightbar per pole)	EACH
02890-413.02	RRFB System (Two Lightbars per pole)	EACH
02890-413.03	RRFB System (____ Lightbars per pole)	EACH

SECTION 421 – PRIORITY CONTROL SYSTEM

421.01 GENERAL

This section sets forth the minimum requirements for the intersection equipment of a Priority Control System. The priority control system shall deliver reliable and accurate emergency vehicle preemption and transit vehicle priority at each installed signalized intersection shown on Plans. The priority control system shall be compatible with the existing vehicle equipment (antenna, radio, and emitter units) used by the City of Memphis Police and Fire Departments.

The required priority control system shall employ data-encoded infrared communication to identify the presence of designated priority or probe vehicles. A record of system users, in the form of vehicle classification and identification number, shall be created. In priority vehicle mode, the data-encoded communication shall request the traffic signal controller to advance to and/or hold a desired traffic signal display selected from phases normally available. In probe vehicle mode, no traffic signal priority is requested. Only a record of the probe vehicle's presence is generated.

The priority control system shall consist of a matched system of data-encoded emitters, infrared detectors, detector cable, phase selectors and system software.

The emitter shall generate an infrared, data-encoded signal. The data-encoded signal shall be detected and recognized by the infrared detectors at or near the intersection over a line-of-sight path of up to 2,500 feet (762m) under clear atmospheric conditions. The phase selector shall process the electrical signal from the detector to ensure that the communication:

- is a valid base frequency,
- is correctly data encoded,
- is within the user-settable priority request activation range, and
- performs priority arbitration between simultaneous users of the system.

If these conditions are met, the phase selector shall generate a priority control request to the traffic controller (i.e., a green light) for the approaching priority vehicles, or record the presence of approaching probe vehicles by classification and identification number.

The system shall require no action from the vehicle operator other than to turn the emitter on. The system shall operate on a first-come, first-served basis. High priority requests shall override Low priority requests. The system shall interface with existing traffic signal controllers in the City of Memphis and shall not compromise normal operation or existing safety provisions.

All wires entering the cabinet are to be labeled to indicate the associated direction and phase.

421.02 PHASE SELECTOR

The phase selector shall accommodate data-encoded communication and shall perform priority level arbitration, validate, identify, classify and record the signal from the detector. It shall be located within the controller cabinet at the intersection. It shall request the controller to provide priority to the requesting vehicle and/or record presence of a probe vehicle.

421.02 Phase Selector

The phase selector is intended for use directly with traffic signal controllers along with the system card rack and suitable system interface equipment and controller software. It shall be a plug-in, two or four channel, multiple-priority device intended to be installed directly into a card rack. It shall be powered from 115 volt (95 VAC to 135 VAC), 60Hz mains and shall contain an internal, regulated power supply that supports up to twelve infrared detectors.

Programming the phase selector, and retrieving the data stored in it, shall be accomplished using an IBM PC-compatible computer and the system interface software. The connection can be made either directly, via the computer's communication (COM) port, or remotely via a modem. The communication port on the phase selector shall be an RS232 interface located on the front and back of the unit. The communication protocol shall be made available upon request for creating software to implement other communication applications.

The phase selector shall include the ability to directly sense the green traffic controller signal indications through the use of dedicated sensing circuits and wires connected directly to the field wire termination points in the traffic controller cabinet.

The phase selector shall have the capability of storing up to 1000 of the most recent priority control calls, probe frequency passages, or unauthorized vehicle occurrences. When the log is full, the phase selector shall drop the oldest entry to accommodate the new entry. The phase selector shall store the record in non-volatile memory and shall retain the record if power terminates. Each record entry shall include ten points of information about the priority call, as follows:

- Classification: Indicates the type of vehicle.
- Identification number: Indicates the unique ID number of the vehicle.
- Priority level: Indicates whether High or Low priority, or Probe frequency is requested by the vehicle.
- Direction: Channel A, B, C, or D; indicates the vehicle's direction of travel.
- Call duration: Indicates the total time in seconds the priority status is active.
- Final greens at end of call: Indicates which phases are green at the end of the call.
- Duration of the final greens: Indicates the total time final greens were active at the end of call.
- Time and date call started and ended: Indicates the time a priority call started and ended; provided in seconds, minutes, hours, day, month, year.
- Maximum signal intensity: Indicates the strongest signal intensity measured by the phase selector during call.
- Priority output active: Indicates if the phase selector requested priority from the controller for the call.

The phase selector shall include several control timers that shall limit or modify the duration of a priority control condition, by channel, and can be programmed from an IBM PC-compatible computer. The control timers shall be as follows:

- MAX CALL TIME: Shall set the maximum time a channel is allowed to be active. It shall be settable from 60 to 65,535 seconds in one-second increments.

421.02 Phase Selector

- CALL HOLD TIME: Shall set the time a call is held on a channel after the priority signal is no longer being received. It shall be settable from one to 255 seconds in one-second increments. Its factory default must be six seconds.
- CALL DELAY TIME: Shall set the time a call must be recognized before the phase selector activates the corresponding output. It shall be settable from zero to 255 seconds in one-second increments. Its factory default must be zero seconds.

The phase selector's default values shall be re-settable by the operator using an IBM PC-compatible computer, or manually using switches located on its front.

The phase selector shall be capable of three levels of discrimination of data-encoded infrared signals, as follows:

- Verification of the presence of the base infrared signal of either High priority, Low priority or Probe frequency.
- Validation of the infrared signal data-encoded pulses.
- Determination of when the vehicle is within the prescribed range.

The phase selector's card edge connector shall include primary infrared detector inputs and power outputs. Two additional detector inputs per channel shall be provided on a front panel connector.

The phase selector shall include one opto-isolated NPN output per channel that provides the following electrical signal to the appropriate pin on the card edge connector:

- 6.25Hz \pm 0.1Hz 50% on/duty square wave in response to a Low priority call.
- A steady ON in response to a High priority call.

The phase selector shall accommodate three methods for setting intensity thresholds (emitter range) for high and low priority signals:

- Using a data-encoded emitter with range-setting capability.
- Using any encoded emitter by manipulating the front panel switches.
- Inputting the range requirements via the communication port.

The intensity threshold shall have 1200 set points. There shall be separate intensity thresholds for the primary detector and the auxiliary detectors.

The phase selector shall have a POWER ON LED indicator that flashes to indicate unit diagnostic mode and illuminates steadily to indicate proper operation. The phase selector shall have internal diagnostics to test for proper operation. If a fault is detected, the phase selector shall use the front panel LED indicators to display fault information. The phase selector shall have a High and Low LED indicator for each channel to display active calls. It shall have the capability of functionally testing connected detector circuits and indicating via front panel LEDs non-functional detector circuits. The phase selector shall provide one isolated confirmation light control output per channel. These outputs shall be user configurable through software for a variety of confirmation light sequences.

The phase selector shall have a test switch for each channel to test proper operation of High or Low priority.

421.03 Infrared Detectors

The phase selector shall properly identify a High priority call with the presence of 10 Low priority data-encoded emitter signals being received simultaneously on the same channel.

The phase selector shall have write-on pads to allow identification of the phase and channel. It shall have the capability to enter unique names for each channel via the interface software.

The NEMA model of the phase selector shall have outputs for the control of NEMA controllers that lack internal preemption capability. This function shall be accomplished through the use of Manual Control Enable, Interval Advance, and Phase Omit options. The NEMA model shall also have the option of providing separate outputs for High and Low priority calls for controllers that do not recognize a 6.25Hz pulsed Low priority request. The NEMA model of the phase selector shall have the capability to set Interval Advance rates as low as once every 200 mSec for Low priority calls. It shall also be able to operate in the Manual Control Enable Mode for Low priority calls and activate a standard preemption output for High priority calls.

The phase selector shall have the capability of recording the presence of a vehicle transmitting at the specified Probe frequency. It shall at no time attempt to modify the intersection operation in response to the Probe frequency.

The phase selector shall have the capability of providing Low priority in a mode where the output to the controller is gated or controlled by timing relationships within the controller cycle.

The phase selector shall have the capability to assign a relative priority to a call request within High or Low priority. This assignment shall be based on the received vehicle class. It shall have the capability to discriminate between individual ID codes, and allow or deny a call output to the controller based on this information. It shall also have the capability to log call requests by unauthorized vehicles.

The phase selector shall have the ability to command an emitter to relay a received code to the next intersection.

The phase selector shall incorporate a precision real time clock synchronized to an AC power line frequency. The clock shall have the capability to automatically adjust itself for changes in daylight saving time. Interface software shall be used to set the clock and to input the appropriate dates and times for daylight saving changes.

The phase selector shall have the capability to set the minimum time between Low priority calls.

An auxiliary interface panel shall be available to facilitate interconnections between the phase selector and traffic cabinet wiring.

421.03 INFRARED DETECTORS

The infrared detectors shall be suitable for mounting on span wire or mast arm and be installed at the locations shown on Plans. The detectors shall be fully compatible with the phase selector. The detectors shall transform the optical energy detected from an approaching, vehicle-mounted emitter to an electrical signal. The electrical signal is transmitted along a cable to the Phase Selector for processing.

The detectors shall be available in three configurations:

421.04 Confirmation Lamp and Beacon

- Single output channel, one detection
- Single output channel, dual detection
- Dual output channel, dual direction

The detectors shall have the following operating parameters:

- Reception Range: 200 ft. (60 m) adjustable up to 2,500 ft. (760 m)
- Electrical: 24 to 28 VDC, 50 MA minimum
- Temperature Range: -30° F (-34° C) to 165° F (74° C)
- Humidity: 5% to 95% relative

421.04 CONFIRMATION LAMP AND BEACON

A. Confirmation Lamp

Confirmation Lamps shall be mounted at locations shown on Plans. The lamps shall meet the follow minimum requirements:

- UL listed, rated for continuous outdoor use in wet conditions.
- 120-140 VAC, 75w minimum, long life halogen PAR38 lamp
- Minimum beam candlepower: 3,000
- Beam angle: 30 degree

B. Confirmation Beacons

Confirmation beacons shall be mounted at locations shown on Plans. The beacons shall meet the follow minimum requirements:

- UL 1638 certified rotating warning beacon, designed and rated for continuous outdoor use in wet conditions.
- Minimum dimension: 5" W x 6" H
- Maximum weight: 2 lbs
- 120VAC, 0.25A, 25w maximum, long life halogen lamp
- Minimum beam candlepower: 6,500
- Dome color: Red
- O-ring gasket between dome and base provides water-resistant seal
- Heavy duty, sealed gear motor rated for continuous operation
- Beacon flash rate: 60 to 100 fpm

421.05 INTERFACE SOFTWARE

The priority control interface software shall be provided to interface with the phase selector. It must run on any IBM-compatible computers equipped with at least Windows® 2000 operating system or higher.

The priority control interface software must accommodate:

- Setting up and presenting user-determined system parameters.
- Viewing and changing settings.
- Viewing activity screens.
- Displaying and/or downloading records of previous activity showing class, code, priority, direction, call duration, final greens at end of call, duration of final greens, time call ended in real time plus maximum signal intensity (vehicle location information).
- Operation via a mouse or via the keyboard, or in combination.

The priority control interface software shall provide menu displays to enable:

- Setting of valid vehicle ID and class codes.
- Establishing signal intensity thresholds (detection ranges), modem initialization, intersection name and timing parameters.
- Setting of desired green signal indications during priority control operation and upload and download capability to view.
- Resetting and/or retrieving logged data and priority vehicle activity.
- Addressing for each card in a multi-drop connected system.
- Confirmation light configuration.
- NEMA Control Parameters.

The interface software shall provide readout of noise levels detected by the detectors. This noise level shall serve as a troubleshooting tool.

The interface software shall provide a real-time activity screen which shall provide the following information:

- Call intensity value even if below threshold.
- Vehicle class and ID.
- Emitter priority level.
- Indication of detection on primary or auxiliary detector
- Indication if call is being serviced or is pending.
- Indication if vehicle is in range.
- Readout for four separate vehicles per channel.
- Detector noise level readout.
- Green phase monitoring with information on the current greens.

421.06 GPS SYSTEM (OPTIONAL)

If requested on Plans or Bid Documents, the Contractor shall furnish and install the priority control system with GPS system. The GPS system shall include a GPS Radio Unit containing a

GPS receiver with antenna and a 2.4 GHz spread spectrum transceiver with antenna. The radio unit is connected to the Multimode Phase Selector via an 11-conductor radio/GPS cable. The GPS system shall also include the corresponding GPS card rack. This option shall include any other required hardware and software to make a complete priority control system with GPS system.

421.07 RELIABILITY

All equipment supplied as part of the infrared priority control system intended for use in the controller cabinet shall meet the following electrical and environmental specifications spelled out in the NEMA Standards Publication TS2 2003, Part 2:

- Line voltage variations per NEMA TS2 2003, Paragraph 2.1.2.
- Power source frequency per NEMA TS2 2003, Paragraph 2.1.3.
- Power source noise transients per NEMA TS2 2003, Paragraph 2.1.6.1.
- Temperature range per NEMA TS2 2003, Paragraph 2.1.5.1.
- Humidity per NEMA TS2 2003, Paragraph 2.1.5.2.
- Shock per NEMA TS2 2003, Paragraph 2.1.9.
- Vibration per NEMA TS2 2003, Paragraph 2.1.10.

Each piece of equipment supplied as part of the priority control system intended for use in or on priority vehicles shall operate properly across the entire spectrum of combinations of environmental conditions (temperature range, relative humidity, vehicle battery voltage) per the individual component specifications.

421.08 QUALIFICATIONS

The manufacturer of the required infrared priority control system shall verify the proven, safe operation of the system's infrared communication technology. Upon request, the manufacturer shall produce a list of user agencies having experience interfacing priority control equipment with electromechanical, solid state and programmable controller types.

421.09 WARRANTY

The Priority Control System shall be replaced or repaired by the manufacturer if its component fails to function as intended due to workmanship or material defects within the first 60 months from the date of being put into field operation at no cost (including shipping) to the City.

421.10 DOCUMENTATION

One copy of the interface software shall be provided to the City. One electronic copy of the system's Operations and Maintenance Manuals shall be provided to the City. The Contractor shall provide to the City the following information for each new item furnished by the Contractor.

- Manufacturer's name, model number, and serial number
- Length of warranty and start date

421.11 TESTING

A. Initial Testing By Contractor

Each piece of equipment that is required to provide the fully functioning priority control system as called for on the Plans shall be tested prior to shipment to the project and installed in the field.

B. Testing Performed by the City Prior to Activation

The following items will be checked by the City of Memphis prior to activation:

- All appropriate equipment has been installed per this specification and the Plans.
- Detectors, confirmation lamps, and beacons located per the Plans.
- Detectors are aligned properly both horizontally and vertically.

C. Testing Performed by the City at Activation

The following items will be checked by the City of Memphis at the time of activation:

- Wires entering the cabinet are labeled with the associated direction and phase.
- Proper communication is established with each detector.
- Proper phase is activated when a priority control call is received.
- Proper Hi/Lo is displayed based on type of call received.
- Confirmation lamps are operational for each specified direction.
- Beacons work properly on all priority control calls.

The Contractor shall be responsible for field fine tuning the priority control system within 2 weeks of final acceptance of the project, if requested by the City of Memphis. This field fine tuning shall include modifying system settings and/or identifying potential issues with equipment and replacing the equipment if it is determined to be malfunctioning.

421.12 MEASUREMENT AND PAYMENT

Accepted priority control system shall be measured as one system for a signalized intersection, complete furnished and installed, per each. Alternatively, each priority control system component can be measured separately if called for on the plan or the quantity sheet, complete furnished and installed, per each.

If measured by each signalized intersection, payment at the contract unit price, per each, shall be made for each accepted priority control system. This shall be payment in full for furnishing and installing the infrared detectors, phase selectors, confirmation lamps, pole-mounted beacons, card racks, power supply unit, and all other cabling, connections, hardware and software as required to render a fully functional priority control system. Field fine-tuning of the system is included in this item. Removal of existing emergency vehicle preemption system is included in this item.

Alternatively, if each priority control system component is measured separately as called for on the plan or the quantity sheet, the payment shall be made at the contract unit price, per each, for each accepted priority control system component such as detectors, phase selectors,

421.12 Measurement and Payment

confirmation lamps, pole-mounted beacons, and card racks with power supply unit. The price for each component shall include all cabling, connections, installation, configuration, testing, field tuning and other required hardware and software to make the component fully functional.

Item Number	Description	Pay Unit
02890-421.01	Priority Control System	EACH
02890-421.02	Priority Control System (with GPS System)	EACH
02890-421.11	EVP Infrared Detector (Single Channel)	EACH
02890-421.12	EVP Infrared Detector (Single Channel Dual Direction)	EACH
02890-421.13	EVP Infrared Detector (Dual Channel)	EACH
02890-421.14	EVP Phase Selector (2 Channel)	EACH
02890-421.15	EVP Phase Selector (4 Channel)	EACH
02890-421.16	EVP Card Rack	EACH
02890-421.21	EVP Confirmation Beacon	EACH
02890-421.22	EVP Confirmation Lamp	EACH
02890-421.31	EVP GPS Radio Unit	EACH
02890-421.32	EVP GPS Card Rack	EACH

SECTION 431 – RADAR DETECTION SYSTEM

431.01 GENERAL

This section specifies the minimum requirements for Radar Detection Systems (RDS). The RDS provides roadway monitoring capabilities via microwave radar detectors transmitting data over Ethernet network equipment specified in these specifications. The data provided includes, but is not limited to, lane occupancy, speeds, classification, and volume.

431.02 MATERIALS

A. Microwave Transmission

The microwave radar detector shall transmit on a frequency band of 24.125 GHz \pm 25 MHz or another approved spectral band. It shall comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC rules or the appropriate Spectrum Management Authority. The RDS shall not interfere with any known equipment. Transmitter power shall not exceed 5 watts.

B. Area of Coverage

The field of view of the RDS shall cover an area defined by a beam its maximum detection range shall be as follows:

- Elevation Beam Width: 40 degrees or more
- Azimuth Beam Width: 10 degrees or less
- Detection Range: 6 to 250 feet

C. Detection Zones

The minimum number of detection zones defined shall be no less than eight lanes simultaneously.

For six foot setback configurations, the minimum number of detection zones defined shall be no less than four lanes simultaneously.

D. Capabilities

The RDS shall be a true presence detector. It shall be suitable for mounting on roadside poles or on overhead structures and provide the following:

- Presence indication of moving or stopped vehicles in either direction in its detection zones, provided by contact closure to existing controllers.
- Traffic data, periodically accumulated over user defined time intervals in a 30 to 900 sec range, shall be transmitted via 10/100 Base-T Ethernet over IP communications lines to an Ethernet switch at a controller location or Ethernet terminal server as shown in the Plans.
- Traffic data shall be available simultaneously with detection zone contact closures and IP communications.
- Side-fired configuration data shall include the following in each of up to eight (8) detection zones (lanes):

- Volume
- Lane occupancy
- Average speed
- Vehicle classification by length in a minimum of 3 user defined classes.
- RDS in forward-looking configuration shall monitor traffic in one lane and be capable of providing the following data:
 - Volume, occupancy, average speed and travel direction in the lane
 - Per vehicle speed and direction
 - Binning of Volume data in up to 7 speed bins
- RDS shall allow the user to define the contents of transmitted data.
- RDS shall provide Fail-Safe indication by a contact pair over IP communications.
- Minimum 8 Mb of internal data storage capacity
- The RDS unit shall have an integrated TCP/IP Ethernet communication interface
- The RDS unit shall support the latest NTCIP 1209 protocol.
- Furnish the unit with the required software for data collection, processing, configuration and set-up, and data logging and retrieval. An operator shall be able to use the software to set detector count periods, sensitivities, and other operational features and parameters. The software must be capable of providing both manual and automatic setup and calibration.

E. Measurement and Accuracy

The following error levels shall be achievable and demonstrated during testing:

Parameter	Error Percentage
Presence	± 5%
Volume	± 8%
Lane Occupancy	±10%
Average Speed	± 10%
Length Classification Limits	±10%
Time Event	5 ms
Input Voltage	± 2%

F. Environmental Conditions

Except as stated otherwise herein, the equipment shall meet all its specified requirements during and after subjecting to any combination of the following:

- Ambient temperature range of -37°C to +74° C
- Relative humidity from 5 to 95 percent, non-condensing
- Winds up to 100 mph (sustained) with a 30% gust factor
- NEMA TS2 or approved equivalent for vibration and shock resistance

G. Mechanical

- The microwave radar detector shall be enclosed in a rugged weatherproof box and sealed to protect the unit from wind up to 100 mph, dust and airborne particles, and exposure to moisture (NEMA Type 3R or 4X enclosure; IP-65).
- Max. weight of the microwave radar detector assembly: 7 pounds
- The mounting assembly shall have all coated steel, stainless steel, or aluminum construction, and shall support a load of 20 pounds or more. The mounting assembly shall incorporate a ball-joint, or other approved mechanism that can be tilted in both axes and then locked into place, to provide the optimum area of coverage.

H. Electrical

- The RDS unit shall be operable from 12 - 24 VDC.
- If specified on Plans, the RDS unit shall be powered by a Power Over Ethernet (POE) injector and power supply unit that comply with the specifications in **Section 302**.
- The RDS unit shall include Power Management features, allowing remote shutdown or cyclical shutdown of the unit.
- The RDS unit shall include a Low-Voltage disconnect feature for battery protection.

I. Electrical Isolation and Surge Protection

All power lines, contact closures, serial and Ethernet ports shall be surge protected within the unit. Contact closures and the serial and Ethernet ports shall be isolated.

J. Data Interface

Data interface shall be available on standard Ethernet port (10/100 Base-T) and Bluetooth for setup, calibration, video, and data access.

K. HD Camera (Optional)

If specified on Plans, the RDS unit shall be equipped with HD Camera which provides the user with visual setup configuration, data capture, and verification over TCP/IP connection. The HD camera shall meet the following minimum requirements:

- Provide visibility from the detector to verify the accuracy of zone setup across all lanes
- Video resolution: 800 x 600 at 10fps minimum
- Video compression: H.264
- Video snapshot: JPEG
- Streaming Format: Real Time Streaming Protocol (RTSP)

431.03 Warranty

- Adjustment of Video: Brightness, contrast, saturation, sharpness and image quality via web browser
- System Interface: 10/100 Base-T Ethernet port
- Security: Password protected user interface

431.03 WARRANTY

RDS unit shall be replaced or repaired by the manufacturer if it fails to function as intended due to workmanship or material defects within the first 24 months from the date of being put into field operation at no cost (including shipping) to the City.

431.04 DOCUMENTATION

One electronic copy of the RDS Operations and Maintenance Manuals shall be provided to the City. The Contractor shall provide to the City the following information for each new RDS unit furnished by the Contractor.

- Manufacturer's name, model number, and serial number
- Length of warranty and start date
- MAC address of the Ethernet network interface

431.05 INSTALLATION

The RDS shall be mounted in side-fired configuration on poles as shown in the Plans, using mounting brackets. The brackets shall be attached with approved ¾-inch wide stainless steel bands. Unless otherwise noted, RDS shall be mounted on new aluminum poles.

The Contractor shall install the detector unit on a pole at the manufacturer's recommended height above the road surface so that the masking of vehicles is minimized and that all detection zones are contained within the specified elevation angle as suggested by the manufacturer. Where mounting on poles adjacent to the roadway, the detector unit shall be mounted for zero-setback configuration as suggested by the manufacturer.

When installing a detector near metal structures, such as building, bridges, or sign supports, the sensor shall be mounted and aimed so that the detection zone is not under and does not pass through any structure to avoid distortion and reflection.

The Contractor shall obtain RDS Configuration Guidelines and the assigned IP address from the City. The Contractor shall install the assigned IP address and configure the device in accordance with these guidelines. Integrate with the existing or proposed Ethernet devices in the cabinet as required. Perform all coordination, setup, and configuration to integrate the RDS with the City's traffic network.

If the RDS unit requires field calibration of the unit for accurate speed detection, the contractor is responsible for calibrating the unit in accordance with manufacturer's recommendations.

431.06 TESTING

The Contractor shall test each conductor and each shield in each cable for continuity and insulation resistance. All RDS communications cables shall be tested from termination point to termination point. Complete all RDS Cable tests for all cables prior to implementing any RDS communications or power service.

With the presence of the City traffic signal maintenance staff and the project inspectors, the Contractor shall demonstrate the following:

- RDS can detect vehicle data in accordance with the accuracy defined in **Section 431.02.E**.
- Ability to communicate successfully and reliably with the RDS management interface using the RDS software from the cabinet edge switch, the hub switch, and the TMC workstation.
- All configuration parameters are in accordance with the City's Configuration Guidelines.

431.07 MEASUREMENT AND PAYMENT

The RDS shall be measured in units of each and paid for at the contract price per each. The price bid shall include furnishing, installing, system integration, and testing of a complete RDS including the unit, the RDS harness cabling, power service connection, interconnection wiring to the Ethernet switch or terminal server port, mounting to support structures, and any other work, equipment, and appurtenances as required to effect the full operation including remote and local control of the RDS site complete in place and ready for use. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

Item Number	Description	Pay Unit
02890-431.01	Radar Detection System (24VDC)	EACH
02890-431.02	Radar Detection System (POE)	EACH
02890-431.03	Radar Detection System (24VDC, Camera)	EACH
02890-431.04	Radar Detection System (POE, Camera)	EACH

SECTION 441 – BLUETOOTH™ DETECTION SYSTEM

441.01 GENERAL

This section details furnishing and installing Bluetooth technology based roadside sensor units (receivers) that collect real-time travel time data. The Bluetooth receiver shall be capable of monitoring and measuring vehicular and pedestrian movement by identifying and comparing Media Access Control (MAC) addresses associated with Bluetooth-enabled electronic devices, both discoverable and non-discoverable. The MAC address received by a sequence of two or more Bluetooth receivers shall be matched and used to develop a sample of travel time for that particular segment of the roadway, based on the relative detection times recorded by the adjacent units.

The Bluetooth sensor working in conjunction with the network's "backend" support data processing system must deliver real-time speed and travel time information for the road(s) where the sensors are deployed. The system shall be able to add multiple pairs of Bluetooth sensors to form a network of manageable travel routes. Each route will display the data for the first and last sensor in addition to the travel-time and speed information for that segment. Sensors can be installed as close as a half (1/2) mile apart without special antenna configuration. The Bluetooth sensor shall be able to detect, at a minimum, within a radius of 600 feet. The detection range shall be configurable by adjusting the transmit power of the Bluetooth radio using settings entered using configuration entered over the air.

To enhance the detection performance for target devices with weaker Bluetooth radios or target devices, which may be attenuated (obstructed) by other cars or structures, the Bluetooth receiver sensitivity shall be at least -90 dbm and transmit power at a maximum +20dbm using a standard antenna. The Bluetooth radio shall implement a Receiver Signal Strength Indicator (RSSI) metric for every detected MAC address, to allow use of distance indication data of detected target devices from Bluetooth sensors. RSSI data shall also be used in the overall monitoring health of the Bluetooth sensor.

The Bluetooth sensor units shall be compatible with the existing Bluetooth travel-time system and server in the City of Memphis.

441.02 POWER SUPPLY OPTIONS

The Bluetooth sensor equipment shall have the following power options:

- AC Power
100/230 VAC 50 Hz to 60 Hz.
- Power Over Ethernet (POE)
A POE injector shall be supplied in accordance with specifications in **Section 302**.
- Solar powered with Battery

If a solar powered Bluetooth sensor is specified on Plans, a school flasher cabinet shall be installed in accordance with specifications in **Section 241.02.A**. The cabinet shall also include solar panels, power system and battery in accordance with specifications in **Section 241.03**.

441.03 DATA OPTIONS

The Bluetooth sensor equipment shall have the following two data options:

- Ethernet

The sensor shall be capable of delivering data from a wired Ethernet connection with POE.

- Cellular Data

If Cellular Data option is specified, the sensor shall be capable of delivering data from a GSM wireless cellular modem that supports quad-band GSM/GPRS/EDGE and tri-band UMTS/HSDPA.

441.04 HARDWARE

The Bluetooth sensor shall comprise of 3 main subsystems: Microcontroller, Communication, and Power. All 3 subsystems shall be integrated onto a common printed circuit board.

The transmit power for the Bluetooth radio shall be adjustable to allow for the detection radius to be customized based on deployment needs.

The data transmission components shall be fully integrated into the microcontroller subsystem for optimal performance, control, and power consumption.

The power subsystem shall support a supply voltage of either 12 or 24 volts. The sensor shall report the current voltage status. In addition, in the case that a battery is used, the sensor shall have a Low Voltage Disconnect (or equivalent) in order to protect the battery from “flooding”.

- Operating temperature range: -30°C to +65°C
- Bluetooth: CSR Bluecore 4 Class 1
- Data Storage: non-volatile, up to 1 year of storage
- Antennae:
 - Bluetooth: 4 dBi Omni (Standard)
 - GSM: I-Bar Penta Band Cellular Antenna
 - GPS: Active Patch 31 dBi
- NEMA 4X Enclosure
- Maximum dimension: 16 in. x 16 in. x 10 in.
- Maximum weight (with battery & mounting brackets): 50 lbs.

441.05 FUNCTIONAL REQUIREMENTS**A. Data Processing and Storage**

Data collected by the Bluetooth sensor shall be delivered to and processed at the existing City of Memphis Bluetooth Travel Time Server. The system shall provide a secure web-based user interface to enable the City to view, analyze and configure data outputs. The system shall support at least 500 real-time field sensors. The data shall be available for

viewing in real time and as post-processed report-generated analysis. Data processing shall include, travel time, flow, speed, and MAC address counts. The data processing shall also filter the following data as needed to deliver the most accurate information:

- Pedestrian
- Vehicular
- Toll-Tag (85th percentile)
- Smoothing
- Mean, Median, etc.
- 2-stage filter
- Multiple Speed

B. Operations and Maintenance

The following shall be included as a complete turnkey operations and maintenance package for the end user:

- Web-based Map with device location and information including:
 - Dynamic color-coded links based on average speeds compared to one of the following:
 - Speed limit
 - Historical average based on the last 12 similar days
 - Customer defined historical average
 - User defined thresholds pair by pair by entering a % to be compare one of the 3 above indexes or an absolute value for red, yellow and green. User also has the option of displaying orange and blue on the speed map.
 - Pop up on each link displaying link name, average speed, historical speed & speed limit will be displayed to the right of the speed map.
 - Full Screen resize option.
 - Color code refresh options of 2, 5 and 10 minutes.
 - Each time a link is selected, a 48 hour graph of that can toggle between speed and travel-time will be displayed below the speed map. In addition, if a historical average is used as an index as stated above, that historical index 48 hour graph will also be included on the graph. Both graphs will have the ability to be turned on and off by selected the title on the legend of the graph. The graph option shall also allow the user to zoom in to any section of the graph and also reset the zoom level back to normal.
- Real-time chart displaying origin, destination, time stamp, travel-time & speed and signal head speed indication. User will have the option of displaying the signal head speed indication based on comparing the actual speed to the following:
 - Speed limit
 - Historical average based on the last 12 similar days

- Customer defined historical average
- Speed map shall be able of being displayed separately via an encrypted URL that will allow the user to select a full screen option and a refresh rate of their choice. The user shall also be able to select either speed or historical values for the speed index.
- 48 hour graphs displaying the Travel-Time or Average Speed in 15 minute increments with the following options being displayed on the same graph:
 - # of matches on a bar graph
 - Raw data matches being displayed as tick marks
- Origin/Destination (O/D) reporting tool with the following outputs:
 - Pie Chart
 - Bar Chart
 - HTML
 - CSV download
- System shall be able to produce alarms with the following options:
 - Alarms based on a % below the historical average speed or absolute speed of any given pair or route.
 - Alarms based on device issues such as no MAC detects, low voltage, no heartbeat
 - User shall be able to configure multiple devices, pair or routes from a single page
 - User shall be able to select the times the alarms are active
 - User shall be able to simply add recipients to receive alarms
 - Alarm notifications shall be by email and/or SMS
 - System shall be able to delay initial alarms by either 0,5,10,15,20,25 or 30 minutes
 - System shall send continuous email and/or SMS until acknowledged. User can select the repeated alarms from 5 minutes to 120 minutes
 - System shall display an active alarm list displaying all the alarms that were setup
- Reporting tool with the following options:
 - Individual pair/route report in 5 min, 15 min or individual match form. User selects day(s) and Time of Day. The user shall also have the option of including a historical index such as the last 12 weeks or speed limit to display with the rest of the report
 - Comparison Report – ability to create a comparison report comparing any pair our route versus another pair or route. User selects day(s) and Time of Day.
 - Historical Index Report – ability to create up to 15 different index's. Each index can be a combination of days/week/months/etc, which will be represented by a single graph or data in a spreadsheet. Each index can also be any day, any combination of days or entire week. The graph output shall have the option of being saved as a JPG, PNG or PDF for future use. The graph option shall also allow the user to zoom in to any section of the graph and also reset the zoom level back to normal.
 - Travel-Time Reliability (TTR) Report – ability to report the Travel-Time Index (TTI), Planning-Time Index (PTI) and Buffer-Time Index (BTI) in a graphical format, HTML

- or CSV. TTR shall be able to be aggregated and viewed in 15 minutes, 30 minutes, multiple hours, day, week, month or quarter. Each pair or route that is selected shall also have the ability to automatically generate the reverse pair or route and in the case of a route, include all the pairs within the route.
- Number of unique MAC detects by unit based on user defined dates and times.
 - All reports shall be available in HTML, CSV or graph format.
 - XML feed for processed data
 - CSV Feed on all reports
 - Software Bug Fixes
 - Software Performance Improvements
 - Remote Firmware Updates
 - Device Replication:
 - Some or all of the reports from Bluetooth sensors reporting to a Bluetooth Stand-Alone Server (SAS) can be forwarded to another Bluetooth SAS, where they will be treated as if they were reporting directly to that server. This will allow multiple agencies to use the same Bluetooth sensor and create unique pairs with it. It is even possible for two SASs to forward sensor data reports to each other. Which sensors' reports to forward can be specified by device ID.

C. Remote Software Monitoring, Diagnostics and Reboot

The Bluetooth sensor equipment shall contain advanced features designed to allow the unit to operate efficiently in a remote environment. Diagnostic “heartbeat” information such as voltage and temperature monitoring, as well as software stability information should be periodically sent along with the MAC address data such that the health and operating status of the sensor is known. The system shall be designed to be able to automatically “reboot” if a condition is detected that requires such action. In the rare case when a total system recovery is required, the sensor shall be designed to automatically re-image the system memory.

In addition, the sensor shall have the ability to download software patches and upgrades over-the-air without the need to physically visit the unit. This remote firmware update shall be performed over the Ethernet connection or the wireless cellular air interface depending upon the configuration installed.

The Bluetooth backend system shall come with 24x7 remote real-time monitoring of each Bluetooth device, which consists of the following:

- Number of heartbeats
- Number of MACS
- Current voltage & average voltage
- Average temp
- Status bit (how many consecutive heartbeats without a reset)
- Number of resets
- GSM bit error rate

- Number of satellites
- Boot RSSI
- GSM channel & RSSI
- Last measured heartbeat timestamp
- Last measured MAC timestamp
- Last inserted heartbeat timestamp
- Last inserted MAC timestamp

Automated email alerts are to set up depending on certain values of the above criteria.

D. Dedicated Short Range Communications (Optional)

If specified on Plans, the device shall be capable of communicating with connected and autonomous vehicles via DSRC 5.9 GHz signal. The Device shall comply with the following standards:

- DSRC Roadside Unit (RSU) Specifications, Version 4.1
- IEEE 802.11p, 1609.3 (WSMP), 1609.4, 802.3at Standards
- IEEE 1609.2, Draft ETSI EN 302 571 and ETSI EN 302 636 Security Standards

441.06 INSTALLATION

Bluetooth detection unit shall be installed according to the manufacturer's requirements and recommendations. Additional installation requirements are provided below. If these additional requirements conflict with manufacturer's recommendations, the contractor shall obtain approval from the Engineer or the City for alternative installation methods.

A. Installation of the detector enclosure:

Enclosure shall be mounted with two 3/4" minimum width steel straps.

For master arm poles, mount the enclosure between the pole mounted signal display and the mast arm. If this space is not available, contact the City or the Engineer to determine an alternative mounting location.

For steel strain poles or wood poles, mount the enclosure immediately below the tether wire. If space is restricted below the tether wire, mount the enclosure immediately above the tether wire.

B. Cable installation and routing from the enclosure to the cabinet:

1. For steel strain poles or mast arm poles:

- Drill cable entrance hole into steel pole and install 3/4" seal flex conduit from the enclosure to the cable entrance hole on pole. Use liquid-tight connectors at both ends of the seal flex conduit.
- Install Ethernet cable inside the seal flex conduit from the enclosure into the steel pole.

- The cable shall enter the cabinet using an existing elbow or conduit (for pole-mounted cabinets) or through underground conduit routed from the pole base to the cabinet (for base-mounted cabinets).

2. For wood poles with an existing conduit riser with adequate space:

- Install a new 2" steel conduit riser with weather head from the detector enclosure mounting location to top of the pole.
- Install a seal flex conduit to connect the bottom of the riser and the detector enclosure. Use liquid-tight connectors at both ends of the seal flex conduit.
- Install proposed Ethernet cable from the detector enclosure to top of pole through the new 2" riser.
- Install proposed Ethernet cable from the weather head of the new riser to the existing weather head of the existing steel conduit.
- Enter cabinet using the existing steel conduit riser.

3. For wood poles with no existing riser or space for the proposed cable:

- For pole mounted cabinet, install a new 2" steel conduit riser from bottom of the pole mounted cabinet to the bottom of the detector enclosure. Install 2" elbow or conduit to enter the cabinet from bottom.
- For base-mounted cabinet, install a new 2" steel conduit riser from pole base to the bottom of the detector enclosure. Install new 2" underground conduit to enter the cabinet base.
- Install a seal flex conduit from the top of the new riser to the detector enclosure. Use liquid-tight connectors at both ends of the seal flex conduit.
- Enter cabinet using the new riser and conduit.

C. Inside the controller cabinet:

- Securely mount the POE injector on the front lip of the top shelf at the far right side of the cabinet. POE injector shall be properly grounded to the cabinet rail.
- Coil 10 feet of the entering Ethernet cable at the bottom of the cabinet.
- Plug in the POE injector power adaptor to an empty outlet. If there is only one empty outlet in the cabinet before the installation, the contractor is responsible for adding one new duplex outlet in the cabinet.

D. Configuration:

The Contractor shall obtain an IP address from the City for each Bluetooth detection unit installed. The Contractor shall configure the unit according to manufacturer's recommendations and fully integrate the unit with the City's existing Bluetooth Travel Time Server located at the City Hall.

441.07 TESTING

With the presence of the City traffic signal maintenance staff and the project inspectors, the Contractor shall demonstrate the following:

- Ability to communicate successfully and reliably with the switch's management interface via HTTP protocol from the cabinet edge switch, the hub switch, and the TMC workstation.
- All configuration parameters are in accordance with the City's Configuration Guidelines.
- Ability to communicate successfully and reliably with all attached Ethernet devices using respective central software from the cabinet edge switch, the hub switch, and the TMC workstation.

441.08 DOCUMENTATION

One electronic copy of the Bluetooth detection system's Operations and Maintenance Manuals shall be provided to the City. The Contractor shall provide to the City the following information for each new switch furnished by the Contractor.

- Manufacturer's name, model number, and serial number
- Length of warranty and start date
- MAC address of the Ethernet network interface

441.09 MEASUREMENT AND PAYMENT

Six types of Bluetooth Detection Systems may be requested by the City:

- **POE Power and Data:**
Bluetooth unit (DSRC RSU type or Regular type) with POE injector for power, no cellular modem.
- **POE Power, Cellular Data:**
Bluetooth unit (DSRC RSU type or Regular type) with POE injector for power, with cellular modem for Data, and cellular services fee for number of months specified in Bid Document.
- **Solar Power, Cellular Data**
Bluetooth unit (DSRC RSU type or Regular type) with solar panel and battery for power, cellular modem for data, and cellular services fee for number of months specified in Bid Document.

Payment at the contract unit price, per each, shall be made for each furnished, installed, and accepted Bluetooth detection system of the type specified. Each such item shall include furnishing and installing the sensor, enclosure, POE injector, solar panel and battery, its integration into the field cabinet, its grounding and electrical isolation, its configuration and setup, its addressing, documentation and integration with the existing Bluetooth server, all mounting accessories, all cabling necessary for communications and power, connectors, all mounting brackets, mounting hardware, power cords, delivery of all required software, factory certification, and testing.

Section 441 – Bluetooth™ Detection System

441.09 Measurement and Payment

Item Number	Description	Pay Unit
02890-441.01	Bluetooth Detection System (AC Power, Ethernet)	EACH
02890-441.02	Bluetooth Detection System (AC Power, Cellular Data, Cellular Service __ Months)	EACH
02890-441.03	Bluetooth Detection System (POE Power, Ethernet)	EACH
02890-441.04	Bluetooth Detection System (POE Power, Cellular Data, Cellular Service __ Months)	EACH
02890-441.05	Bluetooth Detection System (Solar Power, Ethernet)	EACH
02890-441.06	Bluetooth Detection System (Solar Power, Cellular Data, Cellular Service __ Months)	EACH
02890-441.07	Bluetooth Detection System (DSRC RSU, AC Power, Ethernet)	EACH
02890-441.08	Bluetooth Detection System (DSRC RSU, AC Power, Cellular Data, Cellular Service __ Months)	EACH
02890-441.09	Bluetooth Detection System (DSRC RSU, POE Power, Ethernet)	EACH
02890-441.10	Bluetooth Detection System (DSRC RSU, POE Power, Cellular Data, Cellular Service __ Months)	EACH
02890-441.11	Bluetooth Detection System (DSRC RSU, Solar Power, Ethernet)	EACH
02890-441.12	Bluetooth Detection System (DSRC RSU, Solar Power, Cellular Data, Cellular Service __ Months)	EACH

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SECTION 501 – SIGNAL HEADS

501.01 GENERAL

Vehicle and pedestrian signals complete with mounting devices as shown on the Plans and Design Standards shall be provided by the Contractor. Each signal face shall consist of one or more signal sections, each containing an optical unit, lens, main housing, door and visor designed and constructed so as to fit rigidly and securely together, one above the other to present a clean appearance and provide a weather-tight enclosure for the optical and electrical equipment. These signal heads shall meet the requirements of the latest Institute of Transportation Engineers Standards for "*Adjustable Face Vehicle Traffic Control Signal Heads*" and "*Adjustable Face Pedestrian Signal Head*", the National Electrical Code and Manual on Uniform Traffic Control Devices where applicable. Each signal head assembly shall be supplied complete with a traffic signal illuminating device of the required size and ready for operation with the connection of field wiring and installation of an incandescent traffic signal lamp bulb or LED optical system. Each signal head assembly shall be 100% compatible with Eagle SA polycarbonate style signal head. Unless otherwise called for on the Plans or approved by the City, a LED optical system shall be used instead of incandescent optical system.

501.02 MATERIALS

The housing and door of each signal section shall be fabricated from corrosion resistant U.V. stabilized Polycarbonate resin material (G. E. Lexan 103R or equal). The moldings shall be a minimum of 0.090 inches thick and be ribbed for additional strength at points of high stress. Additional thickness shall be provided as necessary to eliminate light transmission through the housing, door, visor, or backplate.

Visors and backplates shall be fabricated from corrosion resistant U.V. stabilized Polycarbonate resin material. Visors shall have a 0.100 inch minimum thickness. Backplates shall have a 0.125 inch minimum thickness.

Side of pole signal mounting brackets and shims shall be fabricated from glass impregnated polycarbonate material (G. E. Lexan 500 or equal).

Materials used for the lens and LED module construction shall conform to ASTM specifications where applicable. Enclosures containing the power supply and electronic components of the LED module shall be made of UL94VO flame retardant materials. The lens of the LED module is excluded from this requirement.

501.03 HOUSING

The housing of each section shall be a one-piece, corrosion resistant, Polycarbonate resin molding with integral sides, top, and bottom and free of voids, cracks, inclusions, or blow holes. Each vehicle signal shall be furnished with provisions for mounting of a backplate. The top and bottom of the housing shall have an opening 2 inches in diameter to accommodate standard 1-1/2 inch pipe, with no other opening in the top or bottom of the housing.

Each housing shall be fitted with four (4) threaded brass inserts to accept the vehicle signal and pedestrian signal door fastening hardware. Individual signal sections shall be fastened together, one above the other into a complete signal face, by means of plated nuts, bolts, and washers in such a manner that any section may be rotated about a vertical axis and positioned at an angle

with respect to an adjacent section. The opening hub shall have 72 circumferential serrations to secure each section in its orientation, adjustable in 5 degree increments, and prevent its inadvertent rotation.

A six position labeled barrier terminal block shall be provided in each signal face for the purpose of field connections. The barrier terminal shall be installed in the circular yellow or yellow arrow section of each signal face. If the face has neither of these sections, the terminal block shall be installed in the uppermost section of the head.

There shall be provisions for the attachment of a 1/4 inch tether line to the bottom of each span wire mounted signal head as shown in the Design Standards. The tether attachment shall be so constructed that it shall provide a minimum of one inch clearance behind the back plate to allow the tether to be attached to the signal head at any angle without interfering with the back plate. The tether attachment shall be attached to the signal head with a three bolt aluminum breakaway tether assembly.

A pinnacle shall be provided to close all 2 inch openings in each housing which shall not otherwise be sealed from the weather when installed with the specified mounting hardware. The door and housing assembly shall be constructed in such a manner as to allow "left" or "right" hinge openings with the door held securely in place in the opened position.

501.04 DOOR

The housing door of each signal section shall be a one-piece, corrosion resistant polycarbonate resin molding free of voids, cracks, inclusions, or blow holes. The outer face of the vehicle signal door shall have four holes equally spaced about the circumference of the lens opening to accommodate the secure mounting of the signal head tunnel visor.

The pedestrian signal door shall be a deep base housing, gasketed to provide a dust free unit. The outer face of the pedestrian signal door shall have six (6) holes, two each on the top and sides.

The visor shall fit flush against the door and no light shall leak between the door and the visor. Two stainless steel hinge pins shall attach the door to the housing, one in the upper left corner and one in the lower left corner of the door. Two stainless steel wing screws, one in the upper right corner and one in the lower right corner of the door, shall be used for opening the door and closing it tight against the housing. The wing screws shall be installed through the door with keepers to prevent their accidental removal or falling out. The removal of the hinge pins and the operation of the wing screws shall not require the use of tools.

The door shall be designed to allow proper visor and lens mounting of either "right" or "left" hinge opening.

501.05 LED OPTICAL SYSTEM

The LED optical system shall consist of an LED traffic signal module for each display. This specification refers to the minimum performance requirements defined in "Vehicle Traffic Control Signal Heads" published in the Equipment and Materials Standards of the Institute of Transportation Engineers, referred to in this document as "ITE VTCSH". This specification refers to the minimum performance requirements defined in "Pedestrian Traffic Control Signal

Indicators” published in the Equipment and Materials Standards of the Institute of Transportation Engineers, referred to in this document as "ITE PTCSI".

The multiple LED light source should be the latest technology available on the market. The LEDs utilized shall be AlInGaP technology for red, Portland Orange, and yellow indications, or InGaN technology for green or white indications. LEDs shall be the ultra bright type rated for 100,000 hours of continuous operation from -40C to +74C.

All LED Ball Signal Modules shall be 12 inch (300mm) and fully compliant to the ITE VTCSH LED Circular Supplement specifications dated and adopted June 27, 2005, or the latest adopted version as listed on the ITE website at time of bid.

All LED Arrow Signal Modules shall be 12 inch (300 mm) and fully compliant to the “Omni-directional” specifications of the ITE VTCSH LED Vehicle Arrow Traffic Signal Supplement adopted July 1, 2007, or the latest adopted version as listed on the ITE website at time of bid.

All LED Countdown Pedestrian Signal Modules shall be 16 inch by 18 inch. The icon configurations shall be the overlaying “walking person” and “upraised hand” icons on the left side, and the clearance time count-down display on the right side. The pedestrian signal modules shall be fully compliant to the ITE PTCSI Part-2: LED Pedestrian Traffic Signal Modules specifications adopted August 4, 2010 or the latest adopted version as listed on the ITE website at time of bid.

Additionally, prior to bid award, the manufacturer shall submit to the City, reports from ETL/Intertek, that certify full compliance of all LED signal modules to the entire ITE specification. Evidence of full compliance to all required testing methods, procedures and sections must be included without any exceptions, changes or omissions. The manufacturer must also submit a data sheet showing the exact catalog number of the items submitted on the bid and the Independent Lab report must show full qualification of the submitted catalog number.

A. Warranty

LED modules shall be replaced or repaired by the manufacturer if an LED module fails to function as intended due to workmanship or material defects within the first 60 months from the date of being put into field operation at no cost (including shipping) to the City. LED modules which exhibit luminous intensities less than the minimum values specified in the ITE specifications within the first 60 months of the date of being put into field operation, shall be replaced or repaired, at no cost (including shipping) to the City.

Alternatively, if a 15-year warranty is requested by the City in the Contract Document, LED modules shall be replaced or repaired by the manufacturer if an LED module fails to function as intended due to workmanship or material defects within 15 years from the date of being put into field operation at no cost (including shipping) to the City. LED modules which exhibit luminous intensities less than the minimum values specified in the ITE specifications within 15 years from the date of being put into field operation, shall be replaced or repaired, at no cost (including shipping) to the City.

501.06 VISORS

Each signal door shall be fitted with a corrosion resistant Polycarbonate resin tunnel visor. Twelve inch signals shall have visors a minimum of 9-1/2 inches long. The visor shall be flat black inside and outside. The visors shall be securely attached to the door at four locations

501.07 Backplates

equally spaced about the circumference of the lens opening with four plated screws. The visor shall fit flush against the door, and no light shall leak between the door and the visor. The visor shall be preformed into a fixed cylindrical shape of the proper diameter to be installed around the lens.

501.07 BACKPLATES

Each signal head assembly, so required by the Plans, shall be equipped with an aluminum louvered back plate with a minimum width of five (5) inches with rounded corners. Stainless steel screws shall be provided for mounting to the signal housing. The back plate shall consist of one piece fabricated from corrosion resistant, flat polycarbonate resin material colored flat black on the front and back.

501.08 PROGRAMMABLE VISIBILITY SIGNAL HEAD

If called for on Plans, Programmable Visibility (PV) signal head shall be installed to limit signal visibility to specific target areas and to avoid motorist confusion when two intersections are in close proximity. The PV signal head shall be modular in design and be assembled in configurations on Plans.

In addition to the requirements described in this section for regular signal heads, the signal sections of the PV signals shall have the capability of being tilted in two-degree increments for a minimum of ten degrees above and below the horizontal axis while still maintaining a common vertical axis. The PV signal shall use a Fresnel lens and a smaller 5" clear lens, and include a masking kit to mask-off portions of the smaller lens to program visibility. Acrylic lenses shall be colored to ITE specifications.

The PV signals shall use 5" LED lamp modules. The LED lamp module shall be capable of direct retrofit replacement for incandescent lamps used in existing PV signals. The LED lamp module shall be compatible with McCain and 3M PV signal heads.

The Contractor is responsible for adjusting the visibility of the PV signal heads to the satisfaction of the Engineer.

501.09 MOUNTING HARDWARE**A. Spanwire**

Spanwire suspension fitting with cable entrance shall be a one-piece malleable iron casting, minimum wall thickness 3/16 inch, and free of flash and voids. The cable entrance shall have a rubber bushing with a minimum inside diameter of 1 1/4 inches. The suspension fitting shall provide six separate clevis pin positions for balancing the signal assembly. The thickness of the solid casting in this suspension area shall be a minimum of 5/8 inch. A hex head threaded malleable iron lock nipple shall be provided for attaching the signal head to the bottom of the suspension fitting for one-face signals or to the top bracket of multi-face signal brackets.

The mounting hardware for each signal face shall include a metal, serrated, 72 tooth lock ring with full locking pins and a circular neoprene gasket, and stainless steel washer for weather sealing.

501.09 Mounting Hardware

All openings in signal heads, top or bottom, which are not otherwise utilized for signal mounting, shall be closed with a hex ornamental pinnacle assembly complete with circular neoprene gasket and malleable hex lock nut. Conduit lock washers are not permitted.

Span wire suspension clamp assembly shall consist of a galvanized, malleable iron span wire clevis saddle, 5/8 inch diameter plated steel clevis pin with cotter key, two - 1/2 inch plated steel "U" bolts with nuts and washers (no "J" bolts are permitted), and a galvanized malleable iron cable locking bar, all fitted for 5/16" guy span. Galvanizing shall be in conformance with ASTM A-153-61.

All span mounted signals shall include one metal reinforcement plate mounted (bolted) to the inside top of the top section of the signal head.

Brackets, where required, shall consist of a malleable iron center outlet body, schedule 40 pipe, elbows, serrated fittings, and other hardware as required to provide a multi-face signal head assembly with internal wiring raceways to each face as specified.

The spanwire bottom bracket, where required, shall consist of 2 5/8" x 1/8" steel brace with an aluminum break-away tether assembly described in **Subsection 611**.

For span wire terminal compartment and hardware for 5 section cluster all hardware specified earlier in this subsection that called for malleable cast iron shall be cast aluminum. The terminal compartment shall be 4-way, cast aluminum, and have a 12 circuit terminal block installed inside. Compartment shall have a plastic door with gasket to provide water proofing. Hardware to provide for a red center mount cluster, Pelco SP-5445 or equal. Back plate shall be louvered and fabricated from 0.125", corrosion resistant UV stabilized ABS plastic, and shall have black color impregnated throughout the material. Back plate shall be Pelco BK-5021 or equal.

B. Pole

The polycarbonate side of pole bracket, where required, shall be one-piece molding with internal wiring raceway for banding or lag screw attachment to steel or wood poles. Brackets shall be designed to withstand 100 mph wind loading on the bracket and the signal head. Each bracket shall have an integrally molded 72 tooth serrated ring for signal head positioning and come complete with 1-1/2 inch nipple, hex lock nut, pinnacle cap, neoprene washer, and two interlocking shims for plumbing signals (Eagle PDM 405 or equal).

C. Mast arm

Signal displays shall be mounted to the mast arms using an astro-brac assembly with a 1 1/2" gusseted aluminum tube. The tube shall have a vinyl insert to conceal the wiring that will allow wire to enter the gusseted tube at any point and be routed from the mast arm to the signal display. The assembly can be mounted to the mast arm using either a cable or band mount (PELCO AB-0116, AB-0125, or equal).

D. Post

The slip fitter collar, where required, shall be malleable iron, including one vertical 1-1/2 inch nipple with hex lock nut, two 1-1/2 inch threaded horizontal entrances; and three set screws for attachment to the post. All horizontal entrances not used for attaching signal brackets shall be closed with pinnacle cap and neoprene washer (Eagle # BK02 or equal).

501.10 COLOR, FINISH, AND PAINTING

Polycarbonate resin hardware shall have color impregnated throughout the material. The finish shall be smooth and unflawed. Signal head parts shall be colored as follows:

- Vehicle Head:
 - Housing - Federal Yellow
 - Door - Flat Black
 - Tunnel Visor - Flat Black inside and out
 - Backplate - Flat Black front and back
 - Pole Bracket - Federal Yellow
- Pedestrian Head:
 - Housing - Federal Yellow
 - Door - Black
 - Tunnel Visor - Flat Black inside and out
 - Pole Bracket - Federal Yellow

All metal hardware, except those specified as galvanized, plated, or stainless steel shall be painted Federal Yellow. The metal parts shall be painted with a primer coat and a finish coat of oven baked enamel meeting the requirements of **Subsection 102.05** of this Specification. Lenses, reflectors, gaskets, and Polycarbonate parts shall not be painted. Five section aluminum clusters shall have an alodine conversion coating and/or a proper base for paint adhesion and be painted yellow.

501.11 PACKAGING

All shipments shall be identified by item number and quantity on a packing list which describes the total order. This packing slip shall accompany the shipment and shall be externally attached in a protective envelope for ready access. Units or accessory parts of the order shall be packaged with the contents clearly marked at two outside end points for ease of checking when stacked one on another. The marking shall indicate the contents, as shown on the packing slip, by item number, by manufacturers' model or type and by the associated purchase order number. All parts of a complete signal head assembly shall be packaged together including backplate, visors, and mounting hardware as required. If more than one carton is required to package a signal head assembly, the cartons shall be banded together and labeled accordingly.

501.12 INSTALLATION

The Contractor shall install the signal heads as required by the Plans and in accordance with the Design Standards. The Contractor shall wire all signal heads complete for operation in accordance with the Plans, and shall provide a complete circuit from the signal head terminal, to the controller cabinet terminal. Labels shall be attached to the controller terminal identifying all signal functions. All signal field circuits shall be tested for continuity, "flashed out" to verify identification, and measured for amperage load with an approved clamp-on ammeter.

501.13 Measurement and Payment

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

501.13 MEASUREMENT AND PAYMENT

Accepted signal heads (vehicle and pedestrian) of each size, section, and mounting arrangement specified shall be measured by the individual unit furnished and installed complete in place, per each.

With regard to items for signal head assemblies, each item shall be distinguished with a code number as follows:

- The first digit is the number of faces per assembly.
- The second digit will indicate the number of 12-inch lenses per assembly (including arrow lenses).
- The third digit is the quantity of 8-inch lenses per assembly.
- The letter "A" indicates an arrow lens and the digit following the "A" indicates the number of 12-inch arrow lenses per assembly.
- 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

Payment at the contract unit price, per each, shall be made for each accepted signal head (vehicle and pedestrian) of each specified size and mounting arrangement. This shall be payment in full for furnishing and installing the signal head including all connection of wiring, testing, and incidental materials for a complete and operable installation.

Item Number	Description	Pay Unit
02890-501.01	Signal Head Assembly (110, Warranty ___ Years)	EACH
02890-501.02	Signal Head Assembly (130 With Backplate, Warranty ___ Years)	EACH
02890-501.03	Signal Head Assembly (130 Pole Mounted, Warranty ___ Years)	EACH

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02890-501.04	Signal Head Assembly (130A3 With Backplate, Warranty __ Years)	EACH
02890-501.05	Signal Head Assembly (150A2H With Backplate, Warranty __ Years)	EACH
02890-501.06	Signal Head Assembly (150A2V Pole Mounted, Warranty __ Years)	EACH
02890-501.07	Signal Head Assembly (130 With Backplate, Programmable Visibility)	EACH
02890-501.08	Signal Head Assembly (130A3 With Backplate, Programmable Visibility)	EACH
02890-501.09	Signal Head Assembly (150A2H With Backplate, Programmable Visibility)	EACH
02890-501.10	Signal Head Assembly (130 With Backplate, Inverted 3-Section Cluster for HAWK Signal)	EACH
02890-501.11	Signal Head Assembly (Description)	EACH
02890-501.12	Signal Head Assembly (Description)	EACH
02890-501.13	Signal Head Assembly (Description)	EACH
02890-501.21	Pedestrian Signal Head (Warranty __ Years)	EACH
02890-501.22	Pedestrian Signal Head (Warranty __ Years), Push Button, & 15" Sign	EACH
02890-501.23	Pedestrian Signal Head (Description)	EACH
02890-501.24	Pedestrian Signal Head (Description)	EACH

SECTION 511 – BLANKOUT SIGN

511.01 GENERAL

The Blankout Sign shall be fully compliant to the “Changeable Message Signs” requirements in the FHWA Manual on Uniform Traffic Control Devices (MUTCD). The blankout sign shall meet or exceed any relevant standards defined in NEMA TS2-2003. The blankout sign shall consist of:

- Powder coat black exterior
- Weatherproof housing and door
- Top and side sun shield
- Single image display, highly visible when illuminated and blank black face when not illuminated
- LED light engine and power supply
- Matte/Clear polycarbonate lens
- Mounting hardware compatible with the signal support shown on Plans

511.02 FUNCTIONAL REQUIREMENTS

A. Size and Legend

Unless otherwise noted in the Plans, the illuminated display size of the blankout sign shall be 24 inch by 24 inch and shall be capable of displaying one symbolic turn prohibition sign. The symbolic sign shall be either regulatory sign R3-1 (No Right Turn) or R3-2 (No Left Turn). The regulatory sign size, color, and legend shall be fully compliant to the latest edition of the MUTCD and Standard Highway Signs. Overall size of the blankout sign shall be less than 30 inch (L) x 30 inch (W) x 12 (D).

B. Visibility

When illuminated, the symbolic sign displayed shall be clearly legible, attracting attention under any lighting conditions. At full intensity, the display shall be highly visible anywhere with a 20 degree cone centered about the optic axis from at least 2000 feet.

No color shall appear in the lenses when deactivated regardless of ambient light conditions.

The blankout sign display shall have automatic dimming feature at night.

511.03 MATERIAL AND CONSTRUCTION

A. LED Light Engine and Power Supply

The sign shall be capable of continuous operation over a range in temperatures from -37°C (-35°F) to +75°C(+165°F).

LED light engine shall be used with a rated life expectancy of 60,000 hours or longer. Each LED in the strip shall be parallel wired to insure independent operation and prevent

511.04 Measurement and Payment

sequential failure. LED color and viewing angle shall be fully compliant with the ITE specifications.

Power consumption shall be less than 100 watts. Electrical connection shall be made via barrier type terminal strip. All fasteners and hardware shall be corrosion resistant stainless steel. The input voltage shall be 120 to 240 volts A/C, at 50/60 hertz, switch selectable. The power supply shall be designed with over current and transient protection.

B. Body and Door

The sign housings shall be constructed of .125" powder coated aluminum and rated NEMA 3R. The bodies shall be continuously welded to provide a weatherproof seal around the entire case.

The sign housing shall have a .125" extruded aluminum door with one side removable to gain access to signal face. All components shall be readily accessible for maintenance when the door is open. Continuous full length stainless steel hinges shall connect to the housing and the extruded aluminum door. Door gaskets shall be 3/16 X 1" neoprene to provide a weatherproof seal around the lenses and doors. Door panels and lens holders shall be colored flat black to maximize legibility when activated.

The blankout sign shall have stainless steel 1/4 turn link-locks or butterfly latches in sufficient number to tightly secure the door. Each door shall be fitted with sun shield of .063" thick aluminum on top and both sides of the sign display.

Finish on signal housings shall be black satin, two coats of exterior signal enamel applied after surface material is acid-etched and primed with zinc-cromate primer.

C. Mounting Hardware

The sign housing shall be fitted with a (1) 2" mounting hub at the center of the top and bottom of the unit for mounting. The sign shall be designed to be mounted overhead on spanwire or mast arm with respective mounting bracket assembly. All fasteners and hardware shall be corrosion resistant stainless steel. The sign, mounting bracket and hardware shall be designed to withstand 100 mph wind loading on the bracket and the sign.

511.04 MEASUREMENT AND PAYMENT

New blank-out signs shall be measured by the number of each furnished, installed, and accepted, in place and complete. This item shall include new mounting hardware, any other miscellaneous hardware, and incidental items and labor required to provide complete installation.

Item Number	Description	Pay Unit
02890-511.01	Blankout Sign (24 x 24 Symbolic No Left Turn)	EACH
02890-511.02	Blankout Sign (24 x 24 Symbolic No Right Turn)	EACH
02890-511.03	Blankout Sign (Description)	EACH
02890-511.04	Blankout Sign (Description)	EACH

SECTION 521 – LED ILLUMINATED SIGN

521.01 GENERAL

The LED Illuminated Sign shall be fully compliant to the requirements in the FHWA Manual on Uniform Traffic Control Devices (MUTCD). The LED illuminated sign shall consist of:

- Single or double sided as required on Plans, highly visible when illuminated and retroreflective face when not illuminated
- Powder coat black exterior and border
- Weatherproof aluminum housing
- LED light engine and power supply
- Mounting hardware compatible with the signal support shown on Plans

521.02 FUNCTIONAL REQUIREMENTS

Unless otherwise noted in the Plans, the illuminated sign size, color, and legend shall be fully compliant to the latest edition of the MUTCD and Standard Highway Signs Manual. Outside black border shall be less than 2 inches wide. Overall thickness of the sign shall be less than 2 inches.

When illuminated, the symbolic sign displayed shall be clearly legible, attracting attention under any lighting conditions. At full intensity, the display shall be highly visible anywhere within a 20 degree cone centered about the optic axis from at least 600 feet.

521.03 MATERIAL AND CONSTRUCTION

A. LED Light Engine and Power Supply

The sign shall be capable of continuous operation over a range in temperatures from -30°C (-22°F) to +60°C(+140°F).

LED light engine shall be used with a rated life expectancy of 60,000 hours or longer. Each LED in the strip shall be parallel wired to insure independent operation and to prevent sequential failure.

Power consumption shall be less than 55 watts. Electrical connection shall be made via barrier type terminal strip. All fasteners and hardware shall be corrosion resistant stainless steel. The input voltage shall be 120 to 240 volts A/C, at 50/60 hertz, switch selectable. The power supply shall be designed with over current and transient protection.

B. Material

The sign legend and background shall use ASTM Type IX retroreflective sheeting.

The sign housings shall be constructed of .125" powder coated aluminum and rated NEMA 3R. The bodies shall be continuously welded to provide a weatherproof seal around the entire case.

Finish on sign housings shall be black satin, two coats of exterior signal enamel applied after surface material is acid-etched and primed with zinc-cromate primer.

Maximum weight is 7 lbs. per sq. ft., single or double-sided.

C. Mounting Hardware

The illuminated sign housing shall be designed to be mounted overhead on spanwire or mast arm with respective mounting bracket assembly. All fasteners and hardware shall be corrosion resistant stainless steel. The sign, mounting bracket and hardware shall be designed to withstand 150 mph wind loading on the bracket and the sign as per AASHTO standard.

521.04 MEASUREMENT AND PAYMENT

New LED illuminated signs shall be measured by the number of each furnished, installed, and accepted, in place and complete. This item shall include new mounting hardware, any other miscellaneous hardware, and incidental items and labor required to provide complete installation.

Item Number	Description	Pay Unit
02890-521.01	LED Illuminated Sign (R10-23, Crosswalk Stop On Red)	EACH
02890-521.02	LED Illuminated Sign (Description)	EACH
02890-521.03	LED Illuminated Sign (Description)	EACH
02890-521.04	LED Illuminated Sign (Description)	EACH

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SECTION 601 – SIGNAL SUPPORT POLES**601.01 GENERAL**

These Specifications apply to the manufacture of poles for the support of traffic signals and signs. The height of poles, shaft dimensions, and wall thickness shall meet the design requirements and mounting height of traffic signals and signs as set forth in these Specifications and on the Plans. Bracket arm lengths are indicated on the Plans.

Steel poles shall be fabricated from hot rolled basic open hearth steel and shall have only one longitudinal electrically welded joint and no intermediate horizontal welds or joints. The shaft shall be longitudinally cold rolled to flatten the weld and increase the physical characteristics so that the metal shall have minimum yield strength of 55,000 psi.

The steel poles covered under these Specifications shall be tapered, upright circular steel with a uniformly tapered shaft and round cross-section. These poles shall be processed to a minimum yield stress of 55,000 psi. The pole wall thickness (gauge) and other specification data in Table and elsewhere in this specification shall relate to the characteristics of the completed pole after fabrication. Steel sign and signal poles shall have a section modulus equal to or exceeding those in **Table 601-1**.

Table 601-1 Minimum Section Modulus for Steel Poles (Inches³)

Location	12-Inch Base Diameter			13-Inch Base Diameter		
	#0 Gauge	#3 Gauge	#7 Gauge	#0 Gauge	#3 Gauge	#7 Gauge
Base	32.6	26.5	19.3	38.5	31.3	22.8
20'	29.3	15.3	11.2	23.2	18.9	13.8
24'	16.4	13.4	9.8	20.6	16.8	12.3
28'	14.2	11.6	8.5	18.2	14.8	10.9
30'	13.2	10.8	7.9	17.0	13.9	10.2
32'	12.2	10.0	7.4	15.9	13.0	9.6

The materials used shall meet or exceed the standards of American Society of Testing and Materials and the Society of Automotive Engineers, as noted, and such standards shall be made a part of this specification. Poles shall be galvanized inside and outside.

All welding shall be performed by welders qualified in accordance with "American Welding Society Standard Specifications for Welded Highway and Railway Bridges." All welding shall be performed in the positions using the electrodes and procedures permitted under the qualification techniques.

All steel and cast iron components, hardware and threaded fasteners, except anchor bolts, shall be galvanized after fabrication in accordance with ASTM Designations A 123, or A 153 or A 385, as applicable.

Strain poles shall be galvanized steel with a uniformly tapered shaft. All poles shall be complete with a removable cast aluminum top cover with stainless steel set screws for fastening cover to top of pole. A "J" hook wire support shall be located inside the pole near the top, and four 2 inch threaded pipe couplings shall be located on the outside near the top of the pole. Two "U" bolt spanwire clamps shall be furnished complete for each pole. The threaded bolt shall be 5/8 inch in diameter and shall be furnished with galvanized hexagon nuts. The clamps shall be sized to fit each tapered pole at a point 18 inches from the top. A 4 inch by 8 inch handhole with 11 gauge galvanized steel or aluminum cover shall be installed 18 inches above the base of anchor base poles. The handhole opening in the pole shall be fitted with a steel frame welded into place. The cover shall be furnished with two (2) 1/4 inch stainless steel installation screws and a #35 stainless steel chain to leash the cover at the handhole. The handhole shall be oriented on the pole so that it is centered between two adjacent anchor bolt holes in the base. A ground lug for #6 AWG ground wire shall be provided inside each pole and accessible from the handhole.

The pole and all of its component parts shall be designed to support traffic signals or signs of the type and number indicated on the Plans, suspended from a span wire assembly. The shaft shall be fabricated from material providing a minimum yield strength of 55,000 psi after fabrication.

A. Anchor Base Plates

Unless otherwise specified, all strain pole traffic signal or sign supports shall be anchor base poles designed for installation on concrete foundations. Anchor base poles shall be provided with a cast base or welded plate base. The base shall be fabricated from drop-forged or cast steel of sufficient cross-section to fully develop the ultimate strength of the poles. The base shall be fastened to the pole by means of a welded connection and shall develop full strength of the pole. The base shall be provided with four holes of sufficient size to accommodate the proper size anchor bolts that are capable of resisting (at yield stress) the bending moment of the shaft at its yield strength stress. Four removable cast iron covers for the anchor bolts shall be provided with stainless steel attaching screws.

B. Anchor Bolts

High strength steel anchor bolts, each fitted with one regular hex nut and one heavy duty square nut, shall be furnished with anchor base type of poles. All nuts and not less than 10 inches of the threaded ends of anchor bolts shall be hot dipped galvanized in accordance with ASTM Designation A 153. The anchor bolts shall have a minimum yield strength of 55,000 psi and a minimum ultimate strength of 90,000 psi each. The anchor bolts shall be capable of resisting (at yield strength stress) the bending moment of the shaft at its yield strength stress.

C. Embedded Poles

All poles designed for direct ground installation shall be furnished with factory installed steel ground line sleeves, each sleeve two (2) feet long. The thickness of the ground line sleeve shall be minimum three-eighths (3/8) inch and shall be factory welded all around the top outside and bottom outside five feet, four inches from the base end of the pole for standard

601.02 Common Requirements for Galvanized Steel Poles

six (6) feet embedment. A steel plate shall be furnished welded across the open butt end of the pole for partial bottom cover and pole bearing.

601.02 COMMON REQUIREMENTS FOR GALVANIZED STEEL POLES

This subsection covers common requirements for galvanized steel span wire suspension poles of the anchor base type and embedded type, galvanized steel mast arm poles of the anchor base type and embedded type, for use by the City of Memphis, Division of Engineering, as traffic signal supports. The common requirements in this subsection also apply to galvanized steel mast arms. Also refer to Subsections 601.03, 601.04, and 601.05 for additional requirements for galvanized steel span wire suspension poles, galvanized steel mast arm poles, and galvanized steel mast arms.

A. General**1. Materials**

The materials used shall meet or exceed the standards of American Society of Testing and Materials and the Society of Automotive Engineers as noted and such standards shall be made a part of this specification. Poles shall be galvanized inside and outside to ASTM A 123.

2. Structure

The poles covered under these specifications shall be tapered, upright circular steel with uniformly tapered shaft and round cross section. Multisided tubular shapes are not considered round. The poles shall be processed to a minimum yield stress of 55000 P.S.I. The pole wall thickness and other specification data in the chart and elsewhere in specification shall relate to the characteristics of completed pole after fabrication.

3. Welding

All welding shall be performed by welders qualified in accordance with "American Welding Bridges." All welding shall be performed in the position using the electrodes and procedures permitted under the qualification techniques.

B. Types of Poles

All poles designed for installation on concrete foundation shall have cast steel bases meeting ASTM A27 Grade 65 35. The base shall have sufficient strength to support the forces generated when the pole is subjected to its rated yield loading. These bases shall be welded onto the tubes at the factory and shall be supplied with galvanized steel nut cover with stainless steel attaching screws. Each pole shall be mounted on its concrete footing with four (4) double nutted steel anchor bolts, which shall be furnished complete with galvanized hexagon nuts leveling nuts threaded in accordance with the "Fastener Standards" published by the Industrial Fasteners Institute. All threads shall be UNC 2, hot dip galvanized with internal threads cut oversized, as specified in ASTM A 563 to provide for proper assembly. The exposed threaded ends of the anchor bolts shall be hot dip galvanized for a minimum of eleven inches as per ASTM A 153. The anchor bolts shall be threaded a minimum of nine inches and shall be sized as per the Plans or the City's Traffic Standard Drawings. The bolts shall each have minimum yield strength of 55,000 pounds per square inch and a minimum ultimate strength of 90,000 per square inch each. The end of the bolt opposite the threaded end has a six (6) inch right angle leg.

601.02 Common Requirements for Galvanized Steel Poles

C. Pole Accessories**1. General**

All accessories listed in this Subsection, and in the appropriate subsection of Subsections 601.03, 601.04, and 601.05, shall be furnished with each pole. The underground conduit entrance is required only in embedded type poles.

2. Handhole and Cover

A four inch by eight inch curved handhole with 11 gauge galvanized steel cover shall be installed 18 inches above the base of anchor base poles and twelve (12) inches above the top edge of the ground line sleeve on embedded poles. The handhole opening in the pole shall be fitted with a steel frame welded into place. The cover shall be furnished with (2) 1/4 inch stainless steel installation screws and a No. 35 stainless steel chain to leash the cover at the handhole. On the anchor base pole, the handhole shall be oriented on the pole, so that it is centered between two adjacent anchor bolt holes in the base and is on the side of the pole away from the street.

3. Pole Top Cover

All poles shall be equipped with a cast aluminum top cover which shall be furnished complete with stainless steel set screws for fastening the cover to the top of the pole.

D. Design Drawing

The Contractor shall submit four copies of design drawings unless otherwise specified. Contractor's estimated weights of the various units shall appear in the design drawings. The successful Contractor shall be required to submit shop drawing for approval, and no fabrication shall be started until such drawing have been approved by the Engineer. This approval, however, is for general design only and shall not relieve the manufacturer of responsibility for the sufficiency of detail, design or correctness of detail dimensions.

E. Inspection and Warranty

All equipment, material or work rejected by the Engineer or their representatives as not being in accordance with the drawing and specifications, or contract, shall be replaced immediately by the manufacturer with other materials or work in accordance with the specifications, drawings or contract and at the manufacturer's expense. Each Contractor shall agree to correct any defects in design, workmanship, or material which may be discovered under normal use within the period of one year from the date of shipment.

F. Shipment and Deliveries

The successful Contractor shall be required to arrange for the proper expediting, delivery and, if required, shipment tracing of all equipment and material required to be furnished under these specifications. The successful Contractor shall furnish the Engineer with copies of bills of lading, shipping manifest and all other paper showing shipment of materials, on the same day shipment is made. Delivery shall be included in the bid price and all material shall be delivered F.O.B. to City of Memphis Traffic Signal Shop, 980 South Third St., Memphis, Tennessee 38106. The successful Contractor shall contact the Traffic Signal Maintenance shop at (901)528 2844 between the hours of 7:15 am to 3:15 pm (Central time) Mon. through Fri. at least twenty four hours before schedule delivery to permit the City to arrange for off loading of poles. Delivery can occur only between the hours of 7:15 am to

601.03 Galvanized Signal Span Wire Suspension Poles

1:00 pm (Central time) Mon. through Fri. Arrival after this time shall require offloading the next scheduled workday.

G. Packaging

Material shall be prepared for shipment, transported and handled by such a manner that no excessive stresses are applied to any part thereof, which shall result in permanent strains or in misalignment of parts of such material.

H. Manufacturer Qualifications

Bids are preferred on materials manufactured by well-established fabricators, particularly those experienced in structural design and have regularly engaged for a period of at least four (4) years in work of a character similar to that covered by the plans and specifications.

601.03 GALVANIZED SIGNAL SPAN WIRE SUSPENSION POLES

This subsection covers specific requirements in addition to the requirements given in Subsection 601.02 above for galvanized steel span wire suspension poles of the anchor base type and embedded type for use by the City of Memphis, Division of Engineering, as traffic signal poles.

A. Design Sketches

Any design sheet, clamp detail sheet, and specification data charts attached to the bidding package are hereby made a part of these specifications.

B. Embedded Poles

All poles designed for direct ground installation shall be furnished with factory installed steel ground line sleeves, each sleeve two (2) feet long. The thickness of the ground line sleeve shall be minimum three-eighths (3/8) inch and shall be factory welded all around the top outside and bottom outside five feet, four inches from the base end of the pole for standard six (6) feet embedment. A steel plate shall be furnished welded across the open butt end of the pole for partial bottom cover and pole bearing.

C. Pole Accessories**1. Internal Wire Support**

A "J" hook wire support shall be located inside and near the top of the pole. It shall be accessible through the top end of the pole.

2. Spanwire Clamps

Two "U" Bolt spanwire clamps shall be furnished complete for each pole. The threaded bolt shall be 5/8 inch in diameter and shall be furnished with galvanized hexagon nuts. The clamps shall be sized to fit each tapered pole at a range from eighteen to forty-two inches from the top. The clamp shall be individually marked on the front half by an ingrained identification size.

3. Ground Lug

A ground lug for #6 AWG. ground wire shall be provided inside each pole and accessible from the hand hole.

601.04 Galvanized Steel Mast Arm Poles

4. Upper Wire Inlet Holes

Three (3), 2" threaded full coupling shall be furnished and welded in holes cut through the pole tube at points 2 feet, 6 inches from the top end. These holes shall be oriented so that one hole is on the vertical centerline with the handhole; the other two holes shall be oriented 90 degrees both directions from the first hole. All coupling shall be furnished with non-staining, rustproof threaded plugs. These plugs shall be installed prior to shipment to prevent damage to the couplings during shipment and handling.

5. Pedestrian Signal inlet holes

Two (2), 1" threaded half couplings shall be furnished and welded in holes cut through the pole tube at points 7 feet, 10 inches from the bottom of the base plate. These holes shall be oriented so that one hole is on the vertical centerline with the handhole, and the other is located on the opposite side of the pole at 7 feet, 10 inches and 180 degrees from the handhole. All couplings shall be furnished with non-staining, rustproof threaded plugs. These plugs shall be installed prior to shipment to prevent damage to the couplings during shipment and handling.

6. Underground Conduit Entrance

One (1) welded 3 inch threaded half coupling, furnished with a removable plastic plug, and shall be installed through the pole tube of embedded type pole at a point approximately 6" below the ground sleeve and in a vertical line with the handhole. The coupling shall be threaded, galvanized, and plugged for shipment.

7. Concrete Base Footing Template

A template shall be provided made of sheet metal, to be manufactured to fit "Bolt Circle" requirement of each specified pole size.

601.04 GALVANIZED STEEL MAST ARM POLES

This subsection covers specific requirements in addition to the requirements given in Subsection 601.02 above for galvanized steel mast arm poles of the anchor base type and embedded type for use by the City of Memphis, Division of Engineering, as traffic signal poles.

The Mast arm poles shall be galvanized steel with a uniformly tapered shaft. The shaft shall be fitted with a removable pole cap, a J hook wire support welded inside near the mast arm connection, a welded frame handhole opposite the mast arm (of like design and installation to lower handhole), and a flange plate assembly to match that welded to the butt end of the mast arm.

Mast arm poles shall have a cast anchor base or welded plate base of adequate strength, shape, and size and shall be secured to the lower end of the shaft. The base shall be fabricated from drop forged or cast steel of sufficient cross section to develop the ultimate strength of the pole. The base shall be fastened to the pole by means of a welded connection and shall develop the full strength of the bending moment of the pole. The base shall be provided with four holes of sufficient size to accommodate a two (2) inch diameter anchor bolt with an eighteen (18) inch diameter bolt circle. The pole shall be provided with removable cast iron covers for anchor bolts complete with stainless steel attaching screws.

A grounding lug for no. 6 AWG ground wire shall be welded to inside of pole at a point readily accessible from the handhole for wiring.

601.05 Galvanized Steel Mast Arms

Where required, mast poles shall be of sufficient height and equipped with proper mounting plates for street light attachments as required in the pole dimensions subsection of this specification.

601.05 GALVANIZED STEEL MAST ARMS

This subsection covers specific requirements in addition to the requirements given in Subsection 601.02 above for galvanized steel mast arms.

Mast Arms shall be fabricated in the same manner as the upright shafts and with the same physical characteristics. The mast arms shall meet the design requirements necessary to support rigidly mounted traffic signals and signs, as designated in the Plans. All arms shall include a removable cap at the tip, signal attachment method of the type and number shown in the Plans, and a signal arm clamp 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.

Mast arms shall be connected to the upright pole at a height of 18' (feet) 6" (inches).

Mast arms shall be connected to the upright pole at a height necessary to provide a minimum clearance of 15'-6" and a maximum clearance of 17'-6" under traffic signal heads. Minimum clearance for signs shall be 18 feet over the entire width of the roadway.

601.06 PEDESTAL POLES**A. General**

The pedestal poles shall consist of one upright pole with suitable base and any other accessories or hardware as required to make 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 cylindrical and uniformly tapered from butt to tip. The cross-section at the tip shall have a 4 1/2 inch outside diameter.

Bases shall be round, octagonal, or square in shape and of an ornamental fabricated cast material of a transformer type base. A handhole shall be provided in the base or 18 inches above the base in the pole. Bases shall be furnished with four steel anchor bolts of sufficient size and length to securely anchor the base to the concrete footing.

B. Aluminum Pedestal

Aluminum pedestals shall be of uniform round cross-section of tubular tapered type construction fabricated from one full length sheet. The shaft shall be threaded so as to be securely screwed into the base. The pedestal shaft shall be fabricated from aluminum tubing 6063-T4, heat treated to T-6 temper after fabrication, and meeting ASTM Designation B 26 - SF 70A-T6 specifications. The top opening of the base shall be threaded to receive the shaft.

C. Steel Pedestal

Steel pedestals shall be of uniform round cross-section and shall have a uniformly tapered shaft of tapered, upright circular steel. The shaft and base shall be threaded so as to be

securely screwed together. The pedestal shaft shall be fabricated of cold rolled steel galvanized according to the Specifications of ASTM A 123.

601.07 WOOD POLE SUPPORTS

Wood service poles and standards shall be of the class and length shown on the Plans and, unless otherwise specified, they shall meet the requirements of the following Specifications:

- Wood service poles and standards shall be of pentachlorophenol treated southern pine, shall be classified according to the latest American Standard Dimensions of Southern Pine Poles and shall meet the requirements of ASA 05.1 except as specified. Preservative treatment of this material shall be in accordance with the American Wood Preserver's Association's Manual of Recommended Practice, Standards C1 and C4.
- All material shall conform to ANSI 05.1, Section 4, except that species shall conform to Treatment Group C, steam conditioning of southern pine, only. Shape where sweep is in one plane and one direction only shall be limited to a deviation of one inch (1") for each ten feet (10') of length where measured in accordance with Section 4 for one hundred percent (100%) of the poles in any shipment.
- The preservative shall be pentachlorophenol. The pentachlorophenol solution shall consist of pentachlorophenol meeting the requirements of AWPA Standard P8 dissolved in a suitable petroleum solvent in accordance with AWPA Standard P9, Section 1, Heavy Petroleum Solvent, or Section 2, Volatile Petroleum Solvent (LPG). The heavy petroleum solvent solution shall have a concentration of not less than five percent (5%) pentachlorophenol by weight when tested in accordance with AWPA Standard A5. The volatile petroleum solvent solution shall have a concentration of pentachlorophenol sufficient to produce the specified retention as determined by assaying the treated wood.
- The pole treatment shall be by the Rueping empty cell process or full cell process. When a heavy petroleum solvent pentachlorophenol solution is used, the treating process shall be Rueping empty cell process in accordance with AWPA Standard C4, Section 2. When volatile petroleum solvent pentachlorophenol solution is used, the treating process shall be the full cell process in accordance with AWPA Standard C4, Section 2. The poles furnished under this specification shall be treated in charges with other material requiring more than a thirty-eight one hundredths (0.38) pound treatment.
- The net retention of preservative shall be not less than 0.38 pounds of preservative, by lime-ignition assay, per cubic foot of material in accordance with AWPA Standard C4, Section 3.1. A minimum penetration of preservative shall be three inches (3") or ninety percent (90%) of sapwood in accordance with AWPA Standard C4, Section 3.2. Determination of penetration for all poles shall be in accordance with AWPA Standard C4, Section 3.212. The pounds of retention by assay shall be marked on the pole below the branded code letters required by this Specification.

601.08 CONSTRUCTION

A. Foundations

Foundations for posts, standards, and pedestals, shall be Class A Portland cement concrete as specified in Section 03050 of these Specifications. Anchor bolts, conduits, and reinforcing steel shall be placed in accordance with the Plans and Design Standards.

Foundations for posts, standards, and pedestals shall be poured monolithically to final grade. The exposed portions shall be formed to present a neat appearance. The bottom of concrete foundations shall rest on firm, undisturbed ground. A vibrator shall be used in the pouring of all foundations to remove voids and air entrapment.

Forms shall be true to line and grade. Tops of foundations for posts and standards, except special foundations, shall be finished at sidewalk grade or as ordered by the Engineer. The tops of foundations shall be 6 inches deep and square, with the dimension equal to the diameter of the foundation. A 1 inch joint material shall be placed around the 6 inch top square. Forms shall be rigid and securely braced in place. Conduit ends and anchor bolts shall be placed in proper position and to proper height and shall be held in place by means of a template until the concrete sets. Conduit entries in addition to those required for the installation shall be placed in each foundation, oriented as shown on the Plans or as directed by the Engineer, and capped according to these Specifications. Calcium chloride shall not be used to speed the setting of the concrete.

Both forms and ground that will be in contact with the concrete shall be thoroughly moistened before placing concrete. Forms shall not be removed until the concrete has thoroughly cured for at least 12 hours and hardened sufficiently to allow form removal without causing damage to the concrete. No pole shall be installed until eight (8) days after the foundation has been poured.

Ordinary surface finish shall be applied to exposed surfaces of concrete. Wherever the edge of a concrete foundation or sidewalk section is within 18 inches of any existing concrete improvement, the sidewalk section shall be extended to meet said existing improvement.

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

B. Installation of Poles

Wood poles, where required, shall be set to the depth shown in the Design Standards or the Plans and with a 30 inch by 12 inch by 3 inch treated crib board and anchor key perpendicular to the resultant vector of the applied strain(s). Steel poles shall be bolted as shown in the Design Standards or the Plans or embedded in a 6 inch concrete envelope. Poles shall be fitted with all necessary hardware to make the installation complete. Steel poles shall be oriented such that the handholes are facing away from the street and oncoming traffic in the near curbs at approximately 90° or more from the curbs, unless otherwise directed by the Engineer.

C. Plumbing of Poles

Plumbing of standards, posts, and pedestals shall be accomplished by adjusting the nuts. Shims or similar devices for plumbing or raking shall not be permitted. After plumbing or raking has been completed, anchor bolts shall be cut off 1/4 inch above the top nut and the exposed surface painted with rust protective paint. Caps shall be placed over the nuts and a cement grout placed under the pole with a weep hole - all as shown on the Plans.

D. Cable Hangers

All cables and conductors running in a pole which enter or leave the pole through a weatherhead, mast arm, signal head, push button, or controller cabinet assembly shall be hung with a strain relief hanger-gripper from the J-hook in the top of the pole before leaving

or after entering the pole. Cable(s) entering or leaving via the pole foundation shall be hung in a strain relief hanger-gripper if the cable(s) rises more than 8 feet above the foundation. The cables and conductors shall be in one or more hanger-grippers with the gripper distributing the weight over a minimum of one foot.

E. Entry Bushings

All entry or exit points through field drilled holes in poles, pedestals, or mast arms at the point of attachment of vehicle or pedestrian heads shall be tapped and shall have a threaded PVC stub extending two (2) inches beyond the outside surface to protect the cable and conductors from sharp edges or corners and to maintain cable alignment in conformance with the Plans.

601.09 MEASUREMENT AND PAYMENT

Accepted sign and signal support poles shall be measured by the individual unit furnished and installed complete in place, per each. Each item includes the pole, foundation, anchor bolts, grounding, and all other hardware shown on the Plans and Design Standards necessary for a complete installation.

Item Number	Description	Pay Unit
02890-601.01	Steel Strain Pole (28 Feet)	EACH
02890-601.02	Steel Strain Pole (30 Feet)	EACH
02890-601.03	Steel Strain Pole (32 Feet)	EACH
02890-601.04	Steel Strain Pole (34 Feet)	EACH
02890-601.05	Steel Strain Pole (36 Feet)	EACH
02890-601.06	Steel Strain Pole (Description)	EACH
02890-601.11	Mast Arm Support (__ Feet Arm)	EACH
02890-601.12	Mast Arm Support (__ Feet Arm)	EACH
02890-601.13	Mast Arm Support (__ Feet Arm)	EACH
02890-601.14	Mast Arm Support (__ Feet Arm)	EACH
02890-601.15	Mast Arm Support (__ Feet Arm)	EACH
02890-601.16	Mast Arm Support (__ Feet Arm)	EACH
02890-601.21	Pedestal Pole (4 Feet, Aluminum, For Push Button)	EACH
02890-601.22	Pedestal Pole (17 Feet, Aluminum)	EACH
02890-601.23	Pedestal Pole (20 Feet, Aluminum)	EACH

Section 601 – Signal Support Poles

601.09 Measurement and Payment

02890-601.24	Pedestal Pole (Description)	EACH
02890-601.25	Pedestal Pole (Description)	EACH
02890-601.31	Wood Pole (Description)	EACH
02890-601.32	Wood Pole (Description)	EACH
02890-601.33	Wood Pole (Description)	EACH
02890-511.34	Wood Pole (Description)	EACH

SECTION 611 – SIGNAL SPAN WIRE ASSEMBLIES**611.01 MATERIAL****A. Signal Span Wire**

Span wire for suspending signal heads between pole supports shall be 9,196 pound minimum breaking strength, 7 strand, Class A, copper clad steel meeting the requirements of ASTM designation A460.

B. Tether wire

Strand cable for tether wires shall be 1/4 inch Siemens-Martin grade unless otherwise noted on the Plans and shall meet the requirements of ASTM designation A 475 for zinc coated steel wire strand, 7 strand, Class A zinc coating.

C. Terminations

All span terminations at poles shall be made with a spiral bite dead-end of the proper material and strand size to fit the guy span used. A galvanized steel thimble of the proper size shall be used between the eye bolt or other fastener and the dead-end. The dead-end material shall be of the same material as the terminating wire. This shall include but not be limited to tether wires, down guys, strut (sidewalk) guys, signal spans, and overhead detector lead-in spans or messengers.

A 5/8 inch diameter by 12 inch length single strand angle type eye bolt with two (2) 2 inch square curved washers, lock washer, and square nut shall be used on wood poles as required by the Plans. When the proper angle and location of the span wire eye bolt exist on a wood pole, as determined by the Engineer, an oval eye nut of drop-forged steel may be used as shown in the Plans, fastened to the threaded end of span wire eye bolt in lieu of this added eye bolt. All components and hardware shall be galvanized in accordance with ASTM designation A123 or A153.

611.02 CONSTRUCTION

The signal span wire assemblies shall be installed by the Contractor in accordance with the Plans and Design Standards.

611.03 MEASUREMENT AND PAYMENT

Accepted span wire assemblies shall be measured in linear feet to the nearest foot. The measurement shall be from face of pole to face of pole.

Payment, assembly at the contract unit price, shall be made for the accepted length of installed span wire. This shall be payment in full for required span wire, tether wire, clamps, pole attachments, and other incidentals required for a complete installation.

Item Number	Description	Pay Unit
02890-611.01	Span Wire Assembly	L.F.

SECTION 612 – MESSENGER WIRE**612.01 MATERIAL**

Strand cable for messenger wire use (other than span wire) shall be of the diameter(s) indicated on the Plans and shall meet the requirements of ASTM designation A 475 for zinc coated steel wire strand, 7 strand, Class A zinc coating. Tether wires and aerial loop detector lead-in support spans shall be 1/4 inch Siemens-Martin grade unless otherwise noted on the Plans.

612.02 CONSTRUCTION

Messenger wire shall be installed by the Contractor in accordance with the Plans and Design Standards.

612.03 MEASUREMENT AND PAYMENT

Accepted messenger wire shall be measured in linear feet to the nearest foot. The measurement shall be from face of pole to face of pole.

Payment, at the contract unit price shall be made for the accepted length of installed messenger wire. This shall be payment in full for pole attachments and other installation incidentals required.

Item Number	Description	Pay Unit
02890-612.01	Messenger Wire	L.F.

SECTION 621 – GUYING ASSEMBLIES

621.01 MATERIAL

All guying components and hardware shall be galvanized in accordance with ASTM designation A 123 or A 153 or A385. Pole guy cable shall be 3/8 inch utility grade unless otherwise noted on the Plans.

Anchors for guys shall be of the pressed steel 4-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 inches. Anchors shall be coated with a black asphalt paint.

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

Sidewalk guy fittings shall include 2 inch I.D. standard galvanized steel pipe of required length with a malleable iron pole plate and guy clamp. The pole plate shall be fastened to pole with 3/8 inch thru bolt and 1/2 inch lag screws. The lower portion of any guy shall be protected as shown in the Plans or Design Standards.

621.02 CONSTRUCTION

Guy assemblies shall be installed by the Contractor in accordance with the Plans and Design Standards.

621.03 MEASUREMENT AND PAYMENT

Guy assemblies of all sizes shall be measured as one complete installed unit, per each. Payment, assembly at the contract unit price, shall be made for each accepted and installed guy. This shall be payment in full for all guy wire, attachment hardware, anchors, and other installation incidentals required.

Item Number	Description	Pay Unit
02890-621.01	Guying Assembly	EACH

PART 7 – CONDUIT, RISERS, AND PULL BOXES

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SECTION 701 – CONDUIT AND RISERS**701.01 GENERAL**

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.

Conduit sizes shall be indicated on the Plans. Signal conduit shall be a minimum of 2 inches in diameter and detector conduit a minimum of 1 inch in diameter, unless otherwise indicated. Conduit for service connections shall be 2 inches in diameter. Conduits smaller than 1 inch diameter shall not be used unless otherwise specified, except grounding conductors at service points shall be enclosed in 3/4 inch diameter PVC conduit. The Contractor may, at his own expense, use larger size conduit than specified, in which case it shall be for the entire length of the run with no reducing couplings permitted.

The Contractor shall install pull wires or tapes with a minimum tensile strength of 600 lbf for all spare conduit.

A. Metal Conduit

Metal conduit and fittings shall be rigid heavy-walled, hot dipped galvanized steel and shall comply with the latest edition of Underwriters Laboratories' Standard UL 6, Federal Specification WW-C-581 and American National Standards Institute C 80.

B. Plastic Conduit

Plastic conduit shall be heavy-walled, extruded moisture and oil-proof Polyvinyl Chloride (PVC) or High-density Polyethylene (HDPE), corrosion resistant, with watertight joints and high impact strength. Conduit and fittings shall be in accordance with NEMA TC-2 Specifications, UL listed.

Schedule 40 PVC or HDPE conduit shall be used in a non-traffic bearing area only. Schedule 80 PVC or HDPE conduit shall be installed under existing pavements by approved drilling methods. Where trenching is allowed in a traffic bearing area, use schedule 40 plastic conduit encased in concrete.

Plastic conduit for electric wires shall be gray in color. Plastic conduit for fiber optic cables shall be orange in color.

For all plastic conduit installed for fiber optic cable, the Contractor shall install a 10 gauge tracer wire in orange color.

701.02 CONSTRUCTION**A. Underground Conduit**

Threads on metal conduits shall be clean cut, straight, and true and of sufficient length to permit proper coupling; long running threads shall not be permitted on any part of the work. Threads shall be protected in transit and during installation, and conduit shall be provided with proper supports and protection during construction to prevent damage to the threads. All ends of pipe installed for future connections shall be properly threaded, reamed, and capped to prevent water and foreign matter from entering the conduit system. Sections shall be made up with pipe dope so that ends of conduit will abut. Threaded ends in pull

boxes and foundations shall be provided with approved conduit bushings. All joints shall be sealed with pipe dope for a waterproof installation.

All bends into pull boxes and foundations shall be free from kinks and of such easy curvature to permit the drawing in of cables without damage to insulation. Conduit between pull boxes, foundations, and poles shall be placed in a straight line, unless otherwise shown in the Plans.

After installation of the conduit is completed, all conduit shall be tested with a mandrel according to the requirements of the testing section of this specification. After the mandrel test, all conduit shall be scoured with a stiff wire brush slightly larger in diameter than the conduit. The Contractor shall clear all conduit in the presence of the Engineer.

All conductors, except sawed loop detector conductors and span wire runs (as shown on the Plans), shall be run in conduit except where the run is inside poles. Where signal conductors are run in standards containing high voltage (over 600 volts) street lighting conductors, the lighting conductors shall be disconnected and encased in flexible metal or rigid metal conduit.

Conduit shall be laid to a depth of not less than 36 inches below pavement grade unless otherwise approved by the Engineer, except conduit may be laid at a depth of not less than 24 inches below top of curb when placed back of the curb. Conduit runs shall be located as shown on the Plans or as directed otherwise by the Engineer.

Conduit terminating in anchor base standards and pedestals shall extend approximately 6 inches above the foundation and shall be sloped toward the handhole opening. Conduit shall enter concrete pull boxes from the bottom and shall terminate not less than 2 inches nor more than 4 inches above the bottom of the box and near the box walls to leave the major portion of the box clear. All such metal conduit terminations shall be fitted with a grounding bushing to protect the cable jackets and to bond the conduits into the ground system in accordance with the Plans.

Existing underground conduit to be incorporated into a new system shall be checked with a mandrel and scoured the same as new conduit, all in the presence of the Engineer.

An approved rope or snaking device shall be placed in all conduit (new and reused) following mandrel check and scouring for use in pulling in pull ropes for installing the wiring cable or conductors. A mandrel, 2" in length and 1/2 inch smaller in diameter than the conduit, shall be passed through the entire length of the conduit immediately before installation of cable.

Conduit under existing pavement shall be placed by an approved jacking or drilling method. Existing pavement shall not be disturbed unless otherwise directed by the Plans or by the Engineer.

B. Conduit Risers

Each conduit riser which brings aerial copper cable into a pole-mounted cabinet shall be fitted with a pair of elbow condulets and enter the cabinet through the bottom. Each conduit riser which brings aerial fiber optic cable into a pole-mounted cabinet shall enter the cabinet through the top.

The exposed top of each conduit riser shall be fitted with either a weatherhead or a sealing bushing sweep, the latter to be used if the riser is to accommodate fiber optic cable. Risers shall be attached to poles as shown on the Plans or Design Standards.

701.03 TESTING

After installation of the conduit is completed, all conduit installed shall be tested with a mandrel having a diameter 1/2 inch smaller than the conduit and a length of 2 inches. All conduit which will not allow passage of the mandrel shall be repaired to the satisfaction of the Engineer; if repairs cannot be made, the conduit shall be removed and replaced at no additional cost to the City. After the mandrel test, all conduit shall be scoured with a stiff wire brush slightly larger in diameter than the conduit. The Contractor shall clear all conduit in the presence of the Engineer.

701.04 MEASUREMENT AND PAYMENT

Accepted, furnished and field installed conduit shall be measured in linear feet to the nearest foot for each size of conduit installed.

A. Conduit

Underground conduit shall be measured along the conduit by one of the following:

- From the face of curb to the outside face of a pull box or outside edge of a pole foundation.
- From the outside face of a pull box to the outside face of a pull box.
- From the outside face of a pull box to the outside face of a pole foundation or the face of a pole, if the conduit is to be on the outside of the pole.
- From the outside face of a pole foundation to the outside face of a pole foundation or edge of a pole, if the conduit is to be on the outside of a pole.

Above ground conduit shall be measured from the ground surface to the underside of a controller cabinet or signal bracket. All other aboveground conduit shall be measured as risers.

Four (4) feet shall be added to the above measurement for each entry to a pull box or pole foundation and each exit of a pull box or pole foundation. For any capped extra entry or exit to a pull box or pole foundation, four (4) feet shall be added to the length of conduit measurement. Four (4) feet shall be added to the above conduit measurement for each connection between underground conduit and aboveground conduit or riser. Three (3) feet shall be added to the conduit measurement for any conduit passing through a pull box or foundation without entry or exit.

No measurement shall be made for conduit in pull boxes, poles, pole foundations, or cabinets except as given above.

Accepted jacked conduit shall be measured in linear feet from the edge of pavement to edge of pavement under which the conduit is jacked.

Payment for each conduit item includes all fittings, couplings, grounding, terminations, banding, and other accessories required for a complete installation. Payment shall include excavation and backfilling of all trenches, including surfacing with sod or other material as removed. Payment shall include removal and in kind replacement of curb, curb and gutter, sidewalk, driveway, and Portland cement concrete and asphaltic concrete pavement.

B. Conduit Risers

Accepted field installed conduit risers shall be measured in linear feet to the nearest foot for each size conduit riser installed on the outside of a pole. The measurement shall be made along the conduit by one of the following:

- From the ground to the weatherhead.
- From the top signal head bracket to the weatherhead.
- From the bottom of the controller cabinet to the weatherhead.

Payment for conduit riser includes required fittings, bushings, condulets, banding, clamps, weatherheads or sealing bushings, and other accessories necessary for complete installation and grounding at all conduit riser locations.

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

Item Number	Description	Pay Unit
02890-701.01	Conduit 1" Diameter (PVC, Trench)	L.F.
02890-701.02	Conduit 2" Diameter (PVC, Trench)	L.F.
02890-701.03	Conduit 3" Diameter (PVC, Trench)	L.F.
02890-701.04	Conduit (Description)	L.F.
02890-701.05	Conduit (Description)	L.F.
02890-701.11	Conduit 1" Diameter (PVC, Jack or Bore)	L.F.
02890-701.12	Conduit 2" Diameter (PVC, Jack or Bore)	L.F.
02890-701.13	Conduit 3" Diameter (PVC, Jack or Bore)	L.F.
02890-701.14	Conduit (Description)	L.F.
02890-701.15	Conduit (Description)	L.F.
02890-701.21	Conduit 1" Diameter (RGS)	L.F.
02890-701.22	Conduit 2" Diameter (RGS)	L.F.
02890-701.23	Conduit 3" Diameter (RGS)	L.F.
02890-701.24	Conduit (Description)	L.F.
02890-701.25	Conduit (Description)	L.F.
02890-701.31	Conduit Riser Assembly (RGS, 1" Diameter)	L.F.

Section 701 – Conduit and Risers

701.04 Measurement and Payment

02890-701.32	Conduit Riser Assembly (RGS, 2" Diameter)	L.F.
02890-701.33	Conduit Riser Assembly (RGS, 3" Diameter)	L.F.
02890-701.34	Conduit Riser Assembly (Description)	L.F.
02890-701.35	Conduit Riser Assembly (Description)	L.F.

SECTION 711 – PULL BOXES

711.01 MATERIALS

Standard traffic pull boxes shall be constructed of Class A concrete reinforced in accordance with the details as shown on the Plans or the City of Memphis Design Standards. Reinforcement shall consist of steel wire fabric, 4" x 4" - No. 4/4 @ 85 lb./100 sq. ft. The cast iron cover shall have a roughened top surface. Notches shall be provided for removing the cover. The words "Traffic Signal" shall be inscribed on the top of the cover with letters 2 inches high and 1/8 inch in relief.

Fiber optic pull box (type A and B) shall be constructed in accordance with the details as shown on the Plans, Design Standards, or TDOT Standard Drawings. The words "Traffic Signal Fiber Optic" shall be inscribed on the top of the cover with letters 2 inches high and 1/8 inch in relief.

Precast pull boxes are acceptable, provided that the dimensions, design and test load ratings of the assembly, and all other details meet the requirements specified above and approved by the Engineer.

711.02 CONSTRUCTION

Pull boxes shall be installed at locations shown on the Plans or where directed by the Engineer. Covers shall be flush with the curb or sidewalk grade or with the surrounding ground, as required. No pull boxes shall be placed in the roadway area.

Electrical cables and conductors and fiber optic cables shall be placed within pull boxes in such a manner as to be clear of any metal frame and the cover. Ground rods shall be placed in the pull boxes where required in accordance with the Plans and Design Standards. Conduit shall enter the pull box in such manner that the minimum bending radius of all cables is provided.

The bottom of the pull box shall rest firmly on a bed of crushed limestone with a minimum depth of 12 inches below the bottom and extending 6 inches beyond the outside edge of the pull box, unless otherwise specified by the Engineer.

711.03 MEASUREMENT AND PAYMENT

Each pull box of the type required shall be measured as one complete installed unit, per each.

Payment, at the contract unit price for each type, shall be made for each accepted pull box installed as a complete unit. This shall be payment in full for excavation, including removal of sidewalks and pavement, installing the unit as detailed in the Plans, backfilling as required, crushed stone base, replacement in kind of sidewalks and pavement, and other incidental items required for the complete installation of the pull box.

Item Number	Description	Pay Unit
02890-711.01	Standard Traffic Pull Box Type "A"	EACH
02890-711.02	Standard Traffic Pull Box Type "B"	EACH

711.03 Measurement and Payment

02890-711.11	Fiber Optic Pull Box Type "A"	EACH
02890-711.12	Fiber Optic Pull Box Type "B"	EACH
02890-711.21	Pull Box (Description)	EACH
02890-711.22	Pull Box (Description)	EACH

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SECTION 801 – ELECTRICAL CABLES AND CONDUCTORS**801.01 GENERAL**

All electrical cables and conductors shall be stranded copper with insulation rated at 600 volts meeting IMSA Specification 19.1. The cable or conductors shall be suitable for use in conduit, duct, aerial, or direct burial installation. Unless noted otherwise, all cables shall be rated THWN-2, suitable for use in wet or dry locations at temperatures not to exceed 90 °C.

Color coding shall not fade and shall be in accordance with the Insulated Power Cable Engineers Association (IPCEA) Color Code Chart No. 2.

The cable size shall be as required by the Plans or as directed by the Engineer. The Contractor may install larger cable than required without extra compensation.

801.02 MATERIALS**A. Power Service Drop**

The wires from the service drop to the controller shall be two #6 AWG copper wire cables with each conductor color coded, insulated, and an outer jacket of PVC, UL listed.

B. Signal Cable

All multi-conductor control cables (3 or more conductors) shall have individual conductor size no.14 AWG, high molecular weight polyethylene color-coded insulation, suitable fillers and binder tape with a PE overall jacket and be rated at 600 volts. These cables shall be suitable for use in conduit, duct, aerial, or direct burial installations. The outer jacket shall be black. The color coded insulation shall not fade and the stripes shall not come off.

All multi-conductor control cable shall be manufactured in accordance with International Municipal Signal Association (IMSA) specification #20-1. The Manufacturer shall provide at or before the time of delivery, three (3) copies of certification stating that the cable was manufactured under and does meet or exceed the requirements set forth in IMSA specification #20-1.

The cable shall be placed on non-returnable reels of sufficient drum diameter so as not to damage the cable by exceeding its minimum bending radius. The reel shall have an arbor hole capable of admitting a spindle of 2-1/2 inches diameter without binding. Each reel shall be stenciled or labeled with the Manufacturers name, plant location, date of manufacture, gross weight, length and description of cable. Both ends of the cable shall be easily accessible for inspection and testing. Each reel shall contain one and only one continuous length of cable. The ends shall be tightly sealed and securely fastened to prevent cable from loosening during shipment and/or storage. A suitable covering shall fill the outer circumference of the reel to prevent damage to the cable during shipment and/or storage.

The manufacturer shall guarantee the cable supplied under this specification to meet all parts of this specification and shall agree to replace any length of cable found defective on material or workmanship during inspection of or installation of the cable. All replacement by the Manufacturer shall be free of charge to the City, including all freight and handling charges. Cable replaced under this guarantee shall, at the written request and expense of the Manufacturer, be returned to the Manufacturer by the City, unless, in the City's opinion, the removal of said cable is prohibitive.

Overruns will not be accepted.

C. Inductive Loop Lead Wire

Between the traffic detector sensor unit and the pull box or other location where the loop detector conductors are spliced to a shielded lead-in cable for the “home run” to the controller cabinet, the loop detector conductors shall be twisted as shown in the Design Standards and Plans. The traffic detector lead conductor shall be stranded copper #14 AWG. The insulation shall be Type XHHW cross-linked polyethylene insulated UL listed and color coded as shown on the Plans.

D. Inductive Loop Saw-cut Sealant

Saw cuts for loop wire installed as shown on the Plans shall be sealed with an approved two-part embedding sealant manufactured specifically for embedding electrical wire or cable in concrete or bituminous pavement. Such sealant shall be on the qualified products list maintained by the Tennessee Department of Transportation’s Materials and Test Division. It shall resist upward movement of the 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 anticipated temperature and weather conditions. Other sealants manufactured for embedding electrical wire or cable in bituminous or concrete pavement shall not be used unless approved by the Engineer.

The encapsulant shall be a one-part elastomeric compound requiring no mixing, measuring or application of heat prior to or during its installation. The encapsulant shall, within its shelf life in original undamaged packing, cure only in the presence of moisture. The encapsulant shall be designed to enable vehicular traffic to pass over the properly filled saw cut immediately after installation without stringing of the material. The encapsulant shall form a surface skin allowing exposure to vehicular traffic within 30 minutes at +24°C (+75 F) and completely cure to a tough rubber-like consistency in two (2) to seven (7) days after installation.

Properly installed and cured encapsulant shall exhibit resistance to effects of weather, vehicular abrasion, motor oils, gasoline, antifreeze solution, brake fluid, deicing chemicals and salt normally encountered, in such a manner that the performance of the vehicle detector loop wire is not adversely affected.

The cured encapsulant shall be temperature stable and exhibit no degradation in performance throughout the ambient temperature ranges experienced within the Continental United States. The encapsulant shall exhibit minimal shrinkage during or after its installation, and in no manner affect the performance characteristics of the material.

The encapsulant shall be designed to permit clean-up of material and application equipment with non-flammable cleaner that shall not threaten harm to workers or the environment.

The encapsulant shall be designed for roadway installation when the surface temperature is between +4°C (+40 F) and +60°C (+140 F). The encapsulant shall have the following physical properties in its cured and uncured states as shown in Table 801-1 and Table 801-2:

Table 801-1 Physical Properties of the Uncured (Wet) Encapsulant

PROPERTY	REQUIREMENT	TEST PROCEDURE	ASTM REFERENCE
A. Weight	10.3 lbs/gal +(-) 0.3 lbs	A. Weight/Gallon	D-1875
B. Total solid by weight	75% minimum	B. Determination of non-volatile content	D-2834
C. Viscosity	5,000-85,000 cps	C. Viscosity	D-1048B
D. Drying time	Touch: 24 hrs. max.	D. Tack-free time	D-1640
E. Non-Flow	70% minimum	E. Retention Test	

Table 801-2 Physical Properties of the Cured Encapsulant

PROPERTY	REQUIREMENT	TEST PROCEDURE	ASTM REFERENCE
A. Hardness (Indentation)	60-85	A. Rex hardness	D-2240
B. Tensile Strength	800 psi min.	B. Tensile and Elongation	D-412A
C. Elongation at break	400% min.	C. Tensile and Elongation	D-142A

The supplier shall provide a letter of certification from the manufacturer confirming the physical properties identified in Table 801-1 and Table 801-2 on each lot shipped.

The encapsulant shall be packaged in five-gallon pails. Such pails shall be DOT-37a80 open head pails and the covers be sealed with tubular neoprene gaskets. Such pails shall contain a minimum of 4.5 gallons of encapsulant material in order to permit pumping directly from the pail to the saw slot by commercially available pumps, requiring insertion of a follower-plate in the plate in the pail to form an appropriate seal. Encapsulant material shall be ordered in multiples of 4.5 gallons. The encapsulant shall have a minimum one year of shelf-life in undamaged original containers when store in a cool, dry environment when packaged in 5 gallon pails.

E. Shielded Loop Lead-in Cable

Shielded loop lead-in cable shall be stranded copper, two conductors twisted, #14 AWG with each conductor polyethylene insulated. The cable shall have an aluminum 100 percent polyester shield with a #16 AWG drain wire having a chrome vinyl jacket. The shield shall be outside the conductors. The outer jacket shall be PVC. The cable shall be UL listed, Style 2106.

For aerial installations of shielded detector cable, the cable shall be a self-supporting aerial cable. The outer jacket shall be polyethylene. The cable shall have an integrated ¼” messenger cable made of 7 wire extra high strength (6,650 lb. test) flooded galvanized steel strand. This cable shall be in accordance with IMSA Specification 20-4.

F. Power Service Cable for Secondary Radar Detection Unit

The wires from the primary RDS cabinet to the secondary RDS cabinet shall be two #14 AWG copper wire cables with each conductor color coded, insulated, and an outer jacket of PVC, UL listed.

801.03 INSTALLATION

All electrical cables and conductors shall be installed according to these Specifications.

A. Cable Pulling in Conduit

All cables and conductors shall be pulled into conduit using ropes or pull lines with pull wheels, making the pull parallel to the conduit opening. Pulling shall be by hand with pulling compound for lubricant approved by the Engineer. No power or mechanical puller shall be used. A cable grip to distribute the pulling force over a minimum of 1 1/2 feet of the cable shall be used. All cable and conductor in any section of conduit shall be pulled as one bundle. The pull force in pounds shall not exceed 0.008 times the summation of the mil cross-section area of the conductor wires being pulled. The insulation on the cables and conductors shall not be used in calculating the pull force.

B. Cables Attached to Spans

Cables shall be attached to span or messenger wire by means of copper clad spiral lashing rods of the proper size for the cable being attached. Lashing rods shall be installed end to end.

C. Inductive Loop Lead Wire in Saw-Cut

The detector loop saw cuts shall be made with appropriate pavement saw and cooling lubricant. The width and depth shall be as required in the Design Standards or Plans. Before placement of the wire, the saw cut shall be cleaned and dried with compressed oil free air. Inductive traffic detection loops shall be installed as required in the Design Standards (T/S 6). Saw cuts for loop wire installed as shown on the Plans and Design Standards shall be sealed with an approved two-part embedding sealant as described in **Subsection 801.02**.

C. Wiring Terminations

All field wiring shall be attached in the controller cabinet to the terminals and labeled as to function of each cable and conductor, conforming to the Plans. The Contractor shall attach the electrical service lead. All wiring ends to be terminated on terminal blocks in the controller cabinets, signal heads, or elsewhere shall be fitted with a crimp-on, vinyl insulated spade wire terminal of the proper size.

D. Power Service Drops

The Memphis, Light, Gas & Water Division (MLG&W) shall provide an electrical secondary service drop for each cabinet. These drops shall be overhead or into the cabinet if source is underground. The Contractor shall coordinate with MLG&W for the service drop and make the connection from the drop to the cabinet panel terminal. The MLG&W service drops shall be a two-conductor No. 6 aluminum cable. The Contractor shall splice to the drop as required to a two-conductor #6 AWG copper cable using a plated split-bolt connector with spacer for joining copper to aluminum. The splice shall be covered and weatherproofed using electrical tape forming an insulation equal or greater than the connecting cables. The Contractor shall bring the overhead drop into the cabinet through the conduit and signal pole system shown on the Plans. Underground power service shall be coordinated with the Memphis, Light, Gas and Water Division with power service provided in a pole or cabinet foundation. The power supply connection shall be made to a 30 ampere circuit breaker mounted in the cabinet separate from the signal terminal panel. Two (2) power outlets with a duplex outlet receptacle with U-type ground slot shall be provided in the cabinet.

E. Signal Cable

All splices in the signal wiring shall be made with solderless connectors of a copper sleeve compressed type, crimped with a suitable crimping tool, and covered with a screw-on, removable, reusable plastic cap. All splices shall be made in the pole bases and conduit. A cover kit shall be placed over splices as shown in the Plans or when directed by the Engineer.

F. Shielded Loop Lead-In Cable:

All splices between Loop Detector Leads and Shielded Loop Lead-In Cable shall be soldered with resin core electrical component material. The soldering unit shall have a heating capability for use with #12 AWG wire connections. A heat sink device shall be used when making the solder joint. The soldered joint shall be covered with a screw-on, removable, reusable plastic cap. After installation of the splice cap, the cap shall be thoroughly filled with an electrical grade fast-drying sealing compound. The splice shall then be held inverted until the compound sets. Splices shall be made in the pole bases, conduit, or pull boxes.

801.04 TESTING

All electrical cables and conductors shall be tested according to **Subsection 103.03 – Circuit Tests**.

All detector loops and leads shall be tested before and after they are sealed in the pavement to be sure there are no shorts to ground in the system and to assure that the loop plus lead-in inductance is within the operating range of the detector, all according to the Standards on loop installation.

801.05 MEASUREMENT AND PAYMENT

The accepted length of electrical cables and conductors of each type and size (number of conductors) installed shall be measured in linear feet to the nearest foot from point to point along the routing for each cable. Any conduit shall be measured and paid separately.

A. Power Service Drop Cable

Horizontal overhead runs of accepted two-conductor power service cable shall be measured from face of pole to face of pole. Vertical runs shall be measured from ground surface to the weatherhead for cable either in a pole or in a conduit. No measurement shall be made for entries or connections. This item includes the required splicing and termination in the cabinet, cable pulling, lashing, and other incidentals for complete installation. When power service is provided in the controller cabinet by others, no payment shall be made to the Contractor for power service cable.

B. Signal Conductor Cable

For accepted signal conductor cable of each size, horizontal measurement shall be made by face to face measurement from pole to pole or, when terminating in a signal head, the distance from face of pole to the signal head. Vertical measurement shall be made by one of the following:

- The distance from the ground to the weatherhead (or mast arm).
- The distance from the bottom of the controller cabinet to the weatherhead (or mast arm).
- The distance from the bottom of the controller cabinet to the ground.
- The distance from the ground to the bottom of the signal head or pedestrian push bottom.
- The distance from the weatherhead (or mast arm) to the top of the signal head or pedestrian push button.

On both horizontal and vertical runs with two or more cables, each cable shall be measured separately. To the above measurement shall be added six (6) feet for each entry and for each exit of a signal head; and for each entry into a controller cabinet, eight (8) feet shall be added. No measurements shall be made of splices required in pole base, condulets, or signal heads and other items which are incidental to the cable.

This item includes all terminations, splices, cable pulling, lashing, and other incidentals required for installation and hookup.

C. Shielded Loop Lead-in Cable

For accepted two-conductor shielded loop lead-in cable installed between the controller cabinet and the loop detector wires, horizontal measurements (overhead or underground) shall be made by one of the following:

- From outside face of pull box to outside face of pull box.
- From outside face of pull box to the outside face of a pole.
- From outside face of pole to outside face of pole.

Vertical measurements shall be made by one of the following:

- From the ground to the weatherhead.
- From the bottom of the controller cabinet to the weatherhead.
- From the bottom of the controller cabinet to the ground.

801.05 Measurement and Payment

On both horizontal and vertical runs with two or more cables, each cable shall be measured separately. To the above measurement shall be added four (4) feet for each entry and for each exit of a pull box or pole foundation. For entry into the controller cabinet, eight (8) feet shall be added. No measurement shall be made of splices required in pull boxes or condulets, lashing rods, and other items which are incidental to the cable installation.

This item includes splicing, pulling, lashing, and other incidentals required for a complete installation.

D. Power Service Cable for Secondary RDS Unit

For accepted power service cable from the primary to the secondary RDS cabinet, measurements shall be made using the same methods defined in the Shielded Loop Lead-in Cable subsection above. This item includes splicing, pulling, lashing, and other incidentals required for a complete installation.

D. Inductive Loop Lead Wire

Accepted inductive loop lead wire furnished and installed shall be measured to the nearest foot along the saw cut and any conduit between the near loop edge to the outside face of a pull box, pole, or edge of pole foundation (whichever applies). Ten (10) feet shall be added to the above measurement for each pull box entry, entry to a pole riser, entry to a pole with the controller cabinet, or entry into a pole (whichever applies). This item include required saw cut, twisted wire, sealant, and other incidentals required for a complete, tested, and operable installation.

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

Item Number	Description	Pay Unit
02890-801.01	Two-conductor Power Service Cable	L.F.
02890-801.02	RDS Power Service Cable (For Secondary RDS Unit)	L.F.
02890-801.03	Power Service Cable (Description)	L.F.
02890-801.04	Power Service Cable (Description)	L.F.
02890-801.11	Signal Cable (3 Conductor)	L.F.
02890-801.12	Signal Cable (5 Conductor)	L.F.
02890-801.12	Signal Cable (7 Conductor)	L.F.
02890-801.14	Signal Cable (12 Conductor)	L.F.
02890-801.15	Signal Cable (16 Conductor)	L.F.
02890-801.16	Signal Cable (Description)	L.F.

Section 801 – Electrical Cables and Conductors

801.05 Measurement and Payment

02890-801.17	Signal Cable (Description)	L.F.
02890-801.18	Signal Cable (Description)	L.F.
02890-801.19	Signal Cable (Description)	L.F.
02890-801.20	Signal Cable (Description)	L.F.
02890-801.21	Shielded Loop Lead-in Cable (2 Conductor)	L.F.
02890-801.22	Inductive Loop Lead Wire	L.F.

SECTION 811 – FIBER OPTIC CABLES, SPLICING, AND TERMINATION**811.01 GENERAL**

This section specifies the minimum requirements for fiber optic infrastructure furnished and installed (underground and aerial). This work includes, but is not limited to, cable, splicing, termination, connectors, closures, panels, installation, and testing.

The fiber optic infrastructure will serve as the backbone for the communications systems (wireline) and will be used to transport data and video signals to/from field device locations using standard Ethernet (TCP/IP) protocols.

A. Applicable Standards and Specifications

The Contractor shall furnish fiber optic infrastructure materials that meet applicable industry standards including, but not limited to:

- Fiber optic cable manufacturer shall comply with RUS Bulletin 1753F-601 and be currently ISO 9001 certified
- Provide and install fiber optic cable in accordance with contract drawings, specifications, IEEE C2 (NESC), NFPA 70 (NEC), ICEA S-83-596, UL 1666
- EIA/TIA-455 Testing procedures
- Telcordia
- UL
- Fiber optic cable physical requirements and cable construction shall be in accordance with ICEA S-87-640, ASTM D 4976
- Fiber optic cables shall be tested in accordance with ASTM C 338

Upon request of the Engineer, provide certification from an independent testing laboratory that certifies that the cable conforms to industry standards.

B. General Requirements

Furnish all fiber optic trunk and distribution cables, drop cable, splice enclosure, fiber optic termination unit, optical termination and connectorization materials, and all ancillary and incidental materials that are single-mode compatible, unless otherwise specified on Plans.

All materials shall meet the following requirements:

- EIA/TIA-568-B.3, 598B, 758, Fiber Optic Connector Intermateability Standard (FOCIS), and Telcordia GR-20 core requirements.
- Manufacturer shall be currently ISO 9001 certified. This requirement applies to assemblers of manufactured components, such as patch cords and termination cabinet interconnection cables.
- All cables and termination infrastructure shall be assembled from Corning SMF28e, OFS All Wave or approved equivalent single-mode optical fiber.

811.02 Fiber Optic Cables (TRUNK and Distribution Lines)

- All cables shall have been manufactured and labeled no earlier than in the third calendar month preceding the City letting date of the contract.

811.02 FIBER OPTIC CABLES (TRUNK AND DISTRIBUTION LINES)

This section covers additional requirements for fiber optic (FO) cable for installation in underground conduit or for aerial installation in which the FO cable is double-lashed to a messenger cable.

A. Cable Design and Construction

FO cable shall be provided in fiber counts, lengths, and types (i.e., single-mode and multi-mode) as required. Furnish fiber optic infrastructure materials recommended by the manufacturer for outside plant use and the intended application.

Provide fiber optic cable that meets the following requirements:

- Rated for conduit and lashed aerial installations
- All-dielectric cable with no metal components
- Loose tube designed cable
- Shall have central strength/anti-buckling member.
- Dry, water blocking materials and construction
- Gel-free cable
- Reverse oscillating “SZ” stranded buffer tube construction
- High tensile strength yarn
- Contain a minimum of one (1) ripcord under the sheath for easy sheath removal
- Medium density polyethylene outer jacket shall be a consistent thickness that is free of holes, splits, and blisters, and containing no metal elements
- Outer jacket polyethylene shall contain carbon black for ultraviolet light protection and does not promote the growth of fungus.
- The fibers in cable shall be separated into individual groups of 12 fibers and grouped in a protective, color-coded sheath or buffer tube. The color coding standard shall meet requirements of EIA/TIA-598C.

B. Transmission Performance

The maximum attenuation measured on the reel shall not exceed the following values:

- Single Mode: 0.35 dB/km at 1310 nm
- Multi-Mode: 1.0 dB/km at 1300 nm

C. Physical and Environmental

- Ensure that the cable can withstand a maximum pulling tension of 600 lbf during installation and 180 lbf installed long term (at rest)
- Storage and operating temperature range: -40°C to +70°C

- Installation temperature range: -30°C to +70°C
- Maximum diameter: 0.45 inches
- Maximum weight: 55 pounds per 1000 foot
- Minimum bending radius: 6.5 inches loaded, 4.5 inches installed

D. Cable Length and Marking

For all locations where both trunk line (hub cabinet to hub cabinet) and distribution line (providing local cabinet drops) cables sharing the same conduit, the trunk line cable shall be black and have a continuous, extruded yellow stripe on cable jacket or sheath. The distribution line cable shall be black with no stripe on cable jacket or sheath.

The cable jacket or sheath shall be marked with the manufacturer's name, the words "TRAFFIC SIGNAL CABLE," fiber type (e.g., single mode or multi-mode), number of fibers, date of manufacture, and sequential length in English unit. The markings shall be repeated every three feet for length markings and at least every six feet for other cable information. Markings shall be in white or yellow and shall be permanent, withstanding normal cable installation and operations. The actual length of the cable shall be within -0/+1 percent of the length marking. The character height of the markings shall be approximately 3/32 inch.

811.03 FIBER OPTIC DROP CABLES

The Contractor shall furnish and install fiber optic drop cables at locations shown on the Plans. Each such drop cable shall comply with the same requirements defined in **Section 811.02** for fiber optic cables.

Individual 250 micron fibers shall be up-jacketed to 0.12 inch fan-out tubing. This tubing shall contain a 900 micron Teflon inner tube, aramid yarn strength members, and an outer jacket. The fan-out tubing shall be secured to the cable in a hard epoxy plug transition. Length of the individual legs shall be a minimum of 3 feet with the length difference between the shortest and longest legs of the assembly being no more than 2 inches.

A. Pre-fabricated Drop Cable Assemblies (Optional)

The Contractor may use pre-fabricated fiber optic drop cable assemblies. The assemblies shall be factory assembled and terminated on one end with a ceramic ferrule LC-compatible, heat cured epoxy connector that meets the specifications in **Section 811.04**. Pre-fabricated drop cables shall meet the same requirements defined in **Section 811.02** for fiber optic cables.

811.04 SPLICE, CONNECTORS, AND JUMPERS

A. Fusion Splice

Provide fusion splices for splicing of all fibers. Do not provide any other type of fiber splicing.

Perform fusion splicing with a fully automatic portable fusion splicer that provides consistent low loss (max 0.10 dB) splices. Splicer shall provide three-axis fiber core alignment using light injection and loss measurement techniques. The fusing process shall be automatically controlled. The splicer shall provide splice loss measurements on an integral display, as well as

a magnified image of the fiber alignment. The Contractor shall retain ownership of the fusion splicer.

B. Connectors

- Provide fiber optic connectors compliant with these specifications for all fiber optic infrastructure including, but not limited to, fiber optic termination cabinets, fiber optic branch panels, and fiber optic patch cords.
- Provide only factory-installed keyed LC compatible connectors for all fiber optic infrastructure. Provide only factory-installed connectors of a type other than LC when required by the Network Switches. Do not use field-installed connectors. Do not use adapter couplers to change connector types.
- Use ceramic ferule connectors factory-installed with a thermal-set heat-cured epoxy and machine polished mating face. Install connectors as per manufacturer application and recommendations, including proper termination to the outer-tubing (900 micron tubing, 3 mm fan out tubing, etc.) required for the application.
- Use connectors rated for an operating temperature of -40°C to +75°C.
- Provide connectors that have an installed insertion loss of less than 0.50 dB, a typical loss of 0.20 dB, and an optical return loss of greater than 45 dB.
- Use simplex connectors for all male LC connectors. Provide latching cover for two male connectors being used in a duplex configuration. Female couplers may be duplex but must allow simplex mating connectors.
- Label each fiber position on panels and termination cabinets containing duplex couplers with the port/position ID as shown in the Plans.
- Provide dust caps for all exposed male connectors and female couplers at all times until permanent connector installation.
- LC connectors shall comply with TIA/EIA-4750000-C and TIA/EIA-604-10A.

C. Patch Cords (Jumpers)

All fiber optic patch cords (jumpers) shall be compatible with the specified fiber types and connector types. Multi-mode patch cords shall be orange in color and single mode patch cords shall be yellow in color. All connectors shall be LC compatible unless specified otherwise on Plans or approved by Engineer.

- All patch cords shall be factory pre-connectorized assemblies adhering to all applicable cable and fiber specifications stated in these Specifications.
- Provide patch cords of the appropriate length for the necessary connections, maintaining minimum bend radius, and with no residual strain at the connector or anywhere on the patch cord itself beyond self-support. Patch cords shall not have excess length beyond what is necessary for equipment connection and routing.
- All patch cords shall be duplex zip-cord fiber cable with simplex LC connectors.
- The two connectors of each end of the patch cord shall be differentiated by different colors.

811.05 Fiber Optic Splice Enclosure

- Provide sufficient flexibility at each end to disconnect one connector without disturbing the other, or to allow swapping of the two connectors within the same duplex coupler without disturbing the remainder of the patch cord.
- Provide strain relief and reinforcement at the point where the duplex cable separates for the individual simplex connectors.
- Fiber cable shall be 3mm jacketed cable with high tensile strength yarn protecting the inner fiber manufactured into a duplex zip-cord configuration. All Inside Plant patch cords shall meet NEC jacketing requirements.
- Connector strain relief boots shall be fixed to the outer jacket and strength yarn.
- No splices of any type are allowed within a patch cord assembly.
- Multi-mode cordage attenuation shall not exceed 3.75 dB/km at 850 nm and 1.5 dB/km at 1300 nm. Single mode attenuation shall not exceed 1.0 dB/km at 1310 nm and 0.75 dB at 1550 nm.
- Fully test each patch cord assembly at the source of manufacture and place those test results on a test tag for each mated pair of connectors. Attach the associated tag to one end of each fiber within the duplex assembly.

811.05 FIBER OPTIC SPLICE ENCLOSURE

Fiber optic splice enclosures shall be designed for outside plant use, and for both aerial or in pull box underground installations. Splice enclosures shall be fully compatible with all components of the fiber optic infrastructure as specified.

- Use fiber optic enclosures that are impact and corrosion resistant and waterproof when immersed in 10 feet of water.
- Enclosures shall be made of high density polyethylene or equivalent non-metallic material. A canister-type splice enclosure shall have cable entry at one end only and a sealed single-molded piece dome. A box-type splice enclosure shall have cable entries at both ends.
- The cable entry end shall be manufactured of a similar material as the dome body and shall seal the enclosure with flexible thermoplastic rubber or polymer gasket seals.
- The cable entry end shall include cable entrance ports that shall seal the cable and port opening with flexible thermoplastic rubber or polymer gasket seals with mechanical compression.
- Enclosures shall be re-enterable and re-sealable without the use of any additional parts. Only a standard size can/ socket wrench, or nut/ screw driver shall be required to re-enter and re-seal the enclosure.
- For canister-type splice enclosures, clamping ring shall have bolts to seal the enclosure. When closing, clamping ring shall be tighten with bolts torqued to 50 in-lb (or manufacture's recommended value). Enclosure design with no-tool sealing system (clamping with no bolts) is not acceptable.
- Do not use any heat shrink or caulk/encapsulate materials for sealing the assembled enclosure or terminated cables.

811.06 Fiber Optic Termination Unit

- Provide splice enclosures with a maximum outer dimensions of 7 inches diameter and 28 inches length for canister-type enclosure. Provide splice enclosures with a maximum dimension of 18" (L) x 10" (W) x 4" (H) for box-type enclosures.
- Splice enclosures shall provide cable entrance ports for at least four fiber optic cables.
- The enclosure shall allow for the storage and express of at least six unopened buffer tubes.
- Provide a splice enclosure with a cable entry end with pre-template cable ports and a split-plate design permitting installation of the enclosure in mid-span cable segments.
- The enclosure shall have a minimum splicing capacity for 96 single-fiber fusion splices.
- Splice trays shall be standard in size by the manufacturer, not customized. Each splice tray shall have 24 single fusion splice capacity. Splice trays can either be metal or plastic, and shall be fully compliant to Telecordia GR-769.
- A minimum of two splice trays shall be installed for each enclosure. If more than 36 splices are required on Plans, four splice trays shall be installed.

811.06 FIBER OPTIC TERMINATION UNIT**A. Termination Unit for Hub Cabinet or TMC**

- Fiber optic termination unit shall be designed for outside plant use and for installation in hub cabinets. Fiber optic termination unit shall be fully compatible with all components of the fiber optic infrastructure as specified.
- Use rack-mount termination units designed to fit standard 19-inch EIA equipment racks.
- Minimum dimensions of a complete termination unit shall be 4 rack units high (7 inches) by 14 inches deep.
- Provide 12 adapter panels with a total of 144 single mode LC fiber connectors, six duplex connector couplers (12 connectors total) per panel. Any unused front panel adaptor positions shall be covered with blanks. Any spare connectors shall be covered front and back by manufacturer recommended method.
- Provide six splice trays for storing 144 single fusion splices, 24 splices per tray.
- Use termination units that integrate the splice trays and connector modules into one compartment within one cabinet, or houses the splice trays and connector modules in separate compartments integrated into one cabinet.
- Use fiber optic termination unit with fully enclosed metallic construction and with a protective hinged front cover for the connector ports.
- Provide all mounting hardware and supports to mount the termination units in the locations shown in the Plans.
- Provide cable access on all sides of the enclosed area behind the connector port panel.
- Connector modules shall include clearly legible and permanent labeling of each of the 12 fiber connector couplers, and shall be labeled and identified as shown in the Plans.
- Provide factory-assembled 12 fiber termination interconnect cables (pigtail cables) to be fusion spliced to the outside plant cable and connected to the rear of the connector modules.

- Provide all incidental and ancillary materials including, but not limited to, grommets, cable strain relief and routing hardware, blank connector panels, and labeling materials.

B. Termination Unit at Field Cabinet (Fiber Distribution Box)

- Fiber distribution box shall be designed for outside plant use and for installation in field cabinets. Fiber optic termination unit shall be fully compatible with all components of the fiber optic infrastructure as specified.
- Fiber distribution box shall allow one 6-fiber drop cable entry.
- Maximum outside dimensions are 8.2" W x 10" T x 3.5" D.
- Provide one adapter panels with six duplex LC connectors (12 connectors total) Any unused front panel adaptor positions shall be covered with blanks. Any spare connectors shall be covered front and back by manufacturer recommended method.
- Fiber distribution box shall be fully enclosed metallic construction, with a lockable side door.
- Provide all mounting hardware and supports to mount the termination units in the locations shown in the Plans.
- Provide factory-assembled 6-fiber termination interconnect cables (pigtail cables) to be fusion spliced to the drop cable and connected to the rear of the connector modules.
- Provide all incidental and ancillary materials including, but not limited to, grommets, cable strain relief and routing hardware, blank connector panels, and labeling materials.

811.07 CABLE MARKER

The contractor shall install cable markers to identify the proposed fiber optic communication cables. Legends and colors for markers are to appear according to the information supplied by the City of Memphis Traffic Signal Maintenance Department. The markers are to be permanent, brightly colored, non-reflective, with black lettering. Markers are to be manufactured of plastic, vinyl or fiberglass material that is durable, UV light-resistant, weather-proof and scratch-resistant.

A. Curb Cable Marker

Curb markers shall be installed to identify cables that are in or near the street. Curb markers are to be four-inch diameter round disks to be applied to concrete or metal surfaces with an adhesive according to the recommendations of the manufacturer. Curb markers are to be installed on cabinet and pole foundations on the side above the cable. Curb markers are to be installed on the street curb over the location of crossing cables. Curb markers are also to be placed on the curb at 150-foot spacing along any run of cable that is parallel to the curb. Where paved shoulder exists instead of curb, place curb markers on the pavement surface one foot from the edge of the surface, or directly over the conduit or cable. Curb markers are to be Duracast style curb markers made by DAS Manufacturing, or approved equal.

B. Aerial Wrap-around Cable Marker

Wrap-around markers shall be installed on overhead cables attached to any pole that is not a traffic signal pole. Wrap-around markers are to be securely attached to the cable in a way that allows the marker to be un-wrapped and re-wrapped multiple times without any tools or

adhesives. Wrap-around markers are to be snap signs manufactured by Rhino Marking and Protection Systems, or approved equal. Wrap-around markers are to be placed on the cable at 150-foot spacing along the aerial cable run, and at locations specified by the City.

C. Post Cable Marker

Post cable markers shall be installed along underground cable runs under wide grass median or roadside grass area. Post markers shall be domed posts made of UV-stable polyethylene with custom graphics permanently molded into the product. Post markers are to be domed posts manufactured by William Frick & Company, or approved equal. Post markers are to be placed on top of the cable run in grass areas at 150-foot spacing.

811.08 INSTALLATION

Install all fiber optic infrastructure according to the manufacturer's recommended procedures and specifications.

A. Installation and Testing Tools

Fiber optic installation and testing tools shall be maintained and calibrated in accordance with the tool manufacturer's recommendations. Provide tool manufacturer certified calibration documentation upon Engineer's request. Installation and testing tools include but are not limited to:

- Fusion splicers
- Cable pulling strain dynamometers and breakaway links
- Cable air jetting/blowing systems
- OTDRs
- Optical attenuation testers (light sources and power meters)

Fiber optic installation and testing tools shall be operated only by Contractor personnel who have been trained and certified by the tool manufacturer. Installation and testing tools requiring certified operators include but are not limited to:

- Fusion splicers
- Cable air jetting/blowing systems
- OTDRs
- Optical attenuation testers (light sources and power meters)

B. Cable Shipping and Delivery

- Package the cable for shipment on factory reels. Each package shall contain only one continuous length of cable. Radius of the reel drum shall not be smaller than the minimum bend radius recommended by the manufacturer for the media. Construct the packaging so as to prevent damage to the cable during shipping and handling.
- Seal both ends of the cable to prevent the ingress of moisture.

- Include with each reel a weatherproof reel tag attached identifying the reel and cable that can be used by the manufacturer to trace the manufacturing history of the cable and the fiber. Include with each cable a cable data sheet containing the following information:
 - Manufacturer name
 - Cable part number
 - Factory order number
 - Cable length
 - Factory measured attenuation of each fiber
- Cover the cable with a protective and thermal wrap.
 - Securely fasten the outer end of the cable to the reel head so as to prevent the cable from becoming loose in transit.
 - Project the inner end of the cable a minimum of 6.5 feet into a slot in the side of the reel or into a housing on the inner slot of the drum, in such a manner to make it available for testing.
 - Plainly mark each reel to indicate the direction in which it is to be rolled to prevent loosening of the cable on the reel.

C. Cable Handling and Installation

- Do not exceed the maximum recommended pulling tension during installation as specified by the cable manufacturer.
- Continuously monitor pulling tensions with calibrated measuring devices, such as a strain dynamometer.
- Protect all pulled installations with calibrated breakaway links.
- Do not violate the minimum recommended bend radius during installation as specified by the cable manufacturer. Unless the manufacturer's recommendations are more stringent, use the following guidelines for minimum bend radius:
 - 20 X Cable Diameter Short Term - During Installation
 - 10 X Cable Diameter Long Term – Installed
- Before cable installation, carefully inspect the cable reels and reel stands for imperfections or faults such as nails that might cause damage to the cable as it is unreeled.
- Take all necessary precautions to protect reeled cable from vandals or other sources of possible damage while unattended. Any damage to reeled cable or the reel itself shall necessitate replacement of the entire cable section at Contractor's expense.
- Whenever unreeled cable is placed on the pavement or surface above a pull box, provide means of preventing vehicular or pedestrian traffic through the area in accordance with the approved Maintenance of Traffic provisions.
- Keep the cable continuous throughout the pull. Cable breaks and reel end splices are permitted only as shown in the Plans.

- Where a cable ends in an underground fiber optic closure, secure and store all unused fibers and buffer tubes in splice trays in preparation for future reel end splicing and continuation.
- Except as otherwise specifically called for on the Plans, fiber optic cables shall enter the cabinets by means of a separate riser or conduit entrance.
- All cabinet entrance and installation requirements in City and TDOT Design Standards shall be followed.
- Sealing bushings rather than weather heads shall be used on all risers containing fiber optic cable. Conduit bends and cabinet entrance fittings shall be designed to accommodate the bending radius limitations of the fiber optic cable. Sealing bushings shall also be provided in new holes drilled into the sides of existing steel poles for the entrance of the fiber optic cables.

C. Cable Storage Coils

- Properly store all cable to minimize susceptibility to damage.
- Maintain proper bend radius, both short and long term, during cable storage.
- Storage coils shall be neat in even length coils, with no cross over or tangling.
- Storage coils of different cables shall be kept completely separate.
- Storage coils shall be secured to cable racking hardware with tie wraps, Velcro straps, or non-metallic cable straps with locking/buckling mechanism.
- Do not use adhesive or self-adhering tapes, metal wires and straps, or rope/cord.
- Unless otherwise noted on the plans, the following are the requirements for cable slack storage:
 - Fiber optic cable in Type “A” pull box (No splicing) – 50 feet total
 - Fiber optic cable in Type “B” pull box (No splicing) – 100 feet total
 - Fiber optic cable in any type pull box (splicing or termination) – 50 feet on each side of the splice enclosure
 - Fiber optic cable in aerial splice – 50 feet on each side of the splice enclosure
 - Drop cable in cabinet – 10 feet
- The Contractor shall submit to the Engineer the cable foot markings for each cable entering and exiting a pull box and splice enclosure to verify that the correct amount of cable is coiled. Any coiling less than the required amount by 5% shall be corrected to the City’s satisfaction and at the Contractor’s expense. Any excessive coiling will not be paid.

D. Fusion Splice

- Perform fusion splicing of all fiber optic splices as shown in the Plans in the locations shown.
- Perform fusion splicing only in enclosed spaces such as splice trailers or tents specifically intended for this operation.

- Completed fusion splices shall have no more than 0.10dB optical loss as measured in accordance with **Section 811.09**.
- Adequately protect all fusion splices in splice trays in a splice closure or termination unit. Provide the splice with strain relief and protection of the stripped fiber splice in a manner recommended by the fiber and the splice tray manufacturers.
- Use fusion splice protectors of a heat shrink tubing that protects the splice and extends over the fiber coating. Splice protectors shall be compatible with and as recommended by the fiber and the splice tray manufacturers.
- No bare fiber may be exposed.

E. Splice Enclosure

- Install fiber optic splice enclosures as shown in the Plans. Install splice enclosures in the center \pm 3 feet of the entire length of stored cable coils, or install at the end of cables that terminate in the pull box.
- Store FO enclosures and cable coils on the pull box cable rack hooks. Keep all enclosures and cable coils off of the bottom of the pull box. Secure enclosures and/or cable coils as needed to hold them in place.
- Secure aerial fiber optic splice closures to messenger cable using manufacturer recommended hanger kit.
- Coil 50 feet of fiber optic cable on either side of splice closure. Bending radius shall not exceed manufacturer recommended bending radius.

F. Termination Unit

- Install all fibers, buffer tubes, and cables following minimum internal and external bend radius, proper management, routing, fastening and protection, and with no residual strain on any connector, fiber, buffer tube or cable.
- Keep all fibers of the outside plant cable buffer tube complete within the same splice tray.
- Label each cable with cable ID on Plans to identify the trunk or distribution cable fibers/buffer tube connected; use permanent overlapping cable labels with clearly legible text.
- Any unused front panel adaptor positions shall be covered with blanks. Any spare connectors shall be covered front and back by manufacturer recommended method.

811.09 TESTING

A. Project Submittal Program Requirements

The Contractor shall provide project submittals for all fiber optic infrastructure as required in Plans and these specifications, including scheduling requirements. The project submittals for fiber optic infrastructure shall include but are not limited to, the additional specific requirements in this subsection.

- Provide project submittals including manufacturer-recommended operations, maintenance, and calibration procedures for the following equipment:

- Fusion splicers
- Cable pulling strain dynamometers and breakaway links
- Cable air jetting/blowing systems
- OTDRs
- Optical attenuation testers (light sources and power meters)
- Submit documentation and proof of manufacturer-recommended operator training and certification for the following equipment:
 - Fusion splicers
 - Cable air jetting/blowing systems
 - OTDRs
 - Optical attenuation testers (light sources and power meters)

B. General Requirements

The Contractor shall conduct a project testing program for all fiber optic infrastructure as required in this section.

All test results shall confirm physical and performance compliance with these specifications including, but not limited to, optical fibers and fusion splices. No event in any given fiber may exceed 0.10 dB. Any event measured above 0.10 dB shall be replaced or repaired at the event point.

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

Provide test results documentation in electronic format and printed format one copy each. Electronic formats shall be readable in Microsoft Excel or other approved application. Printed copies shall be bound and organized by cable segment.

Provide all test results in English units of measure of length.

Submit all test results documentation to the Engineer within 14 days of completion of the tests. The Engineer will review test documentation in accordance with these Specifications.

C. Pre-Installation Test (PIT)

Perform a PIT on all FO Cable prior to any cable removal from the shipping reels. Perform a PIT on each cable reel delivered to the job site.

The PIT for FO Cable shall include but is not limited to:

- A visual inspection of each cable and reel
- An OTDR Test and documentation as required in the SAT below, for three randomly selected fibers from each buffer tube.
- An Optical Attenuation Test is not required. If the contractor decides to perform one for their own protection, said test should be documented and provided to the engineer.

D. Stand-Alone Acceptance Test (SAT)

Perform an SAT on all fiber optic infrastructure after field installation is complete, including, but not limited to, all splicing and terminations. An SAT for each fiber in each cable shall include OTDR Tests and Optical Attenuation Tests. All fibers in all FO Cables and FO Branch Cables shall be tested from termination point to termination point, including active or spare fibers:

- from FO Termination Unit to FO Termination Unit
- between end of fiber and FO Termination Unit
- between end of fiber and end of fiber

1. OTDR Test

- Conduct the OTDR Test using the standard operating procedure and recommended materials as defined by the manufacturer of the test equipment.
- Use a factory patch cord (“launch cable”) of a length equal to the “dead zone” of the OTDR to connect the OTDR and the fiber under test.
- Conduct bi-directional OTDR Tests for each fiber. Calculate bi-directional averages.
- Conduct all tests at 1310 nm for single mode cable.

2. Optical Attenuation Test

- Conduct the Optical Attenuation Test using the standard operating procedure and recommended materials as defined by the manufacturer of the test equipment.
- Conduct bi-directional Optical Attenuation Tests for each fiber. Calculate bi-directional averages.
- Conduct all tests at 1310 nm for single mode cable.

Test documentation shall include but is not limited to:

- Cable & Fiber Identification
 - Cable & Fiber ID and Location – Physical location (device ID and station number of FO Termination Unit or cable end FO closure), fiber number, and trunk or distribution cable ID for both the beginning and end point.
 - Operator Name
 - Engineer’s Representative
 - Date & Time
- Setup and Test Conditions Parameters
 - Wavelength
 - Pulse width Optical Time Domain Reflectometer (OTDR)
 - Refractory index (OTDR)
 - Range (OTDR)
 - Scale (OTDR)
 - Ambient Temperature

- Test Results for OTDR Test (each direction and averaged)
 - Total Fiber Trace (miles)
 - Splice Loss/Gain (dB)
 - Events > 0.05 dB
 - Measured Length (Cable Marking)
 - Total Length (OTDR Measurement)
- Test Results for Attenuation Test (each direction and averaged)
 - Measured Cable Length (Cable Marking)
 - Total Length (OTDR Measurement from OTDR Test)
 - Number of Splices (Determined from As-Builts)
 - Total Link Attenuation

All test results shall confirm compliance with these specifications including, but not limited to, optical fibers and fusion splices. No event in any given fiber may exceed 0.10 dB. Any event measured above 0.10 dB shall be replaced or repaired at the event point.

In addition, overall loss for each link shall not exceed the cumulative specified maximum losses of the components. For example, at 1310 nm, a one kilometer link with two splices and a connector on each end shall not exceed 1.9 dB:

2.0 km x 0.35 dB/km:	0.7 dB
0.1 dB per splice x 2:	0.2 dB
<u>0.5 dB per connector x 2:</u>	<u>1.0 dB</u>
Maximum allowable loss:	1.9 dB

Any overall loss for each link exceeding the maximum allowable loss shall be replaced or repaired.

811.10 MEASUREMENT AND PAYMENT

A. Fiber Optic Cable

The accepted length of fiber optic cables of each type (truck or distribution line, or drop cable) and size (number of fibers) installed shall be measured in linear feet to the nearest foot from point to point along the routing for each cable. Measurements shall be made by center to center horizontal distance measurement from:

- Pull box to pull box
- Pull box to base-mounted cabinet
- Pull box to pole
- Pole to pole and height of pole riser (for aerial installation only)

On both horizontal and vertical runs with two or more cables, each cable shall be measured separately. To the above measurement shall be added fifteen (15) feet for each entry into a controller cabinet or splice enclosure.

811.10 Measurement and Payment

Any storage coils in pullbox, aerial, or other places as specified on Plans shall be added to the above measured quantity according to the coil length required by **Section 811.08**.

The Contractor shall submit to the Engineer the cable foot markings for each cable entering and exiting a pull box and splice enclosure to verify that the correct amount of cable is coiled. Any coiling less than the required amount by 5% shall be corrected to the City's satisfaction and at the Contractor's expense. Any excessive coiling will not be paid.

Payment at the contract unit price shall be made for the accepted length of fiber optic cable of each type and fiber count installed. This shall be payment in full for all terminations, splices, cable pulling, lashing, and other incidentals required for installation and hookup.

B. Fusion Splice, Connector, and Patch Cord

Fusion splices, connectors, and patch cords are included in the quantities of other pay items and will not be measured separately for payment.

C. Fiber Optic Splice Enclosure and Termination Unit

Payment at the contract unit price, per each, shall be made for each accepted fiber splice enclosures or termination unit of the type specified. Such payment shall be payment in full for the splice enclosure or termination unit, splice trays, the splicing and cable terminations within the unit, connectors, adaptor panels, patch cords (jumpers), and any other hardware and incidental items required to provide a complete installation.

D. Cable Markers

Payment at the contract unit price, per each, shall be made for each cable marker furnished, installed, and accepted of the type specified. Such payment shall be payment in full compensation for all labor, tools, materials, equipment and incidentals necessary to complete the work.

Item Number	Description	Pay Unit
02890-811.01	Fiber Optic Trunk Cable (36 Fiber, Single Mode)	L.F.
02890-811.02	Fiber Optic Trunk Cable (__ Fiber, Single Mode)	L.F.
02890-811.11	Fiber Optic Distribution Cable (36 Fiber, Single Mode)	L.F.
02890-811.12	Fiber Optic Distribution Cable (18 Fiber, Single Mode)	L.F.
02890-811.13	Fiber Optic Distribution Cable (__ Fiber, Single Mode)	L.F.
02890-811.21	Fiber Optic Drop Cable (6 Fiber, Single Mode)	L.F.
02890-811.22	Fiber Optic Drop Cable (36 Fiber, Single Mode)	L.F.
02890-811.23	Fiber Optic Drop Cable (__ Fiber, Single Mode)	L.F.
02890-811.31	Fiber Optic Splice Enclosure (In Pull Box)	EACH

Section 811 – Fiber Optic Cables, Splicing, and Termination

811.10 Measurement and Payment

02890-811.32	Fiber Optic Splice Enclosure (Aerial)	EACH
02890-811.33	Fiber Optic Termination Unit (Hub Cabinet)	EACH
02890-811.34	Fiber Optic Termination Unit (TMC Rack)	EACH
02890-811.35	Fiber Optic Termination Unit (Distribution Box)	EACH
02890-811.41	Curb Cable Marker	EACH
02890-811.42	Wrap-Around Cable Marker	EACH
02890-811.43	Post Cable Marker	EACH

SECTION 821 – OTHER COMMUNICATION CABLES**821.01 RDS COMPOSITE CABLE**

Provide RDS Cable that is a composite power/CAT5e/RS-232 or RS-485 limited tray cable with UV-resistant PVC or polyethylene outer jacket rated for wet/dry underground use when RDS poles are separated from an equipment cabinet, as shown in the Plans. RDS Cable shall contain a minimum of two shielded twisted pairs of communications conductors designed for RS-232/485 data signaling, two low voltage power conductors, and a standard CAT5e cable with four twisted pairs of communications conductors. Individual conductor insulation ratings shall be equal or greater than the outer jacket ratings.

Communications conductors shall be a minimum of two twisted pairs and one shield drain wire of #22 AWG 7-strand tinned copper conductors with a continuous foil or braid shield. RS-232/485 signal ground shall be provided by the shield drain wire, an additional conductor, or an additional shielded pair, in accordance with the RDS unit manufacturer's recommendations. Twisted pairs shall be identified by separate insulation colors. Communications pairs shall be individually or commonly shielded.

CAT5e conductors shall consist of four twisted pairs of #24 AWG strand tinned copper conductors with a continuous foil or braid shield. Twisted pairs shall be identified by separate insulation colors.

Low voltage power conductors shall be two #14 AWG 19-strand tinned copper conductors. One conductor shall have red insulation and the other conductor shall have a black insulation. Low voltage power conductors shall not be shielded in common with the communications pairs.

Cable connectorization and termination pin-out on all cables shall be in accordance with the RDS manufacturer's recommendations.

Connection between the RDS and the cabinet equipment shall be provided by a single RDS harness cable that is MS-connector terminated at the RDS and terminated to the RDS communications wiring module in the equipment cabinets. No splices are permitted in the harness cable. The cable shall provide power, RS-232 or RS-485 serial data, and CAT5e interface to the RDS unit.

The MS connector pins must be crimped to the cable conductors and assembled and tested by the manufacturer prior to installation and pulling of cable on site.

Unused conductors in the RDS cable shall be grounded or un-terminated in the cabinet in accordance with the manufacturer's recommendations. Un-terminated conductors shall be individually doubled back and taped, then loosely bundled and secured.

821.02 VIDEO DETECTION CAMERA COAXIAL CABLE

Coaxial cable shall be plenum-rated RG 6/U cable. The bare copper conductor shall be #22 AWG. The bare copper braid shall provide 95 percent coverage.

821.03 Priority Control Detector Cable

821.03 PRIORITY CONTROL DETECTOR CABLE

The priority control detector cable shall be a matched component of the priority control system. The cable shall contain four (4) conductors and a shield. The conductors shall be #20 AWG stranded copper.

The conductors shall have different colored insulation. The orange wire will be for delivery of detector power. The bare braid wire will be the drain wire for detector power return. The yellow wire will be for detector signal #1. The blue wire will be for detector signal #2 or ground, depending on the model of detector installed. The insulation shall have a nominal thickness of 0.1-3/16 inches with a minimum thickness of 0.1 inch at any point. The insulation shall withstand 600 volts and shall be stabilized against the effects of ultra-violet radiation.

The shield shall be an aluminized polyester and have a AWG #20 (7 x 28) stranded and individually tinned drain wire to provide signal integrity and transient protection.

The conductors shall be twisted within the cable in the following color rotation: yellow, orange, blue, bare braid. The conductors shall be twisted at least six (6) turns per foot.

The maximum outside diameter of the cable shall be less than 0.3 inches.

The jacket of the cable shall be formed of black polyethylene having a density of 0.52 to 0.56 ounces per cubic inch as tested in conformance with ASTM D1248. The jacket shall have a nominal thickness of 3/16 to 11/16 inches with a minimum thickness of 3/16 inches at any point.

The cable jacket shall not deteriorate with prolonged exposure to typical roadway run-off components, such as oil and gasoline. The cable shall be suitable for installation in conduit and overhead supported by a messenger cable.

The insulation on the conductors shall be polypropylene or polyethylene.

Each wire entering the cabinet shall be labeled to indicate the associated direction and phase.

821.04 ETHERNET CABLE

Required copper Ethernet cables shall be category 5E or category 6, with appropriate connectors in the same category. Cable wiring shall be compliant with the TIA/EIA-568-A wiring standard. All Ethernet cables shall be UL1666 riser rated for outside plant use suitable for aerial, duct, or direct-burial installation.

For all Ethernet patch cables less than 20 feet, unshielded twisted pair (UTP) cables can be used. For any long run cables, or short run cable sharing conduit or running parallel with other power or data cables, shielded twisted pair cable shall be used. The cable shield shall be grounded at one single point to avoid the generation of ground loops.

821.05 INSTALLATION

Furnish and install cables in accordance with manufacturer's recommendations, **Section 801.03** of these specifications, Plans, and Design Standards.

All cables shall be coiled 20 feet in each underground pull box

821.06 MEASUREMENT AND PAYMENT**A. RDS Composite Cable**

Each RDS Composite Cable shall be 45 feet in length. This item includes all terminations, cable pulling, lashing, and other incidentals required for installation and hookup. Payment at the contract unit price shall be made for each accepted cable.

B. Other Communications Cables

The accepted length of communication cables of each type and size installed shall be measured in linear feet to the nearest foot from point to point along the routing for each cable. Measurements shall be made by center to center horizontal distance measurement from:

- Pull box to pull box
- Pull box to base-mounted cabinet
- Pull box to pole
- Pole to pole and height of pole riser (for aerial installation only)

On both horizontal and vertical runs with two or more cables, each cable shall be measured separately. To the above measurement shall be added fifteen (15) feet for each entry into a controller cabinet or splice enclosure.

20 feet coil in each underground pull box shall be added to the above measurement.

Payment at the contract unit price shall be made for the accepted length of cable of each type installed. This shall be payment in full for all terminations, splices, cable pulling, lashing, and other incidentals required for installation and hookup.

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

Item Number	Description	Pay Unit
02890-821.01	RDS Composite Cable	EACH
02890-821.02	Video Detection Camera Coaxial Cable	L.F.
02890-821.03	Priority Control Detector Cable	L.F.
02890-821.04	Ethernet Cable (CAT 5E, UTP)	L.F.
02890-821.05	Ethernet Cable (CAT 5E, Shielded)	L.F.
02890-821.06	Ethernet Cable (CAT 6, UTP)	L.F.
02890-821.07	Ethernet Cable (CAT 6, Shielded)	L.F.