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Part 1 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.

Part 2 Materials and Equipment

2.01 GENERAL REQUIREMENTS

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.

A. 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); and any other Tennessee Department of Transportation standards or City of Memphis ordinance which may apply. Assembly shall be capable of full interface to City ACTRA Signal System. Should there be any conflict between the above standards and this specification, the specification shall prevail.

B. Materials

1. 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.

2. 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.

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

2.02 TRAFFIC SIGNAL FIELD EQUIPMENT AND MATERIALS

A. SIGNAL HEADS

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.

1. 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.

2. Construction

a. 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.

b. 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.

c. LED Module: The LED module shall be a single, self-contained device, not requiring on-site assembly for installation into existing traffic signal housing. The power supply must fit and mount inside the LED module. The assembly and manufacturing process for the LED assembly shall be designed to assure all internal LED and electronic components are adequately supported to withstand mechanical shock and vibration from high winds and other sources.

3. Optical System (General).

a. The vehicular signal lens, signal lamp socket, and reflector or vehicular signal LED module shall form a sealed module with a molded neoprene gasket holding the sealed optical module securely in the signal door. The gasket shall provide a seal to prevent moisture, dust, and road film contamination from entering the optical module and the signal housing.

b. The pedestrian signal shall provide a sealed optical unit by installing the pedestrian signal LED module against the gasket on the inner surface of the door employing neoprene gaskets and 4 plated screws with each.

4. LED Optical System.

The LED optical system shall consist of an LED traffic signal module for each display. The specification in this section provides the minimum performance requirements for 12 in and 8 in LED traffic signal modules, 12 in LED vehicle arrow traffic signal modules, 5 in LED lamp modules for (Programmable View) P.V. signals (LED lamps), and LED pedestrian modules (12 in by 12 in) . It is not intended to impose restrictions upon specific designs and materials that conform to the purpose and the intent of this specification. This specification refers to definitions and practices described 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 "VTCSH". 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.

a. Retrofit Replacement: LED vehicular traffic signal modules with expanded view designed as retrofit replacements for existing signal lamps shall not require special tools for installation. Retrofit replacement LED modules shall fit into existing traffic signal housings built to the VTCSH Standard without modification to the housing. Installation of a retrofit replacement LED signal module into an existing signal housing shall only require the removal of the following existing components: i.e., lens, lamp module and gaskets. It shall be weather tight and fit securely in the housing; and shall connect directly to existing electrical wiring. The installation of the signal module shall not require the removal of the reflector.

Pedestrian LED traffic signal modules shall be designed as a retrofit replacement for the message bearing surface of a 12” x 12” pedestrian traffic signal housing built to the PTCSI Standard. Installation of a replacement LED pedestrian module into the existing pedestrian housing shall only require

the removal of the existing optical unit components, i.e., lens, lamp, gaskets, and reflector. It shall be weather tight and fit securely in the housing; and shall connect directly to existing electrical wiring. The message-bearing surface of the module shall be supplied with “HAND” and “MAN” outline and overlapping symbols that comply with PTCSI standard for this symbol for a message-bearing surface of the size specified. This message-bearing surface shall be designed so that it can be removed from the sealed unit for replacement without further damage to the module. The lens of the LED pedestrian signal module shall be polycarbonate UV stabilized and a minimum of 1/8” thick. The exterior of the lens of the pedestrian signal shall be smooth and frosted to prevent sun phantom.

b. LED Signal Module: The LED module shall be capable of replacing the incandescent optical unit. The lens shall be tinted or colored to match the wavelength (chromaticity) of the LED as long as the luminous intensity still conforms to **Table 2-1** and Table 2-2. The LED module shall be constructed to allow the replacement of the outer lens and/or the light engine as needed. The configuration of the arrow icon for the LED arrow lens is illustrated in Figure 2-1.

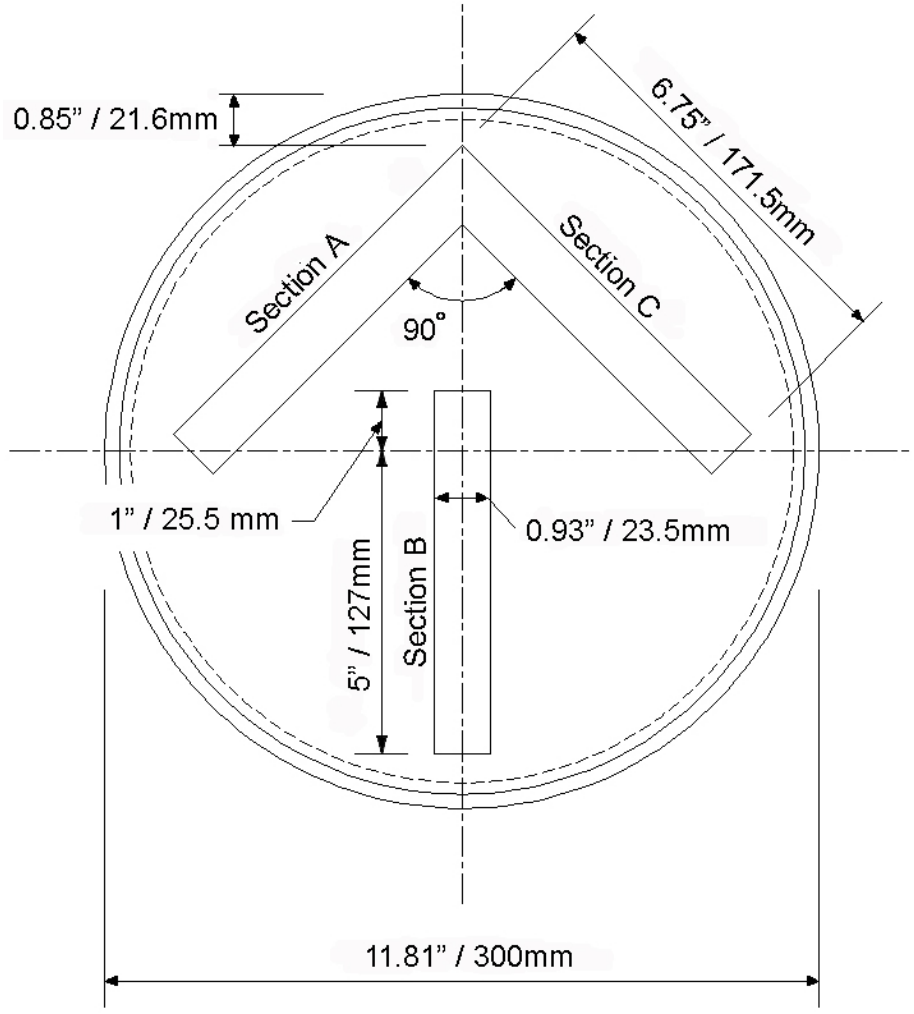

Figure 2-1 Configuration of LED arrow lens

c. Environmental Requirements: The LED module shall be rated for use in the ambient operating temperature range of -40℃ (-40℉) to +74℃ (+165℉). The LED module shall be protected against dust and moisture intrusion as per NEMA Standard 250-2003 requirements for Type 4 enclosures to protect all internal LED, electronic, and electrical components. The LED signal module lens shall be UV stabilized. The lens shall be smooth on the outside to prevent excessive dirt/dust buildup, and be specifically designed to reduce sun reflections (Sun Phantom). The LED module must be supplied with an installed gasket.

d. Construction: The LED module shall be a single, self-contained device, not requiring on-site assembly for installation into a traffic signal housing. The power supply must fit and mount inside the LED module. The assembly and manufacturing process for the LED assembly shall be designed to assure all internal LED and electronic components are adequately supported to withstand mechanical shock and vibration from high winds and other sources.

e. Materials: 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.

f. Module Identification: Each LED module shall be identified on the backside with the manufacturer's name and serial number. The following operating characteristics shall be identified: nominal operating voltage, power consumption, and Volt-Ampere. LED modules shall have a prominent and permanent vertical indexing indicator, i.e., UP ARROW or the word UP or TOP, for correct indexing and orientation inside signal housing.

g. Luminous Intensity and Distribution: The maintained minimum luminous intensity values for red, yellow, and green LED modules throughout the warranty period, under the operating conditions defined in Subsections 02890.2.02.1.01A.4.c, 02890.2.02.1.01A.4.g , and 02890.2.02.1.01A.4.h, and at the end of the warranty period, shall not be less than the values shown in Table 2-1 and Table 2-2, and are required to meet initial luminous values that are 115 percent of the required minimum values in the specification (Table 2-1 and Table 2-1).

When operating within the temperature range specified in Subsection 02890. 2.02.1.01A.4.cduring the warranty period, the maximum luminous intensity for the 8-inch or 12-inch signals shall not exceed 800 candelas for the Red, 1,600 candelas for the Green, and 1,600 candelas for the Yellow.

The optical lens should reflect a light distribution look similar to that of an incandescent lamp with expanded view for special applications. To ensure even illumination 12” LED full ball modules shall consist of a minimum of 100 InGaN (green) or AllnGaP (red and amber) LEDs.

The LED arrow module shall have a full, filled profile, reflecting a light distribution look and appearance similar to that of an incandescent lamp, without the individual LED's being visible. The arrows shall meet all Caltrans specifications on light intensity.

Each pedestrian module shall provide an average luminous of at least 3750 candela per square meter of lighting surface for the "HAND", and 5300 candela per square meter for the "WALKING PERSON" symbol throughout the warranty period over the operating temperature range.

h. Chromaticity: The measured chromaticity coordinates of LED modules shall be between 500 nm and 650 nm, conforming to the chromaticity requirements of Section 8.04 and Figure 1 of the VTCSH standard. The measured chromaticity coordinates of the pedestrian LED signal modules shall conform to the chromaticity requirements of Section 5.3 and Figure C of the PTCSI standard.

Table 2-1 Maintained Minimum Luminous Intensity for 12 inch Expanded View LED Signal Modules Candlepower Values (candelas (cd))

Vertical Angle	Horizontal Angle (Left & right)	12-inch Signal		
		Red	Yellow	Green
17.5° up	17.5°	3	7	7
	2.5°	10	20	20
12.5° up	17.5°	14	27	27
	2.5°	20	41	41
7.5° up	17.5°	20	41	41
	2.5°	54	108	108
2.5° up	17.5°	58	115	115
	2.5°	220	441	441
-2.5° down	2.5°	339	678	678
	7.5°	251	501	501
	12.5°	141	283	283
	17.5°	77	154	154
-7.5° down	2.5°	226	452	452
	7.5°	202	404	404
	12.5°	145	291	291
	17.5°	89	178	178
	22.5°	38	77	77
	27.5°	16	32	32
-12.5° down	2.5°	50	101	101
	7.5°	48	97	97
	12.5°	44	89	89
	17.5°	34	69	69
	22.5°	22	44	44
	27.5°	16	32	32
-17.5° down	2.5°	22	44	44
	7.5°	22	44	44
	12.5°	22	44	44
	17.5°	22	44	44
	22.5°	20	41	41
	27.5°	16	32	32
-22.5° down	2.5°	10	20	20
	7.5°	7	14	14

Table 2-2 Maintained Minimum Luminous Intensity for 8 inch LED Signal Modules Candlepower Values (candelas (cd))

Vertical Angle Down	Horizontal Angle (Left & Right)	8-inch Signal		
		Red	Yellow	Green
2.5°	2.5°	133	267	267
	7.5°	97	194	194
	12.5°	57	113	113
	17.5°	25	48	48
7.5°	2.5°	101	202	202
	7.5°	89	178	178
	12.5°	65	129	129
	17.5°	41	81	81
	22.5°	18	37	37
	27.5°	10	20	20
12.5°	2.5°	37	73	73
	7.5°	32	65	65
	12.5°	28	57	57
	17.5°	20	41	41
	22.5°	12	25	25
	27.5°	9	16	16
17.5°	2.5°	16	32	32
	7.5°	14	28	28
	12.5°	10	20	20
	17.5°	9	16	16
	22.5°	6	12	12
	27.5°	4	9	9

i. Electrical: All wiring and terminal blocks shall meet the requirements of Section 13.02 of the VTCSH Standard. Two secured, color coded, 914 mm (36 in) long 600 V, 20 AWG minimum, jacketed wires, conforming to the National Electrical Code, rated for service at +105℃, are to be provided for electrical connection.

(1) Voltage Range: LED modules shall operate from a 60 ± 3 cycle AC line power over a voltage range from 80 VAC RMS to 135VAC RMS. The current draw shall be sufficient to ensure compatibility and proper triggering and operation of load current switches and conflict monitors in the signal controller that the City procuring traffic authority customer has in use. Nominal operating voltage for all measurements shall be 120 ± 3 Volts RMS. Fluctuations in line voltage over the range of 80VAC to

135VAC shall not affect luminous intensity by more than ± 10 percent. The LED circuitry shall prevent flickering at less than 100 Hz over the voltage range specified above.

(2) Low Voltage Turn Off: There shall be no illumination from the module when the applied voltage is less than 45 volts AC. To test for this condition the unit must first be fully illuminated at the nominal operating voltage. The applied voltage is then reduced to the point that there is no illumination. This point must be greater than 45 volts AC. The same requirement should apply in rising voltage from 0 to 45 with no visible illumination.

(3) Turn-On and Turn-Off Time: The modules shall reach 90% of their full illumination (turn-on) within 100 msec (±10%) after the application of the nominal operating voltage. The LED modules shall not be illuminated (turn-off) within 100 msec (±10%) after the removal of the nominal operating voltage.

(4) Transient Voltage Protection: The LED module on-board circuitry shall include voltage surge protection to withstand high-repetition noise transients and low-repetition, high-energy transients as stated in Section 2.1.6, NEMA Standard TS-2, 2003.

(5) LED Drive Circuitry: The individual LED light sources shall be wired so that the catastrophic failure of one LED will result in the loss of the light from only that one LED. The power supply must be current regulated.

(6) Electronic Noise: The LED module and the associated on-board circuitry must meet Federal Communications Commission (FCC) Title 47, SubPart B, Section 15 regulations concerning the emission of electronic noise.

(7) Power Factor (PF) and AC Harmonics: LED modules shall provide a power factor of 0.90 or greater when operated at nominal operating voltage, and 25℃ (77℉). Total harmonic distortion induced into an ac power line by an LED signal module, operated at nominal operating voltage, at 25℃ (77℉) shall not exceed 20 percent .

j. Quality Assurance:

(1) General:

(a) Quality Assurance Program: LED modules shall be manufactured in accordance with a vendor quality assurance (QA) program. The QA program shall include two types of quality assurance: (1) design quality assurance, and (2) production quality assurance. The production quality assurance shall include statistically controlled routine tests to ensure minimum performance levels of LED modules built to meet this specification.

(b) Record Keeping: QA process and test result documentation shall be kept on file for a minimum period of seven years.

(c) Conformance: LED module designs not satisfying design qualification testing and the production quality assurance testing performance requirements below shall not be labeled, advertised, or sold as conforming to this specification.

(2) Manufacturers' Serial Numbers: Each LED module shall be identified by a manufacturer's serial number for warranty purposes.

(3) Production Quality Assurance (QA) Testing: All new LED modules shall undergo the following Production Quality Assurance testing prior to shipment. Failure of any LED module to meet requirements of these QA tests shall be cause for rejection. QA test results shall be maintained per the requirement above.

(a) Module Burn-in: All LED modules or the electronic circuitry sub-assemblies, including all LEDs, shall be tested by being energized for a minimum of 24 hours, at 100 percent on-time duty cycle, in an ambient temperature of 60℃ (140℉). After burn-in all LED pedestrian modules shall be tested for rated initial luminous intensity. Each module shall be energized at the rated voltage for a five-minute stabilization period before measurement is made. The ambient temperature for this measurement shall be the ambient operating temperature range of -40℃ to 60℃ (-40℉ to 140℉).

(b) Maintained Minimum Luminous Intensity: All LED modules shall be tested for maintained minimum luminous intensity after burn-in. For vehicular signal LED modules, a single point measurement with a correlation to the intensity requirements of Table 2-1 may be used. The LED module shall be operated at nominal operating voltage and at an ambient temperature of 25℃ (77℉).

(c) Power Factors: All LED modules shall be tested for power factor after burn-in per the requirements of Subsection 02890.2.02.1.01A.4.i(7). A commercially available power factor meter shall be used to perform this measurement.

(d) Current: All LED modules shall be measured for current flow in Amperes after burn-in. The measured current values shall be compared against current values resulting from design qualification measurements in Subsection 02890.2.02.1.01A.4.i. Measured current values in excess of 120 percent (vehicular signal) or 110 percent (pedestrian signal) of the design qualification current values shall be cause for rejection.

(e) Visual Inspection: All LED modules shall be visually inspected for any exterior physical damage or assembly anomalies.

(4) Design Qualification Testing: Design qualification testing shall be performed on new LED module designs, and when a major design change has been implemented on an existing design. The minimum sample quantity of LED modules shall be as stated for each test. Failure to meet requirements of any of these tests shall be cause for rejection.

Testing shall be performed once every 5 years or when the module design or LED technology has been changed. Test data shall be retained by the testing laboratory and the LED module manufacturer for a minimum period of 5 years.

(5) Burn-in: LED modules shall be energized for a minimum of 24 hours, at 100 percent on-time duty cycle, in an ambient temperature of +60°C (+140°F) before performing any design qualification testing.

(6) Maintained Minimum Luminous Intensity: After burn-in, a random sample of vehicular signal LED modules shall be tested for maintained minimum luminous intensity at each of the 44 points indicated in Table 2-1. These measurements shall be recorded at an ambient temperature of 25°C after the signal has been in operation for 60 minutes.

Modules to be tested shall be mounted in a temperature testing chamber so that the lens portion of the module is outside the chamber and all portions behind the lens are within the chamber at a temperature of 74°C (165°F). The air temperature in front of the module lens shall be maintained at a minimum of 49°C (120°F) during all tests.

Red and green LED modules shall be tested for luminous output at 74°C, allowing the modules to achieve thermal equilibrium for 60 minutes while the modules are energized at nominal operating voltage. At a 100% duty cycle, a single luminous intensity measurement shall be recorded.

Yellow LED modules shall be tested for luminous output at 25°C, allowing the modules to achieve thermal equilibrium for 60 minutes, while the modules are energized at nominal operating voltage, at a 8.3% (or 1/12) duty cycle (or 5 sec On/55 sec Off).

A single point correlation measurement, accounting for measurement variables, shall be made at 25°C (77°F) for yellow modules. For red and green modules a measurement shall be made at 74°C (165°F) (lens at 49°C (120°F)). The 74°C measurement factored to the 25°C measurement shall be able to be correlated to the requirements of Table 2-1. LED modules not meeting this correlation shall be rejected.

(7) Chromaticity: A representative sample of LED modules shall be measured for chromaticity per the requirements of Subsection 02890.2.02.1.01A.4.h. A spectroradiometer shall be used for this measurement. The ambient temperature for this measurement shall be +25°C (+77°F).

(8) Electrical:

(a) Current: A representative sample of LED modules shall be measured for current flow in Amperes. The measured current values shall be used for quality comparison to the Production Quality Assurance current measurements for the production modules.

(b) Power Factor (PF): A representative sample of LED modules shall be measured for power factor per the requirements of Subsection 2.02.. A commercially available power factor meter shall be used to perform this measurement.

(c) Total Harmonic Distortion (THD): A representative sample of LED modules shall be measured for total harmonic distortion in accordance with the requirements of Subsection 2.02.. A commercially available total harmonic distortion meter shall be used to perform this measurement.

(d) Electronic Noise: A representative sample of LED modules shall be tested per the requirements of Subsection 2.02., relative to the Class A emission limits referenced in Federal Communications Commission (FCC) Title 47, SubPart B, Section 15.

(9) Controller Assembly Compatibility: Due to the low load current draw and high off-state impedance of LED modules, the following design qualification tests shall be performed to ensure the module design is compatible and operates properly with load current switches and conflict monitors in NEMA and Type 170 traffic signal control units.

(10) Load Switch Compatibility: A representative sample of LED modules shall be tested for compatibility and proper operation with load current switches. Each LED module shall be connected to a variable AC voltage supply. The AC line current into the LED module shall be monitored for sufficient current draw to ensure proper load switch operation while the voltage is varied from 80 V RMS to 135 V RMS. Failure of the current draw to ensure proper load current switch operation shall be cause for rejection.

(11) Signal Malfunction Monitoring Unit (MMU) Compatibility: A representative sample of LED modules shall be tested for compatibility and proper operation with signal conflict monitors. Each LED module shall be operated from a 135 V AC voltage supply. A 19.5 ka resistor shall be wired in series in the hot line between the LED module monitor and the AC power supply. A single-pole-single-throw switch shall be wired in parallel across the 19.5 ka resistor. A 220 ka shunt resistor shall be wired between the hot line connection and the neutral line connection and the neutral line connection on the LED module. MMU compatibility shall be tested by measuring the voltage decay across the 200 ka shunt resistor as follows: The single-pole-single-throw switch shall be closed, shorting out the 19.5 ka resistor, allowing the AC power supply to illuminate the LED module. Next, the switch shall be opened and the voltage across the 220 ka shunt resistor shall be measured for a decay to a value equal to or less than 10V RMS within a time period equal to or less than 100 milliseconds. This test shall be repeated a sufficient number of times to ensure testing occurs at the peak of the AC line voltage cycle.

(12) Nondestruct Transient Immunity: A representative sample of LED modules shall be tested for transient immunity using the procedure described in Section 2.1.8, NEMA Standard TS 2-2003.

(13) Environmental:

(a) Temperature Cycling: Temperature cycling shall be performed on a representative sample of LED modules in accordance with MIL-STD-883, Test method 1010. The temperature range shall be in accordance with Section 2.3. A minimum of 20 cycles shall be performed with a 30-minute transfer time between temperature extremes and a 30-minute dwell time at each temperature. LED modules under test shall be non-operating. Failure of a LED module to function properly or any evidence of cracking of the LED module lens or housing after temperature cycling shall be cause for rejection.

(b) Moisture Resistance: Moisture resistance testing shall be performed on representative sample modules per NEMA Standard 250-2003 requirements for Type 4 enclosures.

(14) Mechanical Vibration: Mechanical vibration testing shall be performed on a representative sample modules per MIL-STD-883, Test Method 2007, using three 4-minute cycles along each x, y, and z axis, at a force of 2.5 Gs, with a frequency sweep from 2 Hz to 120 Hz. The loosening of the lens, of any internal components, or other physical damage shall be cause for rejection.

k. 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 of Memphis.

LED modules which exhibit luminous intensities less than the minimum values specified in Table 2-1 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 of Memphis.

l. Samples: Sample modules representative of typical average production units, shall be provided for Traffic Engineering Division approval, if requested. Samples shall not be returned unless requested by the vendor.

m. Documentation: The Contractor shall be required to submit a copy of a test report certified by an independent laboratory approved by the City stating that the LED traffic signal lamp model submitted meets I.T.E. Standards for light distribution, chromaticity, and power (consumption, power factor and harmonic distortion) with the bid. In addition, the independent lab report shall specify the drive current being supplied to individual LED's within the unit. Designs that require LED's to be operated at currents greater than the LED manufacturer's recommended drive current shall not be allowed.

n. Product Qualification: All 12” balls and arrows provided shall have a total installed base in the United States of a minimum of 25,000 units of each model and series number for one year prior to bid date.

o. Connected Wattage: Wattage and power savings are critical. The maximum acceptable wattage for the individual modules is listed in Table 2-3. Proposed LED modules shall provide a wattage maximum less than or equal to the maximum wattage shown below.

Table 2-3 Maximum Acceptable Wattage for Individual Modules

Retrofit	Wattage
12” Red Ball	10 or less
12” Yellow Ball	22 or less
12” Green Ball	12 or less
12” Yellow Arrow	11 or less
12” Green Arrow	5 or less
8” Red Ball	5 or less
8” Yellow Ball	13 or less
8” Green Ball	6 or less

5. Optional Incandescent Optical System.

The incandescent optical system shall consist of a lens, reflector and lamp socket. The system shall be designed to minimize sun phantom and eliminate light spill over. Prefocused incandescent lamps shall be the light source for incandescent optical systems. The signals shall be designed for 116 watt lamps with 2 7/16" LCL in 8 inch signals and 150 watt lamps with 3" LCL in 12 inch signals. All vehicle signal lenses shall be glass and shall conform to the latest Standards of the Institute of Transportation Engineers and American Standards Association Optical specifications. All reflectors shall be of Alzak aluminum construction. The lamp socket shall be Bakelite construction, gasketed, and easily removable from the rear of the reflector for lamp replacement without the use of tools or the removal of the lens or reflector. The socket shall be fixed focus and permit its rotation for a full 360 degrees to orient bulb filament openings. The socket shall be securely held in the reflector so as not to loosen, rotate, or fall out under vibration of traffic and wind movement of the signal head. The lamp socket shall be provided with coded #18AWG copper wire leads. The leads shall be fitted with insulated spade wire terminals and be of sufficient length to make field connections at the barrier terminal block.

6. Incandescent Lamps.

   a. General. All traffic signal lamps shall conform to the current Institute of Transportation Engineers Standard for Traffic Signal Lamps. Lamps shall be etched with manufacturer's name, watts, volts, hours of burning life and date of manufacture code. Lamps shall have an aluminum reflector disc. Lamps shall have a built-in fuse wire in the base of the lamp to prevent damage to the lamp socket or electrical control circuits. Lamps shall be rated at a minimum of 8,000 user hours.

   b. Krypton lamps. Krypton lamps when specified shall be filled to a minimum of 85%, by volume, with krypton gas.

7. Visors.

   Each signal door shall be fitted with a corrosion resistant Polycarbonate resin tunnel visor. Eight inch signals shall have visors a minimum of 7 inches long; 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 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.

8. 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.

9. Legends.

   Pedestrian heads shall be fitted with INTERNATIONAL SYMBOL TYPE LENSES that, when illuminated, shall provide a Portland orange "HAND" and a lunar white "WALKING MAN," all conforming to the Institute of Transportation Engineers "Standard for Adjustable Face Pedestrian Signal Heads". The remainder of the lens shall be black and opaque. When not illuminated, the legends shall not be distinguishable.

   Vehicle traffic signal lenses shall be circular, red, yellow, or green in color, and 8 inch or 12 inch nominal diameter, as specified. No legend shall be permitted. Arrow lenses shall be circular, 12 inches in diameter, green or yellow in color, and opaque except for the arrow legend. If an arrow lens is only applicable for one orientation, i.e., left, straight, or right, this information shall be indicated in a permanent and appropriate manner on the lens without impairing the optical properties of the lens.

10. 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.

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 02890.2.02..

For span wire terminal compartment and hardware for 5 section cluster all hardware specified earlier in this subsection (Subsection 02890.2.02.) 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 l00 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 ½" 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).

11. 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:

a. 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

b. 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 02890.2.03A 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.

12. 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.

13. Guarantee.

The signal shall be fully guaranteed for a minimum period of one year from date of installation, against any imperfections in workmanship or material. Any imperfections or failures of materials which occur during the guarantee period shall be replaced by the manufacturer and contractor at no cost to the City.

B. CONTROLLERS AND CABINETS

1. General.

a. Description. This subsection describes the general and specific construction and operating requirements of new controllers, cabinets, and related equipment to be furnished by the Contractor. As called for on the Plans, controllers shall either be local intersection traffic signal controllers or reversible lane controllers.

This subsection contains design requirements for controllers, controller interfaces, physical standards, functional standards, and coordination standards.

The control equipment described herein is to be capable of being used in operating traffic signals as part of a coordinated system. The local control equipment shall be fully compatible with the signal system and central software, which as called for shall either be existing or to be supplied under other specifications.

The Contractor shall install all local controller databases, including coordination timing and scheduling, using data furnished by the Engineer in standard traffic engineering terminology.

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. As described herein, the traffic controller shall be an Eagle EPAC M52 series controller or equal. An EPAC M34 Series

controller will only be allowed with the special permission of the City Engineer.

b. Advanced Traffic Management System. The City of Memphis currently uses an Advanced Traffic Management System (ATMS) to monitor and control the various traffic control devices in operation. All traffic signal controllers, priority control devices, and signal monitor devices shall be capable of communication with the city ATMS computer software by either fiber-optic, direct hardwire, or remote telephone modem.

c. NEMA Standards. The controller and associated equipment shall, as a minimum, comply with the latest edition of NEMA Standard No. TS 2-2003 "Traffic Control Assemblies with NTCIP Requirements" (hereinafter referred to as NEMA); and that Standard is hereby made a part of this Specification. The controller shall be interchangeable with any other controller meeting the NEMA standard TS 2-2003. 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.

d. Components. The traffic control assembly, referred to as the controller, shall include the timer, (control unit) load relay switches, signal conflict monitor, line filters, and necessary auxiliary equipment mounted in a cabinet. The controller shall be installed at the location shown on the Plans or as directed by the Engineer. Each controller shall be wired complete with the specified auxiliary equipment and ready for operation by making field connections to the signal display equipment, detectors, and electric service line.

e. Documentation. See 02890.4.08A.

f. Solid State Construction. All controllers shall employ high quality, solid-state modular electronic construction designed for continuous unattended operation. No camshafts, rotary stepping line switches, lighting discharge tubes, or vacuum or gaseous tubes, shall be used for internal or external auxiliary circuitry, except incandescent or gaseous tube indicator lamps are acceptable devices.

g. Training. For controllers purchased by the City the Contractor shall provide (with manufacturer personnel), as part of the contract for the controller, a minimum of twenty-four hours of classroom and laboratory instruction on the operation and maintenance of each separate type of controller supplied for three City of Memphis technicians. Instructions shall be on a highly technical level, describing the design and operation of electronic circuitry in detail as well as demonstrating troubleshooting and repair techniques. The rudiments of dial systems and basic solid-state theory are below the level of the instruction required by this Specification. This instruction shall begin at any time when requested by the City, following the contract award. This instruction shall be conducted at a formal factory training facility. The

Contractor shall provide round trip transportation from Memphis to the school site and suitable lodging during the school if the school is held away from Memphis. The proposed training facility shall be listed in the bid and shall be a determining factor in bid award.

h. City of Memphis Phasing Identification by Type. All controllers shall be supplied with the full capabilities called for in Subsection 02890.2.02B. The following identification types describe the phasing to be used for the initial application:

- Type 2A: Two phase semi-actuated.
- Type 2B: Two phase, fully actuated.
- Type 3A: Three phase fully actuated. An advance or leading protected left turn phase is the identifying characteristic of this type.
- Type 3T: Three phase, fully actuated. A trailing or lagging protected left turn phase is the identifying characteristic of this type.
- Type 4: Four phase, fully actuated. The identifying characteristic is a protected left turn phase on one approach of both the artery and the cross street.
- Type 5: Five phase, fully actuated. The identifying characteristic is a protected left turn phase on both artery approaches, with artery phases capable of concurrent but independent timing with another non-conflicting phase.
- Type 6: Six phase fully actuated solid state. The identifying characteristic is a protected left turn phase on one cross street approach and a protected left turn on both artery approaches with any artery phase capable of concurrent but independent timing with another non-conflicting phase.
- Type 8: Eight phase fully actuated. The identifying characteristic is a protected left turn phase on both artery approaches and both cross street approaches, with any phase capable of concurrent but independent timing with another non-conflicting phase.
- RR (Suffix): The suffix "RR" added indicates railroad preemption of the normal signal operation.

i. Bidding and Shipment of Equipment Purchased by the City.

(1) Each bid shall be accompanied by engineering and operational specifications for the equipment bid. Each Contractor shall be required to furnish one controller of each type bid with cabinet meeting these specifications for 30 days testing and evaluation prior to award of any contract. If a Contractor is requested to furnish a sample controller and or cabinet assembly, they shall be furnished to the City within 15 days of date requested. If the equipment is not submitted within that time, or as required, the City shall reject that bid. All material, parts and workmanship shall be guaranteed for a period of two years after field installation with defective equipment either repaired or replaced entirely at Contractor’s expense.

(2) All equipment shall be described completely with the manufactures name, model number, catalogue number, and any other identifying information provided with the unit price.

(3) All equipment shall be securely packed for shipment so as to avoid damage during transit. All cartons shall be clearly labeled as to their contents, including controller type and the City of Memphis contract number.

(4) The successful Contractor shall arrange for the proper expediting, delivery and shipment, tracing or necessary of all equipment awarded to them under this specification. Delivery shall be F.O.B. including inside delivery to the City of Memphis Traffic Signal Shop, 980 S. Third Street, Memphis, Tennessee 38106, Phone (901) 528 2844.

2. Local Intersection Controllers.

a. General. Each new local intersection traffic signal controller shall be a fully-actuated, two-through-eight phase, four-ring solid-state, digitally-timed traffic signal controller. Each model of new controller furnished by the Contractor shall be a proven controller and not a pre-production prototype.

The controller shall be of modular design with an internal power supply all mounted in a suitable sheet metal enclosure. The metal chassis shall be designed for easy access to the printed circuit boards. All pin connectors shall be front mounted.

b. Required Standards. The traffic signal controller shall meet or exceed all requirements of the NEMA TS2-2003 specification. The equipment supplier shall provide a letter from an independent testing laboratory certifying controller compliance to the NEMA TS2-2003 specification.

c. Standard NEMA Configurations. Two Input/Output configurations shall be provided:

(1) NEMA TS-2 Type 1 for serial connection to cabinet Bus Interface Unit

(2) NEMA TS-2 Type 2 for direct parallel connection to load switches and detectors

d. Central Processor Unit (CPU). In addition to NEMA requirements, the CPU shall provide the following:

- Microware OS-9 Operating System with runtime license
- Motorola 68360 microprocessor, 25 MHz version
- 4 Megabytes minimum dynamic random-access memory (DRAM)
- 8 Megabytes minimum FLASH memory organized as a disk drive
- 512 Kilobytes minimum static random-access memory (SRAM)
- 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.
- During power failures, the SRAM and TOD shall be powered by STANDBY voltage from the power supply.

e. Power Supply. In addition to NEMA requirements, the Power Supply shall provide the following:

- 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.

f. Keyboard and Display. In addition to NEMA requirements, the Keyboard and Display shall provide the following:
   - Keyboard shall be removable by pulling off, installed by pushing on, without use of tools
   - Stowed extension cord to allow remote use of keyboard and display
   - 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 8 lines of 40 characters
   - LCD contrast adjustment accomplished via the keypad, no contrast knob allowed.
   - Light-emitting diode backlight for the LCD.
   - Audible electronic bell.
   - Connector compatible with C60 of Joint NEMA/AASHTO/ITE ATC Standard, with the addition of +5VDC supplied by the controller on C60, Pin 1

g. Communications. In addition to NEMA requirements, the controller shall provide the following:
   - Built-in 10 Base-T Ethernet with RJ-45 connector on controller front panel
   - Built-in Internet Protocol (IP) address assigned by Institute of Electrical and Electronic Engineers (IEEE), one unique IP address for each controller.
   - Built-in Infrared (IR) wireless port compatible with Microsoft Windows for Pocket PC Infrared RAW mode.
   - Built-in 1200 bps Frequency Shift Keying (FSK) modem. Modem is optional per Agency specification. Choice of 2 or 4 wire operation per Agency specification.
   - Built-in EIA-232 port for uploading and downloading applications software, as well as to update the operating system.
   - Built-in C60 connector for use with removable Keyboard and Display, Personal Computer COM1 or Personal Digital Assistant (PDA). C60 protocol shall be compliant with the Joint NEMA/AASHTO/ITE ATC standard.

   Unless otherwise approved by the City, all new traffic controllers shall have a built-in 10BASE-T Ethernet port (EPAC M52 series controller or equal) able to natively communicate with the ATMS central software (ACTRA) using Ethernet Protocols (TCP/IP). For controllers designed to operate under a closed-loop system by communicating with on-street master controllers, built-

in Ethernet port is still required, in addition to the required single-mode fiber modem.

h. Required Phase Sequences. 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 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).

i. Specific Design Requirements.

(1) Modules. The design shall allow for easy removal or replacement of all modules without the use of special tools.

(2) Circuitry. 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.

(3) Controller Housing. In addition to NEMA requirements, the controller housing shall provide the following:

- Seven slots with card guides for standard 3U size Versa Module Europe expansion modules. The expansion modules and mating back plane board in controller are optional, per Agency specification.
- Two slots with card guides for standard Joint NEMA/AASHTO/ITE ATC modems. The modems and mating back plane board in the controller are optional, per Agency specification.
- Polycarbonate construction, except that the back panel, rear mounting tabs and power supply mounting plate shall be aluminum for electrical grounding.
- Built-in carrying handle.
- Two adjustable front mounting feet, used to raise the front cables and vary the display viewing-angle.

(4) Fuses. All equipment shall be individually fused with protection devices that are panel-mounted on the front face of the equipment. Fuses shall be provided for both the 120 VAC and 24 VDC power.

(5) Controller Expansion/Modification Capability. Controller shall be provided to operate as a two (2) through eight (8) phase controller. The controller design shall permit the mode of operation to be changed and the vehicle and pedestrian phasing capacity to be increased without requiring that the

controller case be internally modified or rewired. The motherboard and power supply shall be of adequate design to service the maximum configuration of the controller.

j. Additional Required Features.

(1) In addition to NEMA requirements, the controller shall provide the following capabilities:

- o 16 Vehicle Phases
- o 16 Pedestrian Phases
- o 4 Timing Rings
- o 16 Overlaps
- o 80 Detectors

(2) Per-Phase Features. The following per-phase features shall be provided:

- o Extended flashing ped clearance
- o Actuated rest in walk
- o Soft vehicle recall
- o Selective phase omit
- o Selective phase yellow omit
- o Conditional service
- o Detector (stretch, delay and switching)

(3) Per-Unit Features. The following per-unit features shall be provided:

- o Programmed (remote) flash
- o Exclusive ped service
- o Ring configurations (to 4 rings)
- o Start-up flash or all red
- o Remote sequence modifiers (16)
- o Timed trailing overlaps
- o Overlap green/yellow omit
- o Auto timing of ped clear
- o Resident diagnostics
- o Parameter printout
- o Unit-to-unit transfer

(4) Coordination. As a minimum, the following coordination features shall be provided:

- o 4 Dial/4 Split/3 Offset
- o 48 traffic patterns
- o 3 offset correction modes
- o Transition cycles
- o Auto permissives (vehicle and pedestrian)
- o Sync monitoring
- o Manual control
- o Input monitor (walk rest modifier, manual control enable, stop time, remote flash)
- o Dial/split to dial/split copy

- Coordination Modes: Permissive Mode, Yield Mode, Permissive Yield Mode, Permissive Omit Mode, Sequential Omit Mode, Full Actuated Mode.

(5) Time Base. As a minimum, the following time base scheduler features shall be provided:

- 10 week programs
- 99 day programs
- 250 event capacity
- Dimming (per phase by phase output)
- Auxiliary special function outputs, minimum of four (4)
- Max II selection per phase TOD
- Phase omit TOD
- Automatic or user-programmable daylight savings time and leap-year adjustment

(6) Preemption. 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

(a) 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.

(7) Special Detector Capabilities. 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:

- 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 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.

(8) Special Features. As a minimum, the following special features shall be provided:

- Eight (8) system detector/coordination inputs
- 6 Priority Routines
- Detector diagnosis
- Detector assignments and special detector allocation
- Speed report
- Standard reports
- Built-In Diagnostics: MMU Status Display, Cycling Diagnostics, Detector Diagnostics
- Measurements of effectiveness
  - Green utilization
  - Time waiting
  - Cars waiting
  - Volume
- Controller local alarm log. The log shall be accessible from the keyboard. It shall have the ability to store up to 80 alarms, of the following types, and showing the date and time of occurrences.
  - On-line/off-line
  - Power on/off-interrupt
  - Preemptions and user definable alarms
  - Low battery check/replace
  - Watchdog timeout
  - EPROM write/failure counts
  - RTC chip failure/fault/adjust
  - Alarm/Comm/TrafResp./Speed/ MOEs/Detector fault log
  - Communication Faults
  - Diagnostics
  - Coord status and Local/Free
  - Software clock adjust
  - Time change remote/keypad

Alarms shall appear in the order in which they occur. It shall be able to store up to 80 of the latest alarms with any additional alarms replacing the oldest.

- Minimum of four (4) special functions
- Remote "Manual" overrides
- TBC on loss of communications
- Upload and download data
- Communications
- Adaptive Traffic Control:
  - Adaptive Maximum Routines
  - Adaptive Protected / Permissive Routines
  - Conditional Virtual Split Routines
  - Coordinated Adaptive Split Routines.
- Status: Ring Timers, Coordination Timers, Preempt Timers, Time Base, Communication, Detector Diagnostics, Intersection, Input / Output

k. Miscellaneous Requirements.

(1) Keyboard. All input data shall be user-programmable by means of the keyboard and LCD display. All internal time setting shall be programmed via a keypad and stored in a removable EEPROM memory program pack. 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.

(2) Coordination. 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 16 timing Plans.

(3) Clocks. 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.

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

(5) Circuit Boards. All printed circuit boards shall be of fiberglass - epoxy construction with a minimum of two (2) ounce copper circuit track and comply with NEMA.

(6) I/O Component Design. All controller unit input and output integrated circuit components shall be socket mounted to facilitate repair and maintenance of input/output boards. Also, all CPU board integrated circuit components with 14 or more leads shall be socket mounted.

(7) Interchangeability. 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.

(8) Dual Maximum. The controller shall be furnished with at least two maximum time settings for all phases. Each maximum limit shall be timed by internal controller circuitry. No external timers shall be permitted. The selection of the maximum limit to be in effect shall be either by remote selection, internal time base, or time clock(s). Selection of the maximum limit to be in effect for a particular phase shall be independent of the selection of the maximum limit to be in effect for any other phases.

(9) Timing Reference. 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.

(10) 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 amp 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.

(11) I/O Logic Levels. 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.

(12) Transient Protection. 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.

l. Parts Lists and Cross-Referencing. See 02890.4.08A.

m. Software and 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.

n. Internal Communications Transceiver.

(1) General. Each new local 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.

(2) Functions Monitored. As a minimum, the following functions shall be monitored and the status of each transmitted to the central system:

- 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.

(3) Operational status of the intersection (in coordination, in transition, free operation, flash, local manual control or preempted).

(4) Data Transferred. The communications transceiver shall receive from the central system command data including, minimally, the following:

- Timing plan commands.
- Local special function commands (minimum of four).
- Coordinated or free mode.
- Request for local data response.
- System clock update

(5) Database Downloading/Uploading. The communications transceiver shall permit downloading and uploading of the entire local intersection database, including coordination and TBC, to/from disk storage at the central facility.

(6) Design Standards. The communications transceiver's connector shall not be interchangeable with any other connector in the local controller cabinet. As a minimum, the communications transceiver shall provide the following features:

- Time division multiplexing/frequency shift keying techniques.
- Two-way communications over agency-owned cable.
- Parity and error checking diagnostics to assure transmission/reception of valid data.

- Appropriate indicators including, but not limited to, transmitting and carrier reception.
- Local address assignment.
- Transmitter output level which is either user adjustable to a maximum of zero (0) dB or automatically maintained within the range of 0 to 3 dB continuous.
- Transmitter frequency stability of +5 Hz over the NEMA operating temperature range.
- Receiver in-band signal-to-noise ratio of +10 dB or greater.
- Receiver input common mode rejection of greater than 40 dB.

o. Internal Fiber Optic Transceiver (OTR).

(1) General. The internal fiber optic transceiver (OTR) is NOT required for any new designs using Ethernet based communication system, unless called for on the Plans. Instead, the built-in Ethernet Port in the EPAC M52 controllers and a ruggedized Ethernet switch for communication shall be used. The OTR shall either be repeating or line terminating 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 Provision of 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) Repeating OTRs (OTR/RPs). The integral OTRs which are not at the end of a multi-dropped optical string shall provide optical repeating and shall be designated OTR-Repeating or "OTR/RP".

Each OTR/RP shall receive an uplink signal and shall not only drop the signal electrically to the attached controller but it shall also repeat the optical signal to the next downlink attached device. The attached controller shall be programmed to respond to its specific address, thus providing multi-dropped link management. The OTR/RP shall repeat both uplink and downlink received signals to provide communications continuity. Both uplink and downlink received signals shall also be converted to electrical signals which are compatible with and transferred to the attached controller.

Each OTR/RP shall be compatible with the line terminating (i.e., non-repeating) OTRs at the central control facility or field communications hub and with the integral line-terminating OTR in the last controller on each multi-dropped string.

(a) 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 ±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.

(b) Optical Interface. The optical interface to the OTR/RP shall be Single-mode fiber (or Multi-mode if required by Plans and Special Provision of specifications), 8.3 ±0.5/125 ±1.0 microns (core/cladding), using ST connectors. Female ST 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, ST interconnections are required. The OTR/RP shall operate at either 850 or 1310 nanometers. An optical link loss of 14 dB minimum shall be accommodated while providing communications in conformance with this specification to a bit error rate of not more than one error in 10 9 bits.

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 optical repeating process shall not add signal distortion nor optical noise which would compromise the link performance to achieve a 10-9 bit error rate.

(c) Compatibility with Non-Repeating Optical Transceivers. The first and last OTRs of a multi-dropped communications link, including those at the master point of control (i.e., the TCC), may be interconnected with non-repeating OTRs, which are designated as OTR-line terminations, or OTR/LT. The OTR/RPs provided shall be optically compatible with OTR/LTs provided. An OTR/RP shall be usable as a master point of control interface to control the multi-dropped communications link with the upstream communications port terminated.

(d) Communication Performance. All OTR/RPs shall have compatible communications specifications. When two or more OTR/RPs are interconnected by a single-mode fiber optic cable conforming to the following specifications:

Type:	Single-mode	Multi-mode
Core Diameter:	8.3 ± 0.5 microns	62.5 ± 3.0 microns
Cladding Diameter:	125.0 ± 1.0 microns	125.0 ± 2.0 microns

Operating Wavelength: 850 or 1310 nanometers

and the link loss budget between any two OTR/RPs does not exceed 14 dB and the two communications devices:

- o are operated within environmental specifications stated in this document; and
- o are operated within power input variations stated within this document,

then, the receiving OTR/RPs shall provide electrical interfaces to all attached controllers with a bit error of no greater than 1 in 10^9 bits.

(e) Maintenance Interface. 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:

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

(f) Physical. 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 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.

(g) Environmental. 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.

(h) Reliability. 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.

(i) Electromagnetic and Radio Frequency Interference. The OTR/RP shall comply with FCC Class A requirements.

(3) Line Termination OTRs (OTRs/LTs). The optical transceiver (OTR) to support multi-dropped communications without providing optical repeating (i.e., the first and last OTRs of a multi-dropped communication link) shall be designated OTR-Line Termination or "OTR/LT". Each OTR/LT shall perform to the same specifications called for herein for the OTR/RP except that the OTR/LT shall not be required to perform the optical repeating function of the OTR/RP. To this extent, the OTR/LT shall be required to have only two fiber optic connectors (i.e., one each transmit connector and receive connector). Connectors shall be ST-compatible.

3. Traffic Signal Controller Cabinets.

a. General.

(1) Type of Cabinet Required. Base mounted cabinets shall be furnished for multi phase controllers which have a frame capable of providing five to twelve phases. All other controllers shall be furnished in pole mounted cabinets.

(2) Submission of Shop Drawings. Before fabrication of the cabinets is begun, the Contractor shall submit for approval three copies of complete shop drawing of the cabinet to be provided for each type of controller to be furnished.

(3) Documentation. See 02890.4.08A for documentation requirements.

b. Cabinet Material.

Pole-mounted cabinets (required for four phase cabinet) and pedestal-mounted cabinets shall be fabricated from cast aluminum or welded sheet aluminum or a combination of both. All welds shall occur on the inside surface of the cabinet to maintain a clean appearance.

Base-mounted controller cabinets shall be fabricated from cast aluminum or welded sheet aluminum. All welds shall occur on the inside surfaces of the cabinet to maintain a clean appearance.

All new controller cabinets shall have an unpainted natural aluminum finish.

c. 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.

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.

d. 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.

e. Mounting Hardware.

(1) Base-mounted cabinets shall be installed on a concrete foundation using Contractor-furnished hot dip galvanized bolts, nuts, washers, and template.

(2) 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.

(3) Pedestal-mounted cabinets shall be furnished with a galvanized slip-fitter sized appropriately for the pedestal post. The bottom of pedestal-mounted cabinets shall be reinforced as necessary to prevent wobble and/or excessive flexing when the cabinet is attached to the pedestal post.

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. Surge Protection.

(1) 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.

(2) 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)
- 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.

(3) 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.

(4) 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.

(5) 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.

(6) 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.

(7) 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.

h. 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.

i. 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.

j. 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 2-4, Table 2-5, Table 2-6, Table 2-7and Table 2-8. 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.

Table 2-4 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 2-5 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 2-6 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 2-7 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 2-8 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)

k. 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.

Unless otherwise required to accommodate the phase sequence called for on the Plans, cabinets shall be wired as follows:

(1) Four (4) phase cabinets shall be wired for four (4) vehicular phases, 3 pedestrian phases, and 2 overlap phases (set up as the 1+2 and 2+3 overlaps), with the signal monitor programmed accordingly.

(2) Eight (8) phase cabinets shall be wired for eight (8) vehicular phases and 4 pedestrian phases with the signal monitor programmed accordingly.

l. 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:

(1) Single-ring sequences:
- The signals for phase 2 shall flash yellow;
- If phase 1 is a protected-permitted left-turn (i.e., has a 5-section signal head), the circular yellow section in its 5-section head shall flash yellow; otherwise, the signals for phase 1 shall flash red; and
- All other signals shall flash red.

(2) Dual-ring sequences:
- The signals for phase 2 and 6 shall flash yellow;
- If phase 1 is a protected-permitted left-turn, the circular yellow section in its 5-section head shall flash yellow; otherwise, the signals for phase 1 shall flash red;
- If phase 5 is a protected-permitted left-turn, the circular yellow section in its 5-section head shall flash yellow; otherwise, the signals for phase 5 shall flash red; and
- All other signals shall flash red.

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.

m. Dimensions and Equipment Locations. Pole mounted and base mounted cabinets for each type controller shall be supplied consistent with the following minimum and maximum dimensions and equipment locations:

(1) 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.

(2) 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.

(3) 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.

(4) Third shelf (optional) - required if the top and second shelves will not accommodate the conflict monitor, amplifiers and other equipment as required. The third shelf shall allow for the same top and side clearance as on the second shelf.

(5) 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.

(6) 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.

(7) Field loop connections are to be made on terminal strips located on the left wall of the cabinet below the bottom shelf.

(8) 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.

(9) 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.

(10) The maximum outside dimensions of a base-mounted cabinet (exclusive of mounting flanges) shall not exceed 56 inches in height, 44 inches in width, and 30 inches in depth.

(11) Mounted to the underside of the second shelf down shall be one pull-out covered drawer with a flip up lid capable of holding the necessary equipment manuals and drawings. The drawer shall be capable of supporting a laptop computer.

n. Switches Inside Main Door.

(1) 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.

o. 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:

(1) Signal Power Switch: This switch will remove power from the signal Buss.

(2) 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.

(3) 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.

(4) 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 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.

p. Conflict Monitor. Each cabinet shall have a 16-channel conflict monitor which meets the requirements of Subsection 02890.1.01A.4.

q. Load Switches, Flash Transfer Relays, and Flasher. 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). NO EXCEPTIONS WITHOUT PRIOR APPROVAL. 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.

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 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.

Each base-mount cabinet shall be a NEMA P type supplied with sixteen (16) load-switch sockets and six (6) flash transfer relay sockets. Each pole-mounted and pedestal-mounted cabinet shall be a NEMA M36 type supplied with twelve (12) load-switch sockets and six (6) flash transfer relay sockets. The number of load switches supplied shall be equal to the number of vehicle load switch sockets and pedestrian load switch sockets that are in the cabinet unless the plans or specifications state otherwise.

r. Detector Amplifiers. Each controller cabinet shall be supplied with harnesses for four-channel shelf-mounted detector amplifiers which meet the requirements of Subsection 02890.2.02C. The number of harnesses shall be as follows:

(1) One or more harnesses to accommodate the number of local detector amplifier channels called for in the Plans plus a minimum of two (2) spare channels.

(2) One or more harnesses to accommodate the number of system amplifier channels called for in the Plans.

s. Fiber Optic Communications Interface. Unless otherwise called for, each controller cabinet shall be supplied with a Fiber Optic Communications Interface which meets the requirements of Subsection 02890.1.01A.5.

t. Miscellaneous Required Facilities.

(1) A minimum of two (2) fully adjustable metal shelves with brackets to support the controller, signal monitor, detector amplifiers and other accessory equipment. The shelves shall be capable of vertical adjustment through virtually the full height of the cabinet.

(2) Electric Service Line Terminals, Each cabinet shall be equipped with three breakers: a 10 amp, a 20 amp, and a 50 amp. The 50 amp breaker shall have the service line attached to it and shall be the feed for the signal buss. The 20 amp breaker shall feed the receptacle and the interior fan. The 10 amp breaker shall feed the output relay for the conflict monitor.

(3) 120 Volt duplex convenience receptacle with separate 30 amp circuit protection.

(4) Insulated barrier terminals shall be used for detector field connections, AC power supply for amplifiers, and controller inputs from amplifiers. Quantities of terminals shall be supplied for the above connections as follows:

- o Four phase controllers - 36 terminal positions; and
- o Eight phase controllers - 48 terminal positions.

(5) Grounded neutral buss with multiple screw terminals for 12 gauge copper signal neutrals, and 4 gauge copper earth connections.

(6) Insulated barrier terminals (2 positions per phase module) for connection of 12 gauge copper pedestrian detector field wires.

(7) Insulated barrier terminals (5 positions per phase module) for connection of 12 gauge copper signal display field wires.

(8) Insulated barrier terminals (4 positions) for connection of 12 gauge copper system interconnect lines. Install lightning protection per Subsection 02890.2.02B, as appropriate.

(9) Insulated barrier terminals for internal wiring interconnect of all other cabinet accessories and circuitry.

(10) All barrier terminal blocks shall be CINCH TYPE 150 WITH NUMBERING STRIP or equal. This type and size terminal block shall be provided for all applications including controller inputs and outputs, field connections, and detector connections. Terminal pairs shall use a minimum 10-32 size screw and have a minimum center-to-center distance between terminal pairs of 5/8 inch.

(11) A 120 VAC 20 watt, fluorescent light fixture mounted on the cabinet ceiling at the front of the cabinet. Fixture shall employ #F20T12/CW20 watt fluorescent tube. An automatic switch shall turn the light on when the main cabinet door is open and turn it off when the door is closed.

(12) Detector push button switches shall be provided for placing vehicular and pedestrian calls on each individual phase separately. A sufficient number

of switches shall be provided to serve the maximum phase capability of the controller unit supplied in case of future expansion. Switches shall be permanently labeled and identified. The switches shall be located such that calls are not inadvertently placed when the cabinet door is closed against control wiring.

(13) Each cabinet shall have provision for all additional equipment associated with the future expansion to full functional capability including but not limited to load switch bases, complete cabinet wiring, field connection terminals and detector terminals.

4. Malfunction Management Unit (Conflict Monitor)

All cabinets provided by the Contractor shall have a (16) sixteen channel MMU that meets or exceeds all specifications of the NEMA Standard TS2-2003 while maintaining downward compatibility with existing NEMA TS1-1989 Traffic Control Assemblies and is capable of communication with the City ACTRA signal system.

Each conflict monitor shall provide the following features:

a. Dual Indication Monitoring. This monitoring function shall be required to detect simultaneous indications of active green, yellow, walk and red field signal outputs on the same channel. A dual indication fault shall place the monitor into the fault mode causing the output relay contacts to transfer. Dual indication monitoring shall be enabled concurrently with clearance monitoring on a per channel basis through switches to be supplied on the front panel.

b. Conflict/Voltage Monitor Operations. One of three different groups of prohibited dual combinations shall be selected via front panel "dual select" switches to be provided on the front panel for all channels which have been enabled for dual indication monitoring.

DUAL SELECT SWITCH (TO BE PROVIDED)

A	B	COMBINATIONS PROHIBITED
OFF	OFF	NONE (NO DUAL MONITORING)
OFF	ON	[(G OR W) AND Y]
ON	OFF	[(G OR W OR Y) AND R]
ON	ON	[(G OR W) AND Y] OR [(G OR W OR Y) AND R]

(NOTE: A and B "ON" shall be equivalent to only (G and W) allowed.)

*DUAL INDICATION MONITORING SHALL BE DISABLED WHEN THE RED MONITORING ENABLE INPUT IS REMOVED.

An open or no load condition (i.e., burned out bulb) shall be detected as an active signal due to load switch leakage current and shall cause a dual indication fault. Dual indication monitoring should also anticipate a possible conflict in the event that a proceed signal on a channel is constantly detected as active.

c. Green-Yellow Dual Indication Monitoring. This monitoring function shall be provided to detect a simultaneous indication of active green and yellow field signal outputs on the same channel. It shall be used to monitor channels which have an unused red field signal output tied to AC+ (i.e., five section signal head) to be enabled by lacing a front panel option switch labeled "green-yellow enable" in the "ON" position. A green-yellow dual indication fault shall place the monitor into the fault mode causing the output relay contacts to transfer. Green-yellow dual indication monitoring should be enabled concurrently with dual indication monitoring. When green-yellow dual indication monitoring is to be enabled, all channels which have not been selected for dual indication monitoring via front panel switches shall be individually monitored for simultaneous indications of active green and yellow field signal outputs. Any channels which have been selected for dual indication monitoring shall function as described above. Green-yellow dual indication monitoring shall be disabled for all channels when the red monitoring enable input is removed.

d. Clearance (Short or Absent Yellow) Monitoring. This function shall be provided to detect the absence of a minimum 2.8 second period of an active yellow field signal output during a red to green to yellow to red sequence. Clearance monitoring to be enabled concurrently with dual indication monitoring on a per channel basis via front panel switches to be provided.

Clearance monitoring is to be disabled for all channels when the red monitoring enable input is removed.

A clearance (short or absent yellow) fault condition shall place the monitor into the fault mode causing the output relay contacts to transfer. This shall occur when a red input signal to a channel is active following the termination of an active yellow input signal which is less than 2.8 seconds in duration.

e. Controller Watchdog Monitoring. This function shall be provided to monitor an optional watchdog output from the cabinet controller circuitry. The cabinet controller should toggle the watchdog outputs logic state once every 100 milliseconds. Failure of the monitor to receive a change in state from the controller unit for 1500 milliseconds (±100 milliseconds) shall place the monitor into the fault mode and cause the output relay contacts to transfer. An AC+ brownout condition or a complete loss of AC+ power shall reset the watchdog fault state of the monitor.

NOTE: The watchdog logic input shall be harnessed to a spare pin on the front panel connector.

f. Walk Disable (Red Monitoring). This option shall be provided to modify the operation of red monitoring. When enabled, the red monitoring function shall not monitor the walk field outputs. Absence of signals on the green, yellow,

and red field outputs of a channel shall place the monitor into the fault mode and cause the output relay contacts to transfer.

g. Non-Volatile Fault Memory. The loss of AC+ power to the monitor shall not reset a fault condition (conflict, dual indication, red failure, clearance, or a voltage monitor latch option is enabled). A BND or controller watchdog fault shall be reset by an AC+ brownout or drop out condition. The monitor shall store the fault and channel indicator status and the time and date the fault occurred into a non-volatile RAM memory device. Should an AC+ power interruption occur while the monitor is in the fault mode, then upon restoration of AC+ power, the output relay shall remain in the fault and the correct fault and channel information shall be displayed. This mode shall be maintained until the monitor receives a reset command from the reset button or the external test reset input.

h. Real-Time Clock/Calendar. A real-time clock shall be provided in the monitor to identify each fault occurrence with the time of day and date. This information shall be displayed and stored along with the fault status and field output status when the monitor is triggered by a fault condition. The real-time clock shall be backed up by a long life lithium energy cell to maintain accurate time keeping even during AC+ interruptions. Accuracy should remain within approximately +3 minutes per month. Daylight saving time adjustments are to be made to the time of day on the first Sunday of November and the second Sunday of March. The date and month are to be adjusted for leap years.

   Setting the correct time of day and date shall be accomplished using the mode and increment buttons on the front panel.

i. Fault Data Logging. In addition to displaying the fault status and field output status for a fault condition which may have the monitor unit currently triggered, the monitor shall automatically update and maintain a complete record of the last nine faults which caused the unit to trigger. Reviewing these events shall be accomplished at any time by depressing a "Inc/Prev.Fail" button to be provided on the front panel. This "history" shall be maintained in non-volatile RAM memory and shall not be lost due to AC+ power interruptions.

   Faults due to the program card not in place or monitor failures due to internal hardware/firmware problems (monitor fail LED illuminated), are not to be included in the data log.

   A controller voltage monitor (CVM) log disable option switch shall be provided on the front panel to disable data logging of CVM failures. This option preserves the fault "history" when the CVM input is used to transfer from normal operation to flashing operation for night time flash or time-of-day flash requirements.

j. Program Card Readback. In order to verify that the program card information has been properly read by the monitor, the channels programmed as "permissive" on the program card are to be displayed on the field output

status display, if desired. This shall be accomplished using the Mode and Inc. buttons to be supplied on the front panel.

k. Program Card Absent. If the program card is absent or not seated properly in the edge connector, the monitor shall enter the fault mode and cause the output relay contacts to transfer. The "program card" indicator on the fault status display shall be displayed to indicate this condition. A manual reset or external test reset shall be required after the program card is properly seated.

l. Internal Watchdog. The monitor shall generate an internal watchdog pulse from the microprocessor. It shall occur once per line cycle near the start of its program loop. If the internal hardware does not detect a watchdog pulse within 100 milliseconds, the monitor shall enter the fault mode causing the output relay contacts to transfer. A "monitor fail" LED on the front panel shall illuminate to indicate a monitor hardware and/or firmware failure.

m. Reset Input Detection. This function shall be provided to prevent the cabinet controller from being operated with the monitor disabled due to a faulty reset button or external test reset input. The monitor shall monitor the state of the front panel reset button and the external test reset input. When a reset command is detected from either input, the monitor shall remain in the reset mode with all indicators illuminated, the output and start relays energized, and monitoring functions disabled. If the reset command lasts for a continuous duration of 120 seconds, the monitor shall then automatically enter the normal mode and begin monitoring functions, ignoring the state of the reset inputs.

n. Voltage Monitor Fault Latch. When the voltage monitor fault option is enabled by the front panel switch labeled "VM latch" the absence of the proper voltage level at either the CVM input or the two 24 VDC inputs (24V-I & 24V-II) shall place the monitor into the fault mode causing the output relay contacts to transfer. The appropriate fault indicator(s) and the time and date shall be displayed on the fault status display along with the field output signals active at the time of the voltage fault. Restoration of the voltage levels shall not reset the fault state of the monitor. Only a manual reset or external test reset command shall reset the monitor. IF THE VM LATCH AND CVM LOG DISABLE OPTION SWITCHES ARE BOTH ON, CVM FAILURES SHALL NOT BE LATCHED OR DATA LOGGED.

o. Display LCD & LED Test. The monitor shall display all front panel LCD indicators and illuminate all front panel LED indicators when a reset command is issued by the front panel reset button or external test reset input. This function shall provide a way to check the operation of all front panel indicators.

p. Memory Test. The monitor is to verify the proper option of the memory (RAM & EPROM) devices required to operate the monitor. This test shall be performed when AC+ power is applied or a reset command is issued to the monitor. If a monitor will enter the fault mode causing the output relay contacts to transfer, the "monitor fail" LED indicator on the front panel shall illuminate to indicate a monitor hardware and/or firmware failure.

q. Fault Timing and Configuration Display. The fault timing specifications for conflict, red fail, voltage monitoring, dual indication, clearance fail, and controller watchdog fail (if enabled) as set by the factory shall be reviewed on the fault status display using the Mode and Inc. buttons on the front panel. Timing values for conflict, red fail, voltage monitoring, and dual indication are to be shown in milliseconds. Timing values for clearance fail and controller watchdog fail are to be shown in seconds. Also to be displayed are the channels selected by the switches. If the 24V inhibit input is active, the value displayed for +24V-I and +24V-II shall be shown as "off". Similarly, if red enable is not active the value shown for red fail, dual indication, and clearance fail shall be "off". If both dual select switches and the GY enable switch are off, the value shown for dual indication shall be "off". If the BND monitoring function is disabled the display shall show "off". The "off" display shall indicate that the selected monitor function is disabled.

r. BND (Blinking/Noise/Dimming) Error Detection. This error detection shall be provided to supplement the unique firmware sampling and digital filtering method for the field input signals which are to provide limited noise immunity. The BND error detection function shall be designed to recognize many of the possible input waveforms and shall place the monitor into the fault mode and cause the output relay contact to transfer if the varied and erratic signal conditions exist as described below for a pre-determined period of time. The "BND fail" indicator and the front panel channel indicator(s) on which the fault occurred shall be displayed. An AC+ brownout condition or a complete loss of AC+ power shall test reset the BND fault state of the monitor:

(1) Blinking. A signal condition that may exist under certain abnormal circumstances such as: controller output malfunction (i.e., output toggling, pinwheeling, etc.); the output of a load switch intermittently shorting to ground; intermittent field wiring due to corrosion, etc.

(2) Noise. Constant noise on the field output signal that may affect the integrity of the input sample if it occurs exactly within the narrow sampling "window". Depending on the severity and repetition rate of the input noise, a BND error should be detected after the samples have been corrupted for a period of 30 to 200 lines cycles.

(3) Dimming. The sampling and filtering algorithm allows only half wave (positive or negative) suppressed dimming. Other dimming waveforms may be achieved under cabinet controller firmware control and shall be detected as a BND error within approximately 30 periods of the input waveform.

s. Front Panel Description.

(1) Field Output Status Display. The field output status displays shall be liquid crystal displays (LCD). The monitor displays shall exceed the minimum NEMA requirements by showing all four field output signals per channel. When the unit operates normally without a fault condition present, the currently active field output signals shall be displayed. Once triggered by a fault condition, the displays shall retain the signals active at

the time of the fault. Dark solid arrows shall be displayed below the channel number for each channel involved in the fault.

(2) Fault Status Display. The main status display shall be a liquid crystal display (LCD). The monitor shall display nine fault conditions in addition to the time and date that the fault occurred. If the unit is operating normally without a fault or voltage monitor condition present, only the current time and date shall be displayed.

(3) Voltage Monitor Indicators (CVM/WD, 24V-I, 24V-II). One or more of these indicators shall be displayed along with the field output signals active at the time the unit was triggered if the corresponding voltage input is below the minimum specified level. If the voltage monitor latch (VM latch) option is enabled and the unit is triggered by an improper voltage condition, the corresponding indicator(s) shall remain displayed until the unit receives a reset command from the manual reset or external test reset input. If the VM latch and CVM log disable option switches are both enabled (on), CVM failures shall not be latched or data logged. If the controller watchdog monitor option (WD enable) is enabled and the unit is triggered by a controller watchdog output failure, the CVM/WD indicator shall remain displayed until the unit receives a reset command from the manual reset or external test reset input or the AC+ voltage level drops below the specified drop-out level.

(4) Conflict Indicator. A conflict indicator shall be displayed when a conflicting proceed signal fault is detected. The field output status displayed shall show all active field output signals at the time of the conflict. Dark solid arrows shall be displayed below the channel number for each channel involved in the fault.

(5) Dual Indicator. A dual indication indicator shall be displayed when a dual indication fault is detected on a channel. The field output status display shall show all active field output signals at the time of the dual indication fault. Dark solid arrows shall be displayed below the channel number for each channel involved in the fault.

(6) Red Fail Indicator. A red fail indicator shall be displayed when an absence of signal (dark signal head) is detected on a channel. The field output status display shall show all active field output signals at the time of the red failure. Dark solid arrows shall be displayed below the channel number for each channel involved in the fault.

(7) Clearance Indicator. A clearance fail indicator shall be displayed when a short (less than 2.8 seconds) yellow signal or absence of yellow signal is detected on a channel(s) during a red to green to yellow to red sequence. The field output status display shall show all active output signals at the time of the clearance fault. Dark solid arrows shall be displayed below the channel number for each channel involved in the fault.

(8) BND Indicator. A BND fail indicator shall be displayed when a blinking/noise/dimming fault is detected on a channel. The field output status display shall show all active field output signals at the time of the

BND fault. Dark solid arrows shall be displayed below the channel number for each channel involved in the fault. If the BND fault is detected on the red enable input then no dark arrows should be displayed.

(9) Program Card Indicator. A program card indicator shall be displayed if the program card is absent or not seated properly in the edge connector. A field output status shall be displayed to show all active field output signals at the time of the fault. A manual reset shall be required after program card is properly seated.

(10) Previous Failure Indicator. The monitor shall retain complete information on the last nine consecutive faults which triggered the monitor in addition to the current fault information if the unit has been triggered by a fault condition. The previous fault information should be displayed at any time by depressing a "Inc/Prev.Fail" button, to be provided. The "previous failure" indicator shall be displayed with the number if the fault also shown (previous failure 1 [PF 1] is the most recent failure logged). Each button closure shall display the next previous failure information, returning to the current display on the tenth button closure.

(11) Time and Date Display. A clock and calendar display shall alternate between the time of day and the date. The time shall be denoted by either an "AM" or a "PM" indicator. The date shall be denoted by the "date" indicator. If the monitor is displaying current fault information, then the time and date shall indicate when the fault occurred. If the monitor is displaying previous fault information, then the time and date shall alternate with the previous fault number and indicate when the fault occurred. Otherwise, the current time of day and date shall be displayed.

(12) DC Voltage Monitor.

+24 VDC Inputs (Inactive).....less than +18 VDC
(Active).....greater than +22 VDC

(13) Logic Inputs.

Controller voltage monitor,
Ext. reset, +24V monitor inhibit,
Controller watchdog input
(Active).....less than +8 VDC
(Inactive).....greater than +16 VDC

(14) Timing Functions.

(a) Dual indication

(No Fault).....less than 20 milliseconds
(Fault).....equal to or greater than 2.8 seconds

(b) Watchdog

(No Fault).....less than 1400 milliseconds
(Fault).....greater than 1600 milliseconds
(Typical).....1500 milliseconds

(c) AC+ interruption
(Disable).....greater than 475 milliseconds (+25 milliseconds)

(d) Minimum flash after disable.....4 to 15 seconds (±1 second)

(e) Start delay relay timer.....2.5 seconds (±1 second)

t. LED Displays.

(1) Power Indicator. A power LED indicator is to be provided and to blink at a rate of 2 Hz when the AC+ line voltage goes below the drop-out level (92 VRMS). It shall illuminate steadily when the AC+ line voltage returns above the brown-out restore level (100 VRMS). The indicator shall extinguish when the AC+ line voltage is no longer sufficient to provide the DC voltages necessary for proper monitor operation (approximately 60 VRMS).

(2) Fault Indicator. A fault LED indicator shall illuminate when the unit has been triggered by a fault condition or has sensed a +24V voltage monitor condition and indicates that the monitor has caused the output relay contacts to transfer.

(3) Monitor Fail Indicator. A monitor fail LED indicator shall illuminate when one of the following internal monitor failures are detected: internal watchdog failure, memory test failure, or internal power supply failure. This indicator is to inform the service technician of a monitor hardware and/or firmware failure.

u. Miscellaneous Requirements.

(1) Power.

Operating Line Voltage.....75 to 135 VAC RMS
Operating Line Frequency.....60 ±3 Hz Power
Consumption.....5 W (nominal)
Battery Life Time.....Minimum 8 Years
Minimum Battery Voltage.....2.2 Volts

(2) Printer. The monitor shall be equipped with an infrared printer output to provide a hard copy of the data log and monitor setup.

(3) Displays. The MMU shall have two high contrast, large area Liquid Crystal Displays (LCD) which shall continuously show full RYG(W) intersection status. A separate graphic LCD provides a menu driven user interface to status, signal voltages, configuration, event logs, and help systems.

(4) Event Logging. The MMU shall maintain a nonvolatile event log recording the complete intersection status as well as AC line events, configuration changes, monitor resets, cabinet temperature and true RMS voltages. A real time clock shall time stamp each log event with time and date.

(5) Setup Wizard. Set up and use of NEMA Enhanced features of the MMU shall possible by answering a short series of questions regarding intersection design and operation.

(6) Program Card Memory. All NEMA enhanced settings of the MMU shall be in nonvolatile memory located on the Program card, therefore moving the program card to another like MMU shall automatically transfer all settings.

(7) Signal Sequence History Log. The log shall store in nonvolatile memory and graphically display up to 30 seconds of signal status prior to each fault event.

5. Fiber Optic Communications Interface.

a. General. Each new controller cabinet shall have a Fiber Optic Communications Interface, which shall be either a Type 1 interface or a Type 2 interface, as called for by the application shown on the Plans:

(1) At locations where the Plans call for only one fiber optic cable with six (6) or fewer fibers to enter a controller cabinet (including locations where the Plans call for the installation of a prefabricated drop cable, a Type 1 Fiber Optic Communications Interface shall be provided. At these locations, no provisions are required in the controller cabinet for splicing of optical fibers.

(2) At all other locations, a Type 2 Fiber Optic Communications Interface shall be provided. At these locations, provisions are required in the controller cabinet to splice optical fibers.

b. Type 1 Fiber Optic Communications Interface. Each Type 1 fiber optic communications interface shall consist of one of the following:

(1) A prefabricated (i.e., factory-terminated) SMFO or MMFO drop cable of sufficient length to extend with adequate slack to the splice cabinet or aerial/in-pullbox splice enclosure shown on the Plans. Inside the controller cabinet, a minimum of twenty (20) feet of coiled slack shall be provided and secured to the cabinet. The incoming drop cable shall be securely tied to the cabinet walls with tie-wraps at intervals of not more than six (6) inches between the point where the drop cable enters the cabinet and the coiled slack. Between the coiled slack and the controller, approximately four (4) feet of length shall be provided for connection to the Ethernet Switch, the Serial Device Server, or the front panel of the controller, as called for on the Plans. Each prefabricated drop cable shall meet the requirements of Subsection 02890.1.01A.2.

(2) A fan-out kit, pre-connectorized with ST-compatible connectors, which shall be used to link the incoming 6-fiber SMFO (or MMFO) cable with the

controller. The fan-out kit shall provide six (6) 3-foot lengths of fan-out tubing secured in a modular assembly. The jacket of the incoming cable shall be stripped back and each fiber shall be inserted into a fan-out tube. Each fan-out tube insert shall then be snapped into a protective inner housing. When all inserts have been loaded, an outer housing shall be installed to complete the assembly. The resulting fanned-out fibers shall be connectorized and each shall have a loss which does not exceed 0.3 dB. Each fan-out tube shall provide three levels of protection for the fiber, including a Teflon inner tube, a dielectric strength member, and an outer PVC jacket.

c. Type 2 Fiber Optic Communications Interface. Each Type 2 fiber optic communications interface shall include the following:

(1) One (1) splice tray housing with front-panel ST-compatible connectors;

(2) Two (2) or more splice trays; and

(3) Four (4) prefabricated SMFO (or MMFO) patch cables (jumpers) which shall have ST-compatible connectors on each end to connect the front panel of the tray housing with the front panel of the traffic signal controller. Each patch cable shall meet the requirements of Subsection 02890.1.01. A.. 3.

d. Splice Trays. Each splice tray shall be metallic and shall accommodate a minimum of twelve (12) fusion splices plus a minimum of six (6) mechanical splices. The tray shall consist of an aluminum base and an aluminum cover. The design of the tray shall provide physical protection for both types of splices.

Each tray shall have crimpable metal tabs to provide strain relief for the buffer tubes. Additional strain relief points shall be provided for tie-wrapping buffer tubes or pigtails to the tray. Each tray shall contain organizers which shall hold and protect each type of splice.

The approximate dimensions of each tray shall be 12 inches by 4 inches by 3/16 inches A minimum of two (2) trays shall be provided in each housing. Additional trays shall be provided as necessary to accommodate the number of fusion splices required by the initial system construction shown on the Plans.

e. Tray Housing. Each tray housing shall be made of aluminum or stainless steel and shall have the following features:

(1) Accommodation for the number of splice trays required by the initial application called for on the Plans plus 25 percent;

(2) Hinged, lockable door; and

(3) Front panel with a minimum of twelve (12) ST-compatible connectors. A connector shall be provided for each fiber of each FO cable which is brought into the cabinet. The rear of each connector shall have a factory-

connected pigtail, which shall be fusion spliced by the Contractor in a splice tray to the incoming or outgoing fibers.

Each splice tray shall slide into the housing and shall securely lock into place. Tray housings may be wall-mounted or rack-mounted at the Contractor's option.

C. VEHICLE DETECTOR AMPLIFIERS.

1. General.

This subsection defines the minimum acceptable design, operational and functional performance requirements for high performance, multiple channel, inductive loop vehicle detection systems.

a. 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. Detectors shall also be suitable for use in California/New York TYPE 170/179 or ATC input files.

b. Detector units of the same type shall be interchangeable whether used for system sampling or local intersection control.

c. Each detector unit shall include four complete detector channels.

d. Detector units shall have optical outputs for interface with existing or new solid state controllers and computer systems.

e. All connectors and channel indicators shall be mounted on the front panel; controls for selection of sensitivity, mode of operation, reset/circuit breakers and (when specified, DELAY, EXTENSION or timing off) shall be front panel accessible. The front panel shall clearly indicate switch operating positions.

f. All component part and test points shall be clearly identified by permanent marking of circuit references on the P.C. Board.

g. Integrated circuit devices having 16 or more leads shall be socket mounted to facilitate repair and maintenance of units.

h. When monolithic integrated circuits are of such special design that they preclude the purchase of identical components from any wholesale electronics distributor or any component manufacturer, one exact duplicate monolithic integrated circuit shall be furnished with each ten, or fraction thereof, monolithic integrated circuits supplied.

2. Functional Requirements:

a. Each channel shall sequentially energize its loop inputs to eliminate crosstalk (mutual coupling) between large, very closely spaced adjacent loops connected to the same unit. The sequential time sharing and digital processing of loop inductance data shall be accomplished on a single LSI

micro-circuit per unit for maximum reliability. The method of measurement shall be crystal reference digital period counting, multi-channel scanning. Only one channel input per unit shall be active at any point in time.

b. Each unit shall be provided with a frequency switch as an additional aid to control crosstalk between detector units.

c. 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.

d. 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.

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

f. Each detector unit shall contain a front-panel switch position for each channel to provide for manual reset per channel capability.

g. Each channel shall be controlled by a direct reading 16-position thumb wheel switch to allow selection of a minimum of 8 Pulse mode sensitivities, 7 Presence mode sensitivity levels, Channel Reset capability and an Off mode on a per channel basis. The sensitivity setting shall offer 2:1 steps over a range of 128:1 to enable selection of the proper sensitivity (threshold) to insure detection of all motor vehicles. Pulse mode shall be indicated on the push-wheel switch by a pulse symbol over the channel sensitivity numeral. The OFF position shall be selected by setting "X" on the switch.

h. Each channel shall include a mode switch to select presence, pulse or off. The off position shall disable the output and indication when selected. It may also be used to assist in determining the offending channel when crosstalk is present.

(1) Pulse mode shall provide a single 118 ±2 ms output pulse in response to an automobile traveling over a 6'x6' loop at 10mph and should detect successive vehicles traveling over the same loop at speeds of 10 to 60 mph with minimum 1 second headway. If a vehicle remains in the sensing zone the channel shall re-phase after 1.9 seconds to enable detecting additional vehicles on unoccupied portions of the loop after 2 seconds. Additionally, the re-phase time shall be settable from 0.1 to 25.5 seconds using the interface software.

(2) Pulse mode selection shall reset (Clear) presence indications on individual channels.

(3) Presence hold time shall be at least 4 minutes for small 70cc motorcycles over one loop of a series/parallel connected, four 6'x6' loop configuration with 1000' of lead-in. Hold time for a standard automobile shall be at least 60 minutes over one loop of the same configuration.

(4) Special circuitry shall prevent tune-out of continuous peak hour traffic over long or multiple small loops as long as there is vehicle motion into the sensing zone at least every 10 minutes.

i. 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 to over 1,000 feet.

j. 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, i.e., multiple loops connected in series with lead-in/homerun from 50 feet to over 1,000 feet.

k. Each unit shall contain a common, switched, loop oscillator to eliminate mutual-interference/ magnetic-coupling (crosstalk) from multiple loops in adjacent lanes and/or allow use of overlapped loops for directional control and/or use of multi-conductor homerun cable when connected to the same detector unit.

l. Each sensitivity setting shall be equated to nanohenries of inductance change (ΔL) as shown in Table 2-9.

Table 2-9 Sensitivity Setting vs. Inductance Change

Sensitivity Level Setting	Inductance Change ΔL (Nanohenries)
C	1024
1	512
2	256
3	128
4	64
5	32
6	16
7	8

m. Each unit shall contain a frequency switch that shall provide three (3) frequency selections per unit to reduce interaction with loops connected to another unit.

n. Each unit shall maintain the same sensitivity (threshold in nanohenries) in any of the three (3) frequencies selected.

o. The maximum response time to an instantaneous beginning or end of a stimulating inductance change of twice the magnitude required to detect in sensitivity levels 1, 2, and 3, when connected to typical 3 or 4 turn 6-foot x 6-foot loops with from 45 feet to over 1,000 feet of lead-in/homerun cable attached, shall be less than 6 milliseconds for a 4-channel unit.

p. Each unit shall contain a toggle switch with a spring loaded position that will reset all channels and stable positions to allow selection of "Normal" or "Fast recovery" mode to enhance performance in left turn lanes or other queue situations.

q. Each unit shall contain a remote reset input that will allow an external reset of all channels.

r. When the input voltage on pin C falls below 8 VDC for over 15 microseconds, the detector shall reset all active channels and establish a new reference for each "on" loop within 4 seconds.

s. Each channel shall include a DIP switch to invoke a special Microloop mode. Setting this switch shall change the operating mode to be specific to Microloop probes.

t. When Delay and/or Extension timing is specified, each channel shall include a 7 position DIP switch on the PCB to select Delay, Extension or Off, if no timing is desired.

   (1) Delay time shall be selectable in 0 to 63 seconds in 1.0 second increments.

   (2) Extension time shall be selectable in 0 to 15.75 seconds in 25 second increments.

   (3) Selection of OFF shall disable timing in both Pulse and Presence modes.

u. When Delay and/or Extension timing is specified, each channel shall include an external input to control the timing.

   (1) A true condition shall exist if the input voltage falls below 8 VDC for ≥17 microseconds.

   (2) Extension timing shall occur only if the corresponding input to the detector channel is true (low/active) and Delay timing shall only occur if the input is false (high/inactive).

v. Detector units shall be designed to operate over a voltage range of from 10.8 VDC to 37 VDC.

w. Units shall draw less than 50 mA per channel from the DC power source over the input voltage range.

x. Each unit shall have a front panel mounted EIA 232 serial communications port to interface with PC's or other devices.

y. Design of the unit shall provide for user selectable changes in operating characteristics, to allow for modification of performance for unique or special applications, that can be obtained by invoking the options from a computer or other device connected to one of the EIA 232 serial interfaces.

z. The unit shall record the occurrence of an open loop, shorted loop, or excess inductance change ($\pm\Delta 25\%$).

aa. The most recent type of error on each channel and the time of error occurrence shall be made available through the serial interface.

bb. Software command options shall exist to allow the user to:

(1) Choose to eliminate the call output and induction for the open loop condition and other loop problems. It shall not affect the coded flashing fault indicators or software record of failures.

(2) Eliminate the standard 1.9 second pulse rephase altogether, reduce the rephase time to 1.0 seconds or increase rephase time to 3.8 seconds.

(3) Select output Pulse widths of 15 ms., 59 ms., or 236 milliseconds. Standard pulse duration is 118 milliseconds.

(4) Modify minimum (small motorcycle) hold time of 4 minutes (240 seconds) to 7.6 seconds, 120 seconds, or 480 seconds.

(5) Modify standard automobile hold time of typically 1 to 2 hours to .5 to 1 hour, or 2 to 4 hours.

(6) Modify background adapt rate from 0.50 Threshold/second to 0.25, or 1/second.

cc. The interface software shall aid in the setup of the vehicle detector units by presenting all of the user selectable parameters on the personal computer display, allowing the operator to view and change operating parameters as required. It shall be available on CD media. The software shall be compatible and fully operable when used on an IBM PC-compatible microcomputer with Windows 2000 operating system or higher.

dd. The user interface software shall have multiple screens to present all unit setup options, and operating parameters. It shall retrieve and display the unit and loop diagnostics, unit and system measurement values, output status, and it shall download user selectable operating parameters and defaults.

ee. The Loop Activity (live data) screens shall display the elements shown in Table 2-10.

ff. The Unit Parameters to be selected or altered shall include those shown in Table 2-11.

gg. Factory preset defaults shall be stored in memory. User selectable "options" shall be selectable in EEPROM via serial interfaces to modify standard operating parameters.

hh. In addition the TS2 Address (0-7) and the Reset input line status shall be displayed.

ii. The Channel Parameters to be selected or altered shall be as shown in Table 2-12.

jj. The units shall intermate with the 44 pin edge connector shown in Table 2-13.

kk. Polarization keys shall be located between pins B2 and C3, between pins E5 and F6, and between pins M11 and N12.

Table 2-10 Loop Activity Screen Displays

Green Input Signal	On/Off
Vehicle Count	Number
Detection Time (Duration)	Milliseconds
Last Loop Fault	Open, Shorted, ΔL ≥25%
When Occurred	Date and Time
Current Status	Normal or Fault
Call Output	On/Off
Loop Inductance	Microhenries
Loop Frequency	Kilohertz
Reference Frequency	Kilohertz
Max. Delta Inductance Change	Nanohenries
Detect Status	Detect, No detect
Vehicle Count w/Count Reset Button	Count

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Table 2-11 Unit Parameters to be Displayed or Altered

TS2 Compatible (backpanel addressing)	Enabled/Disabled
Vehicle Count Period	0-63.5 hours (15 min., 1 hr., etc.) or Continuous
Detect Open Loop	Yes, No
Detect Shorted Loop	Yes, No
Detect ΔL ≥25%	Yes, No
Number of Channels	2, 4
Serial Port Speed	1200, 2400, 4800, 9600 BPS
Fast Recovery Mode	On, Off
Frequency Selection	High, Medium, Low
Configuration Setup Source	Switches, or EEPROM
Power Line Frequency	Disabled, 50 Hz, or 60 Hz
Microloop Filtering	Yes, No
Noise Margin	Low, Medium, High
Rephase Delay	Off, 0.95, 1.8, 4.0, 8.0 Seconds
Output Pulse Width	15, 59, 118, 236 Milliseconds
Washout Delay	7.6, 120, 240, 480 Seconds
Adapt Rate	0, .25, 150, 1.0 Threshold per Second
Reset	Resets Unit and Data

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Table 2-12 Channel Parameters to be Selected or Altered

Sensitivity Threshold Selection	1-8 Settings in 2:1 Increments
Pulse/Presence Mode	Pulse, Presence
Delay Timing	OFF / 1-63 Seconds in 1 second increments
Extension Timing	OFF / 0.25-15.75 Seconds in 0.25 second increments
Microloop Sensors	Yes, No
Long-loop Count	Enabled, Disabled

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Table 2-13 Edge Pin connector Assignments

Logic (DC) Ground	A	1	Delay/Ext. Ch 1 (DC+input)
DC Supply	B	2	Delay/Ext. Ch 2 (DC+input)
Remote Reset Input	C	3	Delay/Ext. Ch 3 (DC+input)
Loop in Ch 1	D	4	Loop in Ch 1
Loop in Ch 1	E	5	Loop in Ch 1
Ch 1 output (+)	F	6	Detector Address 0
Ch 1 output (-)	H	7	Status output Ch 1
Loop in Ch 2	J	8	Loop in Ch 2
Loop in Ch 2	K	9	Loop in Ch 2
Chassis ground	L	10	Delay/Ext. Ch 4 Det. address 1
AC-neutral	M	11	No connection
AC-line	N	12	No connection
Loop in Ch 3	P	13	Loop in Ch 3
Loop in Ch 3	R	14	Loop in Ch 3
Ch 3 out (+)	S	15	Detector address 2
Ch 3 out (-)	T	16	Status output Ch 3
Loop in Ch 4	U	17	Loop in Ch 4
Loop in Ch 4	V	18	Loop in Ch 4
Ch 2 out (+)	W	19	Data-Transmit
Ch 2 out (-)	X	20	Status output Ch 2
Ch 4 out (+)	Y	21	Data-Receive
Ch 4 out (-)	Z	22	Status output Ch 4

3. Ports.

Each detector unit shall have two serial ports. A front panel RS-232 port and send/receive pins on the card edge connector. Each port shall be capable of party line communication with up to 8 detectors on the party line.

4. Interface Software.

In addition to the software requirements listed in Subsection 1.01A.2 above, the interface software shall provide an activity screen to display loop system operating characteristics, for each channel, to aid in system setup and diagnostics including:

- Loop Status - Ready, Detect, Fault mode and Reset
- Loop inductance (L) in Microhenries (µH)
- Loop frequency (F) in Kilohertz (kHz)
- Reference frequency (F) in Kilohertz (kHz)
- Maximum Delta inductance (ΔL) in Nanohenries (nH)
- Green Input Signal (on/off)
- Last Fault (type) - Open, Shorted, ±25% ΔL
- When Occurred (Date/Time)
- Detection time in milliseconds (ms)
- Vehicle Count with count Reset button

The activity screen shall include a button to take a snapshot of live data that can be frozen and/or saved to file. The interface software shall:

a. Allow assignment of channel number, loop ID and loop length to enable accurate measurement of vehicle occupancy times. Data shall be available via the serial ports.

b. Allow assignment of loop-to-loop distances to enable accurate speed measurement and vehicle length measurement. Data shall be available via the serial ports.

c. Provide a vehicle log setup screen and a log screen to report date, time, channel number, loop description, and;

(1) Duration of detection in milliseconds

(2) Loop-to-loop time in milliseconds

(3) Vehicle length in feet or meters

(4) Speed in miles per hour or kilometers per hour.

5. Miscellaneous Requirements.

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.

a. The detector shall include optically-isolated, solid-state outputs designed to provide a continuous "fail-safe" (fail-call) output in the event of power loss to the unit.

b. The detector shall provide delay and/or extension timing capability of the detection output for each channel, when timing is specified.

c. These NEMA detectors shall contain a means to disable the delay and/or extension green sense input circuit on channel four when timing units are installed into a TS2 card rack. This shall allow the wired, 44-pin, edge connector to enable the detector address bit #1 on pin #10.

d. Back-plane wiring shall provide four (4) hardwired addresses, to accommodate four 4-channel units, and EIA-232 communication support. The units specified shall be tested for conformity to these requirements utilizing properly operating loop configurations and homerun/lead-in combinations described herein. The goal is to obtain detector units that shall detect and hold presence of all licensable motor vehicles (including 70 cc motorcycles) when connected to microloop probe sets and/or loop configurations of from 6 feet x 6 feet up to 6 feet x 90 feet with lead-ins of from 45 feet to over 1,000 feet without detecting vehicles in the adjacent lanes. (Long loops may require special configuration such as the quadrupole configuration to insure adjacent lane rejections.)

e. Detector units shall be in full compliance with the environmental, transient and size requirements of NEMA and the design, operation, electrical and functional performance requirements of this specification.

f. The front panel shall include erasable, write-on pads adjacent to each detect indicator to aid in identification of associated lane, function, or phase activity.

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

The green detect LED indicators shall repetitively cycle on at:

- 4 Hz during Delay timing.
- 16 Hz during Extension timing.
- During fault detection the green channel detect indicators shall provide a steady indication in either pulse or presence mode.

The red fault LED indicators shall repetitively cycle on for:

- One long pulse 1 sec.) and one short pulse (25 sec) to indicate open loop.
- One long pulse (1 sec) and two short pulses (25 sec) to indicate shorted loop.
- One long pulse (1 sec) and three short pulses (25 sec.) to indicate ±25% change of inductance.

6. Testing:

To insure conformance to the operational and performance requirements, detector units shall be tested with at least two channels connected to adjacent loop and lead-in systems:

a. 6'x6' 3-turn loops, 5' apart, with 50', 500', and 1000' of lead-in.

b. 6'x45' 2-turn loops, 5' apart with 50', 500', and 1000' of lead-in. The 6'x45' shall detect small motorcycles, but shall also detect vehicles in adjacent lanes. To eliminate adjacent lane detection, a configuration, such as a 2-turn quadruple loop, may be required in exclusive lanes.

c. A single 4-loop configuration (4-6'x6') series/parallel connected loops with 50', 500', and 1000' of lead-in shall confirm sensitivity.

d. Test procedures are available to confirm the capabilities and conformance to these specifications.

7. Conformance Requirements:

The Contractor shall furnish engineering schematics and operational specifications for the equipment. The Contractor may be required to furnish one detector unit for 30 days testing and evaluation prior to award of any contract. If the Contractor is requested to furnish a sample detector unit, it shall be furnished within five days of the date requested. All material, parts and workmanship shall be guaranteed for a period of two years after field installation with defective equipment either repaired or replaced entirely at Contractor's expense.

All material shall conform to these specifications and the requirements of NEMA standards TSI-Part 7. The City of Memphis reserves the right to return all material not meeting the specifications. The Contractor shall provide one electrical schematic and one manual per 24 channels or fractional part thereof describing theory and circuit operation, geographical parts layout and trouble shooting test points with expected wave shapes and voltage levels at these test points.

D. 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 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.

The conductor shall be placed in a saw cut as shown on the Plans and sealed with a sealant meeting the requirements of Subsection 02890.2.03B.

E. PEDESTRIAN PUSH BUTTON DETECTORS

Each Pedestrian Push Button Assembly shall be actuated by pushing a neoprene surface area at least two (2) inches in diameter. Each push button assembly shall comply with applicable requirements of the Americans with Disabilities Act. The internal button shall be of the spring return type and cause the closure of a set of internal contacts. 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.

F. VIDEO DETECTION

This specification sets forth the minimum requirements for a system that detects vehicles on a roadway using only video images of vehicle traffic.

1. General

a. System Hardware

The video detection system (VDS) shall consist of up to six video cameras, video detection processors (VDP) capable of processing from one to six video sources, either wired or wireless, monitor and a pointing device.

If rack mounted version is called for on the Plans, the system shall include power supply unit and card rack (if not reusing the existing card racks). 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 (For instance, the Vantage Access card for the Iteris Vantage Edge 2 system) 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 pointing device connections.

If a wireless version is called for on the Plan, the wireless video transmission receiver and receiver antenna shall also be included. Video cameras shall be wireless type with integral transmitter antenna.

b. System Software

The system shall include software that detects vehicles in multiple lanes using only the video image. Detection zones shall be defined using only an on board video menu and a pointing device 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.

2. Functional Capabilities

a. Available System Configuration

(1) The VDS shall be deployed at locations where site conditions and roadway geometry vary. The VDS system may also be deployed at locations where existing cabinets or equipment exist. Existing site configurations shall dictate the availability of cabinet space and VDS usage.

(2) The proposed VDS shall be available in various configurations to allow maximum deployment flexibility. Each configuration shall have an identical user interface for system setup and configuration. The

communications protocol for each configuration shall be identical and shall be hardware platform independent.

Table 2-14 VDS Configuration

Configuration	**No. Video Inputs**	**No. Video Outputs**	**Mounting Configuration**	**Power Supply Requirements**
Multi-channel Shelf Mount	N/A	N/A	Shelf Mount	Integrated
Single Channel Shelf Mount	N/A	N/A	Shelf Mount	External Power Supply Required
Single or Dual Channel Rack Mount	1 or 2	1	Rack Mount (Type 170/2070 or NEMA TS-1/TS-2 Racks)	12 or 24 VDC Power From Rack

(3) An option to have wireless video transmission between the camera sensor and VDP shall also be available from the VDS manufacturer.

(4) Wired camera systems shall be able to transmit NTSC or PAL video signals, with minimal degradation, up to 1000 feet under ideal conditions.

(5) Wireless camera systems shall be able to transmit an NTSC or PAL video signal, with minimal signal degradation, up to 500 feet under normal conditions and up to 900 feet under ideal electromagnetic interference 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.

(6) The multi-channel shelf mount configuration shall use modular components and shall be capable of being serviced (remove and replaced) without the need to open or remove the equipment enclosure. Each module shall have retention screws to firmly affix the module into the equipment enclosure. Pull-tabs or pull-bars shall be provided for each removable module to facilitate the ease of maintenance. Unused modular slots in the enclosure shall be covered with blank spacers. The use of stand-alone rack mount units placed in a rack does not meet the requirements of this configuration.

b. System Interfaces

The following interfaces shall be provided for each of the configurations identified in Table 2-14.

(1) 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.

(2) 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.

(3) 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. For rack mounted version, if multiple processors / extension modules are used, an integration card served as a central switching point (For instance, the Vantage Access card for the Iteris Vantage Edge 2 system) should be included so that the operator can then switch to, control and setup any of the peripheral processors without the need of switching any monitor, communication, or pointing device connections.

(4) 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.

(5) Contact Closure Output: Open collector contact closure outputs shall be provided. Eight (8) open collector outputs shall be provided for the single channel shelf-mount configuration. Thirty-two (32) open collector outputs shall be provided for the multi-channel shelf-mount configuration. 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.

(6) Detection LEDs: LEDs shall be provided on the front panel. The LEDs shall illuminate when a contact closure output occurs. A minimum of eight (8) LEDs shall be provided for each shelf-mounted video processor. Rack-mounted video processors shall have a minimum of four (4) LEDs. Rack-mounted extension modules shall have two (2) or four (4) LEDs to indicate detection, depending on the model.

(7) 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 with each video processor.

c. General System Functions

(1) 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.

(2) 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.

(3) The VDP shall detect vehicles in real time as they travel across each detection zone.

(4) The VDP shall have an RS232 port for communications with an external computer. The VDP RS232 port shall be multi-drop capable.

(5) 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.

(6) 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.

(7) 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.

(8) 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.

3. Vehicle Detection

a. Detection Zones

(1) Multi-Channel Shelf Mount - Up to 6 camera inputs shall be accepted. 24 detector zones per camera configuration shall be supported and each detection zone shall be sizeable to suit the site and the desired vehicle detection region.

(2) Single-Channel (Rack Mount and Shelf Mount) - 24 detection zones shall be supported and each detection zone shall be sizeable to suit the site and the desired vehicle detection region.

(3) Dual-Channel Rack Mount - 24 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.

b. Detection Outputs

(1) Multi-Channel Shelf Mount - The VDP shall provide 32 channels of detection outputs through either a NEMA TS1 contact closure port or a NEMA TS2 port.

(2) Single-Channel Shelf Mount – The VDP shall provide up to 8 channels of vehicle presence detection through a NEMA TS1 contact closure port or through a standard detector rack edge connector and one or more extension modules.

(3) Single or Dual Channel Rack Mount - 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.

c. 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.

d. Placement of detection zones shall be done by using only a pointing device, 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.

e. Up to 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.

f. 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.

g. 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.

h. 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.

i. 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.

j. 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.

k. 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.

l. The VDP shall process the video input from each camera using a separate microprocessor at 30 frames per second.

m. 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.

n. 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.

o. 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.

p. 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.

4. VDP Hardware

   a. Single or Dual Channel Rack Mount - 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 plan. 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.

   b. Multi-Channel Shelf Mount - The VDP shall be housed in a durable metal enclosure suitable for shelf mounting or 19" rack mounting in a roadside traffic equipment cabinet. The VDP enclosure shall not exceed 7" height, 17.75" width, and 10.5" depth. The VDP shall be modular in construction with plug-in field replaceable units (FRU's) to minimize trouble-shooting and repair time.

   c. Single Channel Shelf Mount - The VDP shall be housed in a durable metal enclosure suitable for shelf mounting in a NEMA type traffic equipment cabinet, or attaching to the side rails of a Type 170 traffic equipment cabinet. The VDP enclosure shall not exceed 7.1" height, 2" width, and 6.2" depth.

   d. Input Power

      (1) Multi-Channel Shelf Mount - The VDP shall be powered by 120 VAC 60 Hz single-phase power. Surge ratings shall be as set forth in NEMA specifications. Power consumption shall not exceed 135 watts.

      (2) Single Channel Shelf Mount - The VDP shall be powered by 24 VDC. Power consumption shall not exceed 10 watts.

      (3) Single Channel Rack Mount - 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.

   e. Detection Outputs

      (1) Multi-Channel Shelf Mount - The VDP shall include ports for transmitting TS1 and TS2 detections to a traffic controller. The TS1 contact closure port shall be a 37-pin "D" connector on the front of the VDP. The TS2 port shall be a 15-pin "D" connector on the front of the VDP.

      (2) Single Channel Shelf Mount - The VDP shall include a port for transmitting up to 8 channels of detection to a traffic controller. This port shall be a 9-pin "D" subminiature connector on the front of the VDP.

(3) Single or Dual Channel Rack Mount - The VDP and EM shall include detector output pin out compatibility with industry standard detector racks.

f. Video Inputs

(1) Multi-Channel Shelf Mount - The front of the VDP shall include up to six BNC video input connections suitable for RS170 video inputs. Each 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. The video inputs to the VDP shall include transient voltage suppression and isolation. Amplification that shall assure the 1-volt peak to peak video signal integrity is maintained despite video cabling losses and externally induced transients. The amplifier shall have a minimum common mode rejection at 60 Hz of 90 dB.

(2) Single Channel (Rack Mount and Shelf Mount) - 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 on the rack mounted configurations is not permissible.

g. Video Outputs

(1) Multi-Channel Shelf Mount - The front of the VDP shall include one BNC video output. Any one of the six video inputs shall be switch selectable for output on this BNC connection via the pointing device at the VDP, momentary push-button switch, or through software and a personal computer connected through the RS-232 multi-drop port via a full duplex modem link.

(2) Single Channel (Rack Mount and Shelf Mount) - 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.

h. Mechanical

(1) The VDP shall operate satisfactorily in a temperature range from -34°C (-29°F) to +74°C (+165°F) and a humidity range f rom 0% to 95% RH, non-condensing as set forth in NEMA specifications.

(2) Multi-Channel Shelf Mount. The VDP enclosure shall include provisions to be bonded to a good earth ground. The VDP shall consist of functional modular field replaceable units (FRU's) to facilitate maintenance and expandability. Each camera video input shall be processed of a separate higher performance RISC processor.

(3) Single or Dual Channel Rack Mount. 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.

(4) 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.

(5) 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.

(6) 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.

5. Installation

The video detection system shall be installed by supplier factory certified installers and as recommended by the supplier and documented in installation materials provided by the supplier. Proof of factory certification shall be provided.

6. Limited Warranty

a. The supplier shall provide a limited two-year warranty on the video detection system.

b. During the warranty period, technical support shall be available from the supplier via telephone within 2 hours of the time a call is made by a user, and this support shall be available from factory-certified personnel or factory-certified installers.

c. During the warranty period, updates to VDP software shall be available from the supplier without charge.

7. Maintenance and Support

a. The supplier shall maintain an inventory of parts as required to support maintenance and repair of the video detection system. These parts shall be available for delivery within 30 days of placement of an order at the supplier's then current pricing and terms of sale for said parts. Repair of all parts shall be performed within the United States of America.

b. The supplier shall maintain an ongoing program of technical support for the video detection system. This technical support shall be available via telephone, or via personnel sent to the installation site upon placement of an order at the supplier's then current pricing and terms of sale for on site technical support services.

c. Installation or training support shall be provided by a factory-authorized representative who shall be a minimum IMSA-Level II Signal Technician Certified.

d. The VDP shall be manufactured within the United States of America.

e. All product documentation shall be written in the English language.

G. PRIORITY CONTROL

1. General

This subsection sets forth the minimum requirements for a Priority Control system providing advanced features for user security, identification, communication with the City's ACTRA central ITS software, and mutual aid.

2. System Description

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:

(1) is a valid base frequency,
(2) is correctly data encoded,
(3) is within the user-settable priority request activation range, and
(4) 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 most traffic signal controllers and shall not compromise normal operation or existing safety provisions.

3. 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.

a. The phase selector, designed to be installed in the traffic controller cabinet, shall accommodate data-encoded signals and is intended for use directly with numerous controllers. These include California/New York Type 170 controllers with compatible software, NEMA controllers, or other controllers along with the system card rack and suitable system interface equipment and controller software.

b. The phase selector shall be a plug-in, two or four channel, multiple-priority device intended to be installed directly into a card rack located within the controller cabinet.

c. The phase selector 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.

d. 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.

e. 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 the field wire termination points in the traffic controller cabinet.

f. 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:

(1) Classification: Indicates the type of vehicle.

(2) Identification number: Indicates the unique ID number of the vehicle.

(3) Priority level: Indicates whether High or Low priority, or Probe frequency is requested by the vehicle.

(4) Direction: Channel A, B, C, or D; indicates the vehicle's direction of travel.

(5) Call duration: Indicates the total time in seconds the priority status is active.

(6) Final greens at end of call: Indicates which phases are green at the end of the call.

(7) Duration of the final greens: Indicates the total time final greens were active at the end of call.

(8) Time and date call started and ended: Indicates the time a priority call started and ended; provided in seconds, minutes, hours, day, month, year.

(9) Maximum signal intensity: Indicates the strongest signal intensity measured by the phase selector during call.

(10) Priority output active: Indicates if the phase selector requested priority from the controller for the call.

g. 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:

(1) 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.

(2) 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.

(3) 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.

h. 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.

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

(1) Verification of the presence of the base infrared signal of either High priority, Low priority or Probe frequency.

(2) Validation of the infrared signal data-encoded pulses.

(3) Determination of when the vehicle is within the prescribed range.

j. 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.

k. 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:

(1) 6.25Hz ± 0.1Hz 50% on/duty square wave in response to a Low priority call.

(2) A steady ON in response to a High priority call.

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

(1) Using a data-encoded emitter with range-setting capability.

(2) Using any encoded emitter by manipulating the front panel switches.

(3) Inputting the range requirements via the communication port.

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

n. The phase selector shall have a POWER ON LED indicator that flashes to indicate unit diagnostic mode and illuminates steadily to indicate proper operation.

o. 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.

p. The phase selector shall have a High and Low LED indicator for each channel to display active calls.

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

r. 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.

s. The phase selector shall have write-on pads to allow identification of the phase and channel.

t. The phase selector shall have the capability to enter unique names for each channel via the interface software.

u. 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.

v. 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.

w. 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.

x. 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.

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

z. 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.

aa. 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.

bb. The phase selector shall have the capability to discriminate between individual ID codes, and allow or deny a call output to the controller based on this information.

cc. The phase selector shall have the capability to log call requests by unauthorized vehicles.

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

ee. The phase selector shall have the capability of functionally testing connected detector circuits and indicating via front panel LEDs non-functional detector circuits.

ff. The phase selector shall incorporate a precision real time clock synchronized to an AC power line frequency.

gg. 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.

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

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

4. Interface Software

a. 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.

b. The priority control interface software must accommodate:

(1) Setting up and presenting user-determined system parameters.

(2) Viewing and changing settings.

(3) Viewing activity screens.

(4) 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).

c. The priority control interface software shall accommodate operation via a mouse or via the keyboard, or in combination.

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

(1) Setting of valid vehicle ID and class codes.

(2) Establishing signal intensity thresholds (detection ranges), modem initialization, intersection name and timing parameters.

(3) Setting of desired green signal indications during priority control operation and upload and download capability to view.

(4) Resetting and/or retrieving logged data and priority vehicle activity.

(5) Addressing for each card in a multi-drop connected system.

(6) Confirmation light configuration.

(7) NEMA Control Parameters.

e. The interface software shall provide readout of noise levels detected by the detectors. This noise level shall serve as a troubleshooting tool.

f. 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.

5. Reliability

   a. 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.

   b. 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.

6. 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.

7. Responsibilities

   The manufacturer of the required infrared priority control system and/or the manufacturer's representative shall provide responsive service before, during and after installation of the priority control system. The manufacturer and/or the manufacturer's representative, as consultants to the installer, shall provide certified, trained technicians having traffic systems industry experience and operational knowledge of priority control systems.

8. Substantiated Warranty

   a. The manufacturer of the required infrared priority control system shall warrant that, provided the priority control system has been properly installed, operated and maintained, component parts of a matched component system (see Subsection 02890.1.01A.10) that prove to be defective in workmanship

and/or material during the first five (5) years from the date of shipment from the manufacturer shall be covered in a documented system-protection plan, plus provide an added five-year maintenance coverage for repair or replacement at a fixed deductible charge for a total of ten (10) years of product coverage.

The manufacturer must substantiate its financial ability to respond to warranty claims. The guarantee shall be determined in reference to the manufacturer's business assets and financial experience over the preceding five-year period.

b. In addition, upon request, the manufacturer shall provide documentation proving ability to financially support the ten (10) year provisions of the warranty/maintenance period. Documentation shall include appropriate financial reports for the previous five business years.

c. In total, the warranty/maintenance coverage shall assure that system components shall be available to allow system operation during the ten (10) year warranty/maintenance coverage.

d. A copy of the manufacturer's written warranty outlining the conditions stated above shall be supplied with the bid. Coverage and coverage limitations are to be administered as detailed in the manufacturer's Warranty/Maintenance document.

9. Certificate of Insurance

The manufacturer of the required infrared priority control system shall provide a certificate of product liability insurance protection for $5,000,000 assuring the priority control user that the manufacturer is insured against civil damages if proven to be at fault for an accident due to equipment failure within the system of matched priority control components.

10. Certification

The manufacturer of the required infrared priority control system shall certify that all component products are designed, manufactured and tested as a system of matched components and shall meet or exceed the requirements of this specification.

H. SIGN AND SIGNAL SUPPORT POLES.

1. 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 2-15 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 2-15.

Table 2-15 Minimum Section Modulus for Steel Poles (Inches^3)

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 Poles. 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 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.

2. Common Requirements for Galvanized Steel Span Wire Suspension Poles, Galvanized Steel Mast Arm Poles, and Galvanized Steel Mast Arms

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 02890. 1.01A.3, 02890.1.01A.4 and 02890.1.01A.5 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.

c. Pole Accessories

(1) General. All accessories listed in this Subsection, and in the appropriate subsection of Subsections 02890. 1.01A.3, 02890.1.01A.4 and 02890.1.01A.5, 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 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.

3. Galvanized Signal Span Wire Suspension Poles

This subsection covers specific requirements in addition to the requirements given in Subsection 02890.1.01A.2 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.

(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.

4. Galvanized Steel Mast Arm Poles

This subsection covers specific requirements in addition to the requirements given in Subsection 02890.1.01A.2 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.

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 sbsection of this specification.

5. Galvanized Steel Mast Arms.

This subsection covers specific requirements in addition to the requirements given in Subsection 1.01A.2 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.

6. 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 tabular 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.

7. 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:

a. 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.

b. 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.

c. 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.

d. 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.

e. 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.

I. CONDUIT AND RISERS.

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.

Plastic conduit (PVC) shall be heavy-walled, extruded moisture and oil-proof polyvinylchloride, corrosion resistant, with watertight joints and high impact strength. Conduit and fittings shall be in accordance with the NEMA TC-2 and WC-1094 Specifications, UL listed.

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. The latter shall be used if the riser is to accommodate fiber optic cables.

J. PULL BOXES.

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 as indicated in the Design Standards.

Fiber optic pull box (type A and B) shall be constructed in accordance with the details as shown on the Plans or City of Memphis Standard Drawings. 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 in the City of Memphis Standard Drawings.

K. ELECTRICAL CABLES AND CONDUCTORS

Traffic signal conductors, power service drops, detector conductors, and shielded loop lead-in cable 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. 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.

1. Power Service Drops.

   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.

2. 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.

   a. All multi-conductor control cable shall be manufactured in accordance with International Municipal Signal Association (IMSA) specification #20-1.

   b. 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.

   c. 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.

   d. 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.

e. OVERRUNS WILL NOT BE ACCEPTED.

3. Shielded Detector Cable.

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 ib. test) flooded galvanized steel strand. This cable shall be in accordance with IMSA Specification 20-4.

4. 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.

5. Preemption Detector Cable.

a. Type 2 lead-in cable shall contain four (4) conductors and a shield. The conductors shall be #20 AWG stranded copper.

b. 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.

c. 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..

d. 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.

e. The maximum outside diameter of the cable shall be less than 0.3 inches.

f. 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.

g. 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.

h. The insulation on the conductors shall be polypropylene or polyethylene.

i. The cable shall be a matched component of the emergency vehicle preemption system.

6. CAT6 Ethernet Data Cable.

Required copper Ethernet cables shall be category 6 or above, with appropriate connectors in the same category. Cable wiring shall be compliant with the Telecommunications Industry Association (TIA) TIA/EIA-568-A wiring standard. For cables installed in the cabinet, conduit, and poles in the field, appropriate rated cables suitable for use in conduit, duct, aerial, or direct burial installations must be used. Power and data cables shall not be installed in the same conduit. If shielded cable is used, the cable shield should be grounded at one single point to avoid the generation of ground loops.

L. SIGNAL SPAN WIRE ASSEMBLIES

1. 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.

2. Tetherwire.

Strand cable for tetherwires 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.

3. 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 tetherwires, 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.

M. MESSENGER WIRE.

Strand cable for messenger wire use (other than span wire above) 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. Tetherwires and aerial loop detector lead-in support spans shall be 1/4 inch Siemens-Martin grade unless otherwise noted on the Plans.

N. GUYING ASSEMBLIES.

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.

O. FIBER OPTIC COMMUNICATIONS SYSTEM.

1. Fiber Optic Cable

a. General. This specification covers the 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.

Except as otherwise called for, all FO cables shall be of stranded loose tube design, containing a central member, filled buffer tubes containing up to twelve (12) fibers per tube, water blocking yarns in the cable interstitial areas, high tensile strength yarns, and a medium density polyethylene jacket. The buffer tubes shall be stranded around the central member using the reverse oscillation stranding process.

FO cable shall be provided in fiber counts, lengths, and types (i.e., single mode and multi-mode) as required. The fiber optic cable design shall be dielectric and shall contain no metallic components.

b. Applicable Specifications. The FO cable shall be an accepted product of the United States Department of Agriculture Rural Utilities Services (RUS) as meeting the requirements of 7 CFR 1755.900 and the ANSI/ CEA Standard for Fiber Optic Outside Plant Communications Cable, ANSI/CEA S-87-640-1999.

c. Maximum Attenuation. The attenuation measured on the reel shall not exceed the following values:

Single Mode: 0.35 dB per kilometer at 1310 nm.
Multi-Mode: 1.0 dB at 1300 nm or 3.5 dB at 850 nm.

d. Cable Jacket Markings. Unless otherwise approved by the Engineer, the jacket or sheath shall be polyethylene and shall have a continuous, extruded yellow stripe and 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 meter markers. The markings shall be repeated every meter for length markings and at least every two meters 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.

The cable shall contain a minimum of one (1) ripcord under the sheath for easy sheath removal.

e. Fiber Grouping and Identification. 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-598, "Color Coding of Fiber Optic Cables." Munsell color shades shall be utilized. Each fiber within the bundled fiber group with protective inner cable sheath shall be color coded with ultraviolet (UV) curable inks to provide ease of identification by installation technicians and also follow EIA telecommunications color coding standards with each buffer tube having fibers as follows:

1. Blue	4. Brown	7. Red	10. Violet
2. Orange	5. Slate	8. Black	11. Rose
3. Green	6. White	9. Yellow	12. Aqua

Fiber counts per buffer tube shall be provided as defined in Table 2-16. Cable fiber count shall be as called for in the Plans.

f. Diameter and Weight of the Fiber Optics Cable. The outside diameter of the cable shall not exceed the dimensions specified in the Table 2-16. The physical weight of the cable shall not exceed the weight specified. This weight applies to the non-metallic, dielectric cable as required by this specification.

Table 2-16 Fiber Count vs. Cable Size and Weight

No of Fibers	No. of Tubes	Fibers per Tube	Cable Diameter (millimeters, ±2 mm)	Cable Mass (Kg/Km ±0.5 Kg)
6	1	6	10.1	121
12	2	6	11.3	106
18	3	6	11.3	106
24	4	6	11.3	106
36	6	6	11.8	114
48	4	12	12.2	122
60	5	12	12.2	122
72	6	12	13.0	138
96	7	12	14.8	178
144	12	12	18	258

g. Cable Length, Marking and Shipping Requirements.

(1) General Consideration of Packaging and Shipping. The completed cable shall be packaged for shipment on reels. The cable and reel shall be wrapped in a solar resistant thermal wrap which includes water resistant properties.

Each end of the cable shall be securely fastened to the reel to prevent the cable from coming loose during transit. Six (6) feet of cable length on each end of the cable shall be accessible for testing. Both ends of the cable shall be sealed to prevent the ingress of moisture. The cable ends shall be securely fastened so as not to protrude beyond any portion of the reel and to prevent it from becoming loose during transport.

Each cable reel shall have a durable weatherproof label or tag providing information as specified in Subsection 02890.2.02O. A shipping record shall also be included in a weatherproof envelope showing required information.

The cable shall be in one continuous length per reel with no factory splices in the fiber. Each reel shall be marked to indicate the direction the reel should be rolled to prevent loosening of the cable.

(2) Reel Dimensions. Reel dimensions shall be compatible with standard commercial transportation (truck, rail and ship) as well as cable installation equipment normally associated with fiber optics cable installation. The reels shall also be size and weight compatible with standard cargo handling equipment found within transportation terminals, warehouses and field installation sites. Reels shall be shipped with lifting provisions preventing cable damage. Reel markings shall include clear instructions for handling and lifting procedures.

The reels shall also include size and weight markings supporting shipping and lifting and complying with equipment and transportation safety standards.

The reel's maximum dimensions shall be approximately 4.5 feet width with an outside diameter of 8.2 feet. The arbor holes on the reel shall be provided to permit use of a 2.5-inch diameter spindle without binding. The drum diameter shall be a minimum of 30 inches or 30 times the diameter of the cable on the reel, whichever is larger.

(3) Information Accompanying the Reel. The following information shall be securely attached to the reel as a weatherproof tag.

- Order Number
- Job Number
- Reel Number
- Termination
- Ship Date
- Manufacturer's Name
- Factory Reel Number
- Weight of Cable and Reel
- Cable Construction (Dielectric, Light Armor, Heavy Armor)
- Type of Cable (SM/MM/OFNK, etc.)
- Cable Installation Application (e.g., Aerial/Lashed, Aerial Self-Supporting, Buried/Conduit or Direct Bury)
- Number of Fibers in the Cable
- Length of Cable
- Beginning and Ending Length Markings
- Manufacturer's Cable Code

A copy of the transmission loss data and other test information shall be included underneath the thermal wrap or lagging. A shipping record shall also be included in a weatherproof envelope showing the above information and also including date of manufacture, cable characteristics, and other information.

The reel shall be permanently marked with reel number, size, weight, lifting/handling safety information, direction of rotation to prevent cable loosening, and other applicable data as required by the contract and shippers.

(4) Pre-shipment End Sealing and Termination. The ends of all cables shall be sealed to prevent the escape of filling compound and to prevent the entry of moisture during shipping, handling, storage and installation.

(5) Thermal Wrap for Cable on Reel. A thermal-protective wrap shall be securely applied over the outer turns of the cable on each reel. The wrap shall be weather resistant and limit solar heating of the cable such that cable surface temperatures do not exceed 50 degrees F above ambient temperature under solar radiation loading of 93watts per square foot in still air. The wrap shall be labeled "Do Not Remove Wrap Until Cable Is Placed." (This wrap may be omitted when lags or other mechanical reel

protection devices are provided.) Specifications of thermal wrap are suitable for compliance validation.

h. Miscellaneous Requirements.

(1) Life Expectancy. The life expectancy of the cable when installed per manufacturer's instructions and operated within environmental conditions specified herein shall be 30 years. Cable aging shall not cause a loss of attenuation exceeding 1.0 dB over the installed cable length.

(2) Interface Compatibility. The cable shall be designed to interface with termination equipment and devices normally found within the optical industry.

(3) Fire Safety. The cable shall not be constructed from materials which sustain fire and flame within outdoor equipment cabinets.

i. On-Reel Testing. On-reel testing shall be performed in accordance with Subsection 02890.4.04B.

2. Prefabricated Fiber Drop Cable Assemblies.

At certain locations as called for on the Plans, the Contractor shall furnish and install prefabricated fiber drop cable assemblies. Each such drop cable shall comply with the following requirements:

The specified number of optical fibers shall be contained inside a single loose buffer tube. The fibers shall not adhere to the sides of the tube.

Each fiber shall be distinguishable from the fibers in the trunk cable.

The colors shall be stable during temperature cycling and shall not be subject to smearing onto each other. The colors shall not cause the fibers to stick together.

The buffer tube shall be filled with a non-hygroscopic, non-nutritive to fungus, electrically non-conductive, homogeneous gel, which shall be free from dirt and foreign matter. The gel shall be removable with conventional non-toxic solvents.

The cable core interstices shall be filled with a water-blocking compound, which shall be a thixotropic gel containing a Super Absorbent Polymer (SAP) material. The gel shall be non-nutritive to fungus, electrically non-conductive, and homogeneous. The gel shall be free from dirt and foreign matter and removable with conventional non-toxic solvents.

The cable shall contain at least one ripcord under the sheath for easy sheath removal.

Tensile strength shall be provided by high-tensile-strength fiberglass yarns, which shall be helically stranded evenly around the central tube.

The cable shall be sheathed with medium-density polyethylene. The minimum jacket thickness shall be 0.055 inches. Jacketing material shall be applied

directly over the tensile strength members and flooding compound. The polyethylene shall contain carbon black to provide ultraviolet light protection and shall not promote the growth of fungus.

The jacket or sheath shall be free of holes, splits, and blisters, shall contain no metal elements, and shall be of consistent thickness. The maximum diameter of the cable shall not exceed 0.4 inches.

The cable jacket markings requirements shall be same as called for in Subsection 02890.2.02O for fiber optic cable.

The maximum pulling tension shall be 600 pounds during installation and 200 pounds long-term installed.

The shipping, storage, and operating temperature of the cable shall be -40 degrees F to +158 degrees F. The installation temperature range shall be –22 degrees F to +158 degrees F.

The assemblies shall be factory assembled and terminated on one end with a ceramic ferrule ST-compatible, heat cured epoxy connector with an operational temperature of -40 degrees F to +158 degrees F. Each connector shall have a minimum of 1-inch strain relief boot.

Insertion loss for each connector shall not exceed .30 dB. Each assembly shall be fully tested and those test results shall be placed on a test tag for each assembly. Each assembly shall be individually packaged within a box or reel with the manufacturer's part number on the outside of the package.

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.

3. Fiber Optic Patch Cables (Jumpers).

All fiber optic patch cables (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 ST or LC compatible as required by 100FX and 1000LX systems. Color and jacketing material shall comply with NEC requirements for the environment in which installed. All cordage shall incorporate a 900 micron buffered fiber, aramid yarn strength members, and an outer jacket. Patch cords may be simplex or duplex, depending on the application. 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.

4. Splice Trays.

Each splice tray shall be metallic and shall accommodate a minimum of twelve (12) fusion splices plus a minimum of six (6) mechanical splices. The tray shall

consist of an aluminum base and an aluminum cover. The design of the tray shall provide physical protection for both types of splices.

Each tray shall have crimpable metal tabs to provide strain relief for the buffer tubes. Additional strain relief points shall be provided for tie-wrapping buffer tubes or pigtails to the tray. Each tray shall contain organizers which shall hold and protect each type of splice.

The approximate dimensions of each tray shall be 12 inches by 4 inches by one-quarter inch. A minimum of two (2) trays shall be provided in each housing. Additional trays shall be provided as necessary to accommodate the number of fusion splices required by the initial system construction shown on the Plans.

5. Splice Tray Housings.

Each tray housing shall be made of aluminum or stainless steel and shall have the following features:

Accommodation for the number of splice trays required by the initial application called for on the Plans plus 25 percent;

a. Hinged, lockable door; and

b. Front panel with a minimum of twelve (12) ST-compatible connectors. A connector shall be provided for each fiber of each FO cable which is brought into the cabinet. The rear of each connector shall have a factory-connected pigtail, which shall be fusion spliced by the Contractor in a splice tray to the incoming or outgoing fibers.

   Each splice tray shall slide into the housing and shall securely lock into place. Tray housings may be wall-mounted or rack-mounted at the Contractor's option.

6. Splice Enclosures.

Fiber optic splice enclosures shall be corrosion resistant, water-tight, and comply with Bellcore GR-771-Core, “Generic Requirements for Fiber Optic Splice Enclosures.” Assembly shall not require power supplies, torches, drill kits, or any special tools. Reentry shall require no additional materials. Splice closures shall have a reliable dual seal design with both the cable jackets and core tubes sealed, without the use of water-blocking material. Splice closures shall be able to be opened and completely resealed without loss of performance. Underground splice closures shall not exceed dimensions greater than 36 inches and shall fit comfortably within the underground pullboxes. Each aerial splice enclosure shall be furnished with a strand mounting bracket for aerial mounting.

The splice closure shall seal, bond, anchor, and provide efficient routing, storage, organization, and protection of fiber optic cable and splices. It shall provide internal configuration and end cap with a minimum of two express ports for entry and exit of uncut trunkline cable, sufficient number of ports for branch cables to accommodate splicing per plans, plus at least one additional spare port for future branch cable.

The splice enclosure shall have one (1) oval port, which accommodates two (2) fiber optic cables, and at least four (4) round ports for other cables. The enclosure shall accommodate expressing unspliced buffer tubes through the enclosure. A basket shall be provided to store buffer tubes that are expressed through the enclosure. The enclosure shall have a flash test valve and mechanical dome-to-base seal. The enclosure shall have the number of hinged splice trays necessary to store the number of splices in the enclosure, plus the capacity to house six (6) additional splices. As a minimum, two (2) trays with a capacity of twelve (12) splices per tray shall be provided. Provide additional capacity in the splice closure to add at least one more splice tray.

7. Fiber Splice Cabinets.

Fiber optic splice cabinets shall be NEMA Type 3R rated, shall be fabricated from aluminum, shall be base-mounted or pedestal-mounted as called for on the Plans, and shall contain splice facilities to accommodate the incoming fiber optic cables.

The minimum size of pedestal-mounted cabinets shall be 24 inches high x 10 inches wide x 6 inches deep. The minimum size of base-mounted cabinets shall be 36 inches high x 12 inches wide x 6 inches deep.

The foundation for base-mounted splice cabinets shall conform to the foundation requirements of the Typical Drawings for base-mount cabinet installation except as follows: No ground rod shall be required; the minimum depth below ground elevation shall be 8 inches; and the foundation shall extend a minimum of 3 inches beyond the outside of the splice cabinet on all four sides.

The door of each fiber optic splice cabinet shall be equipped with a Corbin lock which accepts a City of Memphis master key. One (1) key shall be furnished with each lock. The door shall be essentially the size of the height and width of the cabinet.

The splice facilities shall consist of two (2) or more fiber splice trays per Subsection 02890.2.02O above and one tray housing. The housing shall be as required per Subsection 02890.2.02O above except that the front-panel connectors shall not be required.

8. Central Fiber Termination Facilities.

Fiber termination facilities at central control sites shall include an enclosure which incorporates a splice housing for storage of splice trays and a fiber distribution cabinet for termination of field fibers. The facilities shall include:

A fiber distribution center with:

- Splice facilities to accommodate the incoming fiber optic cables;
- Patch panel with connectors;
- A tray housing per Subsection 02890.2.02O above and two (2) or more fiber splice trays per Subsection 02890.2.02O above ;
- Racks and rack-mount drawers for the OTRs; and
- Prefabricated fiber optic jumpers to connect the OTRs with the fiber distribution center.

All connectors shall be ST-compatible. All connectors for single mode fibers shall be distinctly and permanently identified as being single mode.

Each enclosure shall be aluminum and shall be equipped with a Corbin lock which accepts a City of Memphis master key. Two (2) key shall be furnished with each lock. The door of the enclosure shall be essentially the size of the height and width of the enclosure. Each enclosure shall be wall-mounted or floor-mounted as called for on the Plans.

All fiber splicing facilities shall be sized to accommodate all splicing initially required by the Plans plus a minimum of 25 percent spare capacity.

9. Field Fiber Termination Facilities.

Fiber termination facilities at field hub cabinet and local controller cabinet shall include a splice housing for storage of splice trays and termination of field fibers. The facilities shall include a fiber distribution center with:

- Splice facilities to accommodate the incoming fiber optic cables;
- Patch panel with connectors;
- A tray housing per Subsection 02890.2.02O above and two (2) or more fiber splice trays per 02890.2.02O;
- Prefabricated fiber optic jumpers to connect the OTRs or switch ports with the fiber distribution center.

All connectors shall be ST-compatible. All connectors for single mode fibers shall be distinctly and permanently identified as being single mode. All fiber splicing facilities shall be sized to accommodate all splicing initially required by the Plans plus a minimum of 25 percent spare capacity.

10. Ruggedized Ethernet Cabinet Switch

This subsection details furnishing and installing Ethernet Cabinet switches that are manufactured to be installed in field environments. The furnished switches shall be installed and integrated into field cabinets at locations shown in the plans. Integrate switch with fiber optic cable installed and integrated by others. Equipment furnished shall meet the specifications described herein.

a. Ethernet Ports
   - Minimum RJ-45 10/100Base TX Ports: 4
   - Minimum (Single-mode or Multi-mode) Fiber optic ports 1000Base-LX (Single-mode) or 1000Base-SX (multi-mode) (LC connectors): 2
   - Each fiber port shall functionally support the link distances identified in the plans, but shall be no less than 10 kilometers

b. Power Supply
   - Power Consumption 10W Maximum
   - 24VDC

c. Physical
   - Maximum Height: 4.0"
   - Maximum Width: 7.0"

- Maximum Depth: 14.0"
- Maximum Weight: 12.0 lbs
- Enclosure: 20 AWG galvanized steel enclosure
- Mounting: DIN rail ,panel mounted, or stand alone
- Operating Temperature Range: -40℃ to +60℃
- Comply with NEMA TS2 environmental requirements

d. Minimum Switch Properties
   - Switching method: Store & Forward
   - Switching latency: 10 us (100Mbps)
   - Switching bandwidth: 1.8Gbps
   - MAC address table size: 16kbytes
   - Priority Queues: 4
   - Frame buffer memory: 1 Mbit
   - VLANs: 64
   - IGMP multicast groups: 256
   - 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 or other approved indicators

e. 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.

f. Warranty
   - Minimum of 3 Years-Applicable to design or manufacturing related product defects.

g. Network Management
   - ROSVue HTTP graphical web-based
   - SNMP v1, v2c, v3
   - Telnet, VT100
   - Command Line Interface (CLI)

h. 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
   - 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

i. 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

j. IETF SNMP MIBS
- RFC1493-BRIDGE-MIB
- RFC1907-SNMPv2-MIB
- RFC2012-TCP-MIB
- RFC2013-UDP-MIB
- RFC2578-SNMPv2-SMI
- RFC2579-SNMPv2-TC
- RFC2819-RMON-MIB
- RFC2863-IF-MIB
- draft-ietf-bridge-rstpmib-03-BRIDGE-MIB
- draft-ietf-bridge-bridgemib-smiv2-03-RSTP-MIB
- IANAifType-MIB

11. Ruggedized Ethernet HUB Switch

This subsection details furnishing and installing Layer 3 Ethernet Hub switches that are manufactured to be installed in field environments. The furnished switches shall be installed and integrated into field cabinets at locations shown in the plans. Integrate switch with fiber optic cable installed and integrated by others. Equipment furnished shall meet the specifications described herein.

a. Ethernet Ports
- Minimum (Single-mode or Multi-mode) Fiber optic ports 1000Base LX (Single-mode) or 1000Base-SX (Multi-mode) (LC connectors): 19. Each fiber port shall functionally support the link distances identified in the plans, but 16 ports shall be no less than 10 kilometers and 3 ports shall be no less than 20 kilometers.

b. Power Supply
   - Unit shall be provided with any required transformers or power supplies to power the unit from 120VAC.

c. Physical
   - Maximum Height: 4.0"
   - Maximum Width: 19.0"
   - Maximum Depth: 14.0"
   - Maximum Weight: 12.0 lbs
   - Enclosure: 20 AWG galvanized steel enclosure
   - Mounting: DIN rail ,panel mounted, or stand alone
   - Operating Temperature Range: -40℃ (-40℉) to +60° C (+140℉)
   - Comply with NEMA TS2 environmental requirements

d. Switch Properties
   - Layer 3 hardware forwarding architecture
   - Layer 3 forwarding performance: up to 400 mpps
   - Switching method: Store & Forward
   - Switching latency: 10 us (100Mbps)
   - Switching bandwidth: 9.2Gbps
   - MAC address table size: 64 Kbytes
   - Priority Queues: 4
   - Frame buffer memory: 2 Mbit
   - VLANs: 255
   - IGMP multicast groups: 256
   - 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 or other approved indicators

e. Approvals
   - ISO 9001: 2000 certified quality program
   - 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.

f. Warranty
   - Minimum of 3 Years-Applicable to design or manufacturing related product defects.

g. Network Management
   - ROSVue HTTP graphical web-based
   - SNMP v1, v2c, v3
   - Telnet, VT100
   - Command Line Interface (CLI)

h. IEEE Compliance: Supply a Layer 3 Ethernet switch that meets or exceeds the following standards:
   - 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
   - 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 Multiple Spanning Tree Protocol

i. 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

j. IETF SNMP MIBS
   - RFC1493-BRIDGE-MIB
   - RFC1907-SNMPv2-MIB
   - RFC2012-TCP-MIB
   - RFC2013-UDP-MIB
   - RFC2578-SNMPv2-SMI
   - RFC2579-SNMPv2-TC
   - RFC2819-RMON-MIB
   - RFC2863-IF-MIB
   - draft-ietf-bridge-rstpmib-03-BRIDGE-MIB
   - draft-ietf-bridge-bridgemib-smiv2-03-RSTP-MIB
   - IANAifType-MIB

12. Serial Device Server

This subsection details furnishing and installing serial device servers that are manufactured to be installed in field environments. The serial device servers shall be installed and integrated into field cabinets at locations shown on the plans and shall provide the electrical interface between the Ethernet traffic signal control software and the RS-232 equipped traffic signal controller. Equipment furnished shall be Digi PortServer TS H MEI or equivalent as approved by the engineer. The contractor shall configure and test the Digi RealPort software on the Central Communication Server in Traffic Operation Center (TOC), to ensure that all traffic signal controllers communicating over the fiber optic Ethernet network via terminal servers in the cabinet (i.e., controllers that do not natively support Ethernet) must be able to communicate successfully and reliably with the ACTRA traffic management software

a. Features
   - o 1- 10/100Base-T Ethernet port
   - o 1- DB-9 serial port with DB-9 cable, or RJ-45 serial port with RJ-45/DB-9F crossover cable
   - o Switch-selectable RS-232/422/485 RJ-45 serial
   - o Baud rates up to 230 Kbps
   - o Full modem and hardware flow control
   - o TCP/UDP Socket Services
   - o UDP Multicast
   - o Telnet and Reverse Telnet
   - o Patented RealPort® with encryption for COM and TTY ports
   - o 9-30VDC power input
   - o RFC 2217
   - o Modem emulation
   - o SNMP (read/write)
   - o PPP
   - o SSHv2
   - o Port buffering
   - o Low latency
   - o Modbus to Modbus/TCP conversion
   - o HTTP
   - o SSL/TLS
   - o Digi Port Authority–Remote management diagnostics and auto-discovery tool
   - o DHCP/RARP/ARP-Ping for IP address assignment
   - o LED status for link and power

b. Dimensions
   - o Length: 5.25 in (13.34 cm)
   - o Width: 3.33 in (8.46 cm)
   - o Depth: 0.95 in (2.41 cm)
   - o Weight: 2.25 oz (64.00 g)

c. Regulatory Approvals
   - o FCC Part 15, A
   - o CE

- EN55024
- EN55022, Class A
- UL/CUL60950
- IEC60950 & CB
- AS/NZS 3548
- VCCI V–3/99 .05

d. Power Requirements
   - 9-30VDC @ 0.5 Amps max (12VDC extended temp power supply sold separately)

e. Environmental
   - Operating temperature: -35ºC to +74ºC (-31ºF to +165ºF)
   - Relative Humidity: 5% to 90% (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

13. Field Hub Cabinet

This subsection describes the specifications and requirements for field cabinets to be used for housing hub switch and related equipment at site locations specified in the Plans and technical specifications. Typical field cabinet layout(s) and location are shown in the contract Plans.

The Contractor shall provide the required cabinets as shown in the Plans and as per the guidelines stated in these specifications. The cabinets shall be Off-the-Shelf products.

Custom field cabinets are not required or desired. Field cabinets shall include all mounting accessories, access doors, proper ventilation, locking system, handles, door stops, rack assembly, light, shelf/drawer and all required equipment and peripherals as required by the Plans.

Interconnections to the field cabinet and field cabinet equipment from field equipment shall be by means of a terminal block as specified in the Contract Documents. Fiber optic connections to the field cabinet shall be provided via the terminal facility harness by means of mating "ST" type connectors.

All field cabinets of the same type shall be identical in size, shape, and quality throughout the entire contract. In addition, the field cabinets shall be equipped internally as specified herein, and as required to suit the specific complement of equipment shown on the Plans.

The field cabinets shall be provided with fully wired back and side panels with all necessary terminal boards, wiring harnesses, connectors, and attachment hardware for each field cabinet location. All equipment shall be shelf-mounted. All terminals and panel facilities shall be placed on the lower portion of the field cabinet walls below all shelves.

Field Hub Cabinets shall be base-mounted. The maximum outside dimensions (exclusive of mounting flanges) shall not exceed 56 inches in height, 44 inches in width, and 30 inches in depth. Construction shall be of seam welded aluminum and incorporate a three point locking door latch system. Provided cabinets shall meet all City of Memphis required specifications. Cabinet foundation shall be constructed in accordance with the City of Memphis Traffic Standard Drawings. Field cabinet grounding shall be accomplished in accordance with the National Electric Code and in accordance with these special provisions.

a. General

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.

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 electronic circuitry shall provide the means to adjust or recalibrate to the normal operational settings of all components.

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. Electrical

The field cabinets shall be furnished with a power distribution panel mounted on the lower left hand inside wall when facing the front door opening of the cabinet. This panel shall include a Duplex Outlet which is a 115 VAC convenience outlet with integral ground fault interrupt, protected by a circuit breaker. The left panel shall have:

- Circuit Breaker(s)
- Radio frequency Interference Suppressor
- Power Cable Input and Junction Terminals

(1) Circuit Breaker(s)

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 the Plans. Breakers shall have a minimum interrupt capacity of 10,000 amperes.

(2) Radio Frequency Interference (RFI) Suppressor

All field cabinets shall be equipped with a radio frequency interference (RFI) suppressor installed at the circuit breaker. The suppressor shall provide a minimum attenuation of 50 dB over a frequency range of 200 kilocycles to 75 megacycles. 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 the proper current rating as determined by the Contractor per the equipment complement as indicated on the Plans, 120/240 Volts, 60 Hertz operation, and shall be approved by UL and EIA.

(3) Power Cable Input and Junction Terminals

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.

c. Wiring

Field cabinet wiring shall be provided for the equipment complement as specified on the Plans. 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.

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.

d. Terminal Blocks

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.

e. Power-Line Surge Protector

A power line surge protector shall be installed in each cabinet between the load side of the input power circuit breaker or fuse and ground. The surge protector shall have the following characteristics:

Working Voltage: The unit shall be rated for operation on AC power lines with a voltage rating of 130 volts RMS and 184 volts peak or 275 volts RMS and 389 volts peak for nominal 120 VAC and 240 VAC, respectively.

Surge Voltage: The unit shall limit the surge voltage applied to the equipment to 650 volts peak while conducting a peak surge current of at least 6000 amperes. The surge current shall be an unsymmetrical triangular wave (designated 8 x 20 microseconds) that requires 8 microseconds to reach the peak value and at 20 microseconds shall have half the peak value.

Energy Rating: The unit shall be capable of dissipating 50 joules of surge energy without damage to itself. The unit shall have a 15-Watt power dissipation rating.

f. Field Cabinet Thermostat

A surge and transient noise suppressor in the form of a varistor shall be installed across the thermostat that is used to control the fan. The varistor shall have characteristics equal to or better than the following:

- GE Model Number VI5OLAIOA
- Stetron 250NRO7-1
- Siemens SIOK150

g. Field Cabinet Grounding

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.

h. Access

All the field cabinets should be provided with doors in the front. All doors shall be securely gasketed to prevent the entrance of dust and moisture. The main door of all field cabinets shall include substantially the full area of the front of the field cabinet. The door shall be provided with a catch to hold the door open at 135 degrees, plus or minus 25 degrees. The catch shall hold the door securely open until released. Doors shall be hinged on the right-hand side by means of three (3) butt hinges with 1/4" (minimum) stainless steel hinge pins. While placing the field cabinet in the field, the Contractor should

make sure that the door opens away from the flow of traffic as indicated in the Plans.

i. Ventilation

A pleated media fiber filter should be provided in the doors. All field cabinets shall be furnished with a thermostatically controlled ventilation fan or fans mounted within a rain-snow and insect tight housing. The electric fan(s) shall have a rated capacity of at least 200 cubic feet per minute. The louver area shall be of sufficient size to permit the free flow of air corresponding to the rated capacity of the associated cabinet fan. All field cabinets shall be furnished with suitable vents and louvers properly designed to provide natural ventilation to the interior. Filters shall be provided on all louvers. The fan and cabinet ventilation louvers shall be located with respect to each other so as to direct the bulk of the air flow throughout the entire cabinet and in particular over the field equipment units as approved by the Engineer. The thermostat shall be adjustable to turn the cabinet fan on between 90℉ and 120℉ (32℃ and 49℃).

j. Locking System

The lock for the door shall be of the self-locking heavy-duty five-pin tumbler cylinder rim type. Locks shall be keyed identically. All field cabinets shall be furnished with a 3-point positive locking door. One key shall be provided for each field cabinet. The locking system shall be factory lubricated and the key slot shall be protected against water spills and insect intrusion.

k. Handles

The handles should be made with stainless steel and they should be provided with padlock feature.

l. Service Light

A fluorescent light should be provided in front for all the field cabinets. A panel mounted 40-Watt weatherproof incandescent lamp with an on-off switch shall be positioned to provide light to the face of the equipment installed in the field cabinet.

m. Lower Input Termination Panel

A lower input termination panel should be provided to terminate all input field wires.

n. Shelf/Drawer/Rack

Adjustable shelves shall be provided to hold the equipment specified in the Plans. Shelf adjustment shall be at 2-inch intervals in the vertical positions. The shelves shall be positioned from the internal top of the field cabinet in accordance with the actual equipment configuration of the particular field cabinet. All devices/sub-assemblies shall be mounted on the rack if possible.

Otherwise, they should be placed on the shelves (as shown in the Plans). Field cabinets shall be provided with adjustable shelves only.

Racks and rack-mount drawers shall be provided for the Ethernet hub switches and the rack-mount fiber optic splice and termination enclosures.

o. Quality Assurance Provisions

The following water spray test shall be performed on each type of empty field cabinet:

Water shall be sprayed from a point directly overhead at an angle of 60° from the vertical axis of the field cabinet. This procedure shall be repeated for each of eight equally spaced positions around the field cabinet for a period of not less than five minutes in each position. The water shall be sprayed using a domestic type-sprinkling nozzle at a rate of not less than one gallon per minute per square foot of surface area. The field cabinet shall then be inspected for leakage. Evidence of water leakage shall be cause for rejection.

A Manufacturer's certification of successful completion of the water spray test and that the field cabinet conforms to this specification shall be the basis of acceptance of the field cabinet. Separate submission of test field cabinets shall not be required.

p. Maintenance

All modules and assemblies shall be clearly identified with name, model number, serial number, and any other pertinent information required to facilitate equipment maintenance.

All equipment shall be designed for ease of maintenance. All component parts shall be readily accessible for inspection and maintenance. The only tools and test instruments required for use by Maintenance personnel shall be simple hand held tools and basic meters.

The equipment shall be designed so that it can easily be installed and maintained. Fault location, accessibility, serviceability and features that shall lead to simplified maintenance shall be a prime consideration.

The Contractor shall be required to furnish and install galvanized steel safety hasps on specific field cabinets as indicated on the Plans.

q. Fiber Optic Splice and Termination Enclosure

Fiber termination facilities at field hub cabinet shall include one or more splice enclosures which incorporate splice housing for storage of splice trays and termination of field fibers. Each splice enclosure shall include:

- Splice facilities to accommodate the incoming fiber optic cables;
- Patch panel with a minimum of 24 connectors;
- A tray housing per Subsection 02890.2.02O and two (2) or more fiber splice trays per Subsection 02890.2.02O;

- Prefabricated fiber optic jumpers to connect the OTRs/Ethernet Hub Switches with the fiber splice and termination enclosure.

All connectors shall be ST-compatible. All connectors for single mode fibers shall be distinctly and permanently identified as being single mode.

All fiber splice enclosures shall have a minimum of 24 ports. Total number of ports shall be sized to accommodate all splicing initially required by the Plans plus a minimum of 25 percent spare capacity.

Furnish rack-mount splice enclosures that are manufactured in such a manner to be suitable for in-cabinet installation. All enclosures shall be aluminum.

P. REVERSIBLE LANE SYSTEMS.

1. General.

This subsection sets forth the minimum acceptable equipment and materials requirements for reversible lane control systems. Such equipment includes :

- Reversible lane controllers;
- Multi-state lane use control signals;
- Blank-out signs; and
- Gantry structures

2. Gantry Structures.

Each gantry structure shall be a galvanized steel monotube structure. Both the structure and its concrete foundations shall be fabricator designed. The span length and lane control signal placement shall be as shown in the plans.

For both the structure and the foundations, the Contractor shall submit, for the Engineer's review and approval, shop drawings and design calculations sealed by a Tennessee professional engineer.

3. Reversible Lane Controllers and Cabinets.

a. Reversible Lane Controllers.

(1) General. Each new reversible lane controller shall be a solid-state, modular unit which provides for control and monitoring of multi-state lane-use control signals to provide dynamic operation of reversible lanes.

(2) Required Controller Type. All reversible lane controllers furnished and installed by the Contractor shall be identical. Each shall be a solid-state controller which provides the following minimum functionality:

- 4 signal plans (each equivalent to a cam-stack)
- 16 timing plans (each equivalent to dial/split)
- 24 intervals per signal plan
- 3 offsets per timing plan
- 4 special function outputs

(3) Specific Controller Requirements. Each reversible lane controller shall:

(a) Comply with the following portions of the local intersection signal controller specifications in Subsection 02890.2.02B:

- Modularity
- Circuitry
- Equipment housing
- Fuses
- Time-base
- Parts lists and cross-referencing
- Software and software updates

(b) Be fully compatible with the signal system central software called for in other subsections and shall support polled communications using the fiber optic communications system. During each poll, the controller shall accept the download of the desired control pattern, which shall include the on-off status of the special functions. During each poll, the controller shall also upload status information including pattern in effect, special function status, and local alarm status.

(c) Fully comply with the environmental standards and test procedures set forth in NEMA Section 2.

(d) Have an internal communications transceiver identical in function and equal to or better in quality than the internal communications transceiver required by these specifications for the local intersection signal controllers.

(e) Have an internal fiber optic transceiver identical to the internal transceiver required by these specifications for the local intersection signal controllers.

The controllers shall accommodate the control of four active state on up to six (6) signs. Additionally, the controllers shall allow each state to be either steady or flashing.

(4) Conflict Monitor Functions. Each reversible lane controller shall be connected to a conflict monitor which is identical to the conflict monitors called for in Subsection 02890.2.02B. The conflict monitor shall be programmed to ensure that back-to-back lane-use control signals over the same lane do not display indications which are incompatible.

Any and all other combinations shall be recognized as a conflict and the monitor shall open a relay which de-energizes the lane-use control signals.

b. Reversible Lane Cabinets.

(1) General. Each new reversible lane controller cabinet shall accommodate the reversible lane controller called above.

(2) Specific Requirements. Each reversible lane controller cabinet shall fully comply with the specifications for new traffic signal controller cabinets as set for in Subsection 02890.2.02B above:

4. Lane-Use Control Signals.

a. Display Indications. All lane-use control signals shall be fiber optic and shall be uni-directional, i.e., control traffic in only one direction of approach. In each multi-state sign, all of the required lane-use indications shall be overlaid and mounted in the same housing. Each indication shall consist of a matrix of fiber-optic bundles forming a signal with nominal height and width of 18 inches by 18 inches. Two types of lane-use signals shall be provided:

(1) Single-state signals shall display a single, fixed indication. Type A-1 signals shall display a red X and Type A-2 signals shall display a green down arrow.

(2) Standard three-state signals (Type B signals) shall display, as commanded by the controller, either a red X, a yellow X, or a green down arrow. Each such indication shall be displayed separately and never concurrently. No moving parts shall be permitted to change the display.

b. Visibility. Under any lighting conditions varying from total darkness to bright sunlight or where high intensity background lighting is present, the fiber-optic indications shall be clearly discernable and legible at a minimum distance of 800 feet by a person with visual acuity sufficient to qualify for a Tennessee drivers license. Hoods, visors, or other means of shielding shall not be necessary to ensure visibility (even though visors are required as described below). When not energized, each indication shall be blanked out (unreadable) with no phantom images, regardless of solar intensity or orientation. The message shall be visible with a limited cone of visibility of 24 ± 4 degrees centered about the optical axis in relation to the surface of the message area.

c. Environmental Conditions. The fiber-optic signals and signs shall be capable of continuous operation within a range of –37ºC (–35ºF) to +74ºC (+165ºF) with no observable degradation of visual quality.

d. Housing. The housing shall be fabricated of 6061-T6 extruded aluminum with a minimum overall thickness of 1/8 inch. All seams shall be heliarc welded.

The exterior case dimensions shall be nominally larger than the message plate. A minimum of four nylon vented 1-inch plugs shall be located in the lower corners of the housing to prevent the collection of water. At least two quarter-turn locks shall be mounted on the housing to tightly sandwich the gasket material between the door and the housing.

e. Door. The door shall be made of 6061-T6 extruded aluminum with a minimum overall material thickness of 1/8 inch. The door shall not contain any welds. The door shall be fastened to a continuous stainless steel piano hinge along a side of the aluminum housing.

f. Visor. The visor shall be made of 5052-H32 aluminum with a minimum top overhang of 6-7/8 inch. The visor shall be fastened to the aluminum door frame by stainless steel self-tapping screws.

g. Transformers. There shall be one transformer per light source. Transformers shall have class A insulation impregnated with a double coating of epoxy resin or lacquer. Transformers shall not be painted. The primary voltage shall be 120 VAC and the secondary voltage shall be approximately 10.8 VAC. Each transformer shall be rated at 48.5 volt-amps.

h. Light Source. The lamps shall be multi-mirror reflector quartz halogen bulbs operating at an approximate color temperature of 2900 K. They shall have an average rated life of 8,000 hours of operation at a supply voltage of approximately 10.8 VAC and shall consume 45±5 watts of power per bulb. It is preferred that a single primary/spare bulb set be used to illuminate the entire display. Alternately, the fibers from each separate bulb set shall be randomly mixed so as to provide illumination of the complete display in the event of a bulb failure.

i. Fiber-Optic Message Module.

(1) General. The fiber-optic message module shall consist of fiber-optic bundles, lamps, color filters, and a matrix message panel. The spacing of the fiber bundles shall be approximately 1.5 inches between centers. The matrix message panel shall be black anodized 5052-H32 aluminum 1/8-inch thick, and it shall not be painted. Inside the housing, the matrix message panel shall be protected with a latex rubber covering. Lamps shall be mounted horizontally or at an angle to prevent water collection.

(2) Color Filter. There shall be provisions for a colored glass filter for each light source. Filters shall be color fast and in accordance with the ITE Signal Color Specification for chromaticity. Green, yellow, and red filters shall be provided to create the appropriate colored indications. Written certification of compliance with the standard shall be submitted to the City.

(3) Optical Fiber. The optics shall be a glass on glass fiber with an 83% core to 17% cladding ratio. It shall have an average numerical aperture of 0.56 with a maximum transmission attenuation of 800 dB per kilometer. Each fiber shall have a 0.002 ± 0.0002 inch diameter with an included acceptance angle of 68 degrees. All fiber ends shall be ground smooth and polished to an 8 micron finish, minimum. Breakage shall be limited to 3 percent of the total bundle area.

(4) Input Bundle Assembly. The input fiber bundle located at each light source shall have a maximum diameter of ¾ inch. The input bundle shall be housed in an aluminum end.

(5) Output Bundle Assembly. In all indications, each 0.16 inch diameter (nominal) fiber-optic bundle shall be fully bias randomized and bifurcated between the dual light sources. In the event of a lamp failure in a display, the alternate lamp shall continue to keep every output bundle illuminated

in the signal indication. Five percent (5%) spare output bundles shall be provided for each lamp pair. Damaged output bundles shall be replaceable using these spares. A minimum of 270 individual fibers shall be in each "arm" feeding each pixel displayed.

(6) Lenses. Each output bundle shall have a biconvex, fire-polished, glass, 5/8 inch diameter lens. The lenses shall be held in place positively by a non-corrosive connector able to be removed without aid of any special or unique tools. The lens holder shall be mechanically threaded to the fiber-optic output bundle. No epoxies or glues shall be necessary to hold the output bundle or lens assembly in place. The finished lens assembly shall not protrude from the signal face by more than 0.2 inches.

(7) Protection of Fiber Bundles. A PVC jacket or other method approved by the engineer shall be provided to protect the fiber bundles from damage during signal head maintenance activities.

j. Mechanical Characteristics.

(1) General. The matrix panel shall be removable from the door extrusion. The door shall be fully gasketed against the housing. Each transformer shall be mounted on an extruded aluminum bracket fastened to the housing extrusion. The transformer mounting brackets shall not be affixed to the message plate. All other components shall be mounted on the message plate.

(2) Electrical. Nominal input voltage shall be 110 to 120 VAC. Connections for both primary and secondary shall be made with stranded #14 AWG THHN or XHHW insulated copper wire. All wires shall be bundled and tied.

(3) Hardware and Materials. All nuts, bolts, screws, washers, lock washers, link locks, hinges, and other fastening materials shall be stainless steel. Other metallic parts shall be aluminum. Acrylic or fiberglass parts are not acceptable. All gasketing shall be closed-cell neoprene.

(4) Surface Finishes. The surfaces inside and outside the signal housing, door, visor, and face of the display shall be pre-treated for painting in the following stages: degrease, hot rinse, etch with an iron phosphate solution, hot rinse, chemical seal, and dry for at least 10 minutes at 300 to 390 degrees F. Each such surface shall then be painted with a single coat of environmentally safe, ultraviolet resistant, polyester powder coating which shall be applied electrostatically at 90 kV and baked for 20 minutes at 375 degrees F per ASTM D-3359, ASTM D-3363, and ASTM D-522. The door, housing interior, visor interior, and face of the display shall be painted flat black. The housing and visor exteriors shall be painted Traffic Signal Yellow #13538 in Federal Standard Specification TT-C-595a. Stainless steel parts shall not require painting. Black anodized finishes shall pass a 50% nitric acid solution test per ASTM 136-77.

(5) Mounting. The lane-use signal mounting hardware shall be appropriate for each application. When existing lane-use control signals are being replaced, the new mounting hardware shall be equal or better in design and quality to the existing hardware. Catalog cuts or shop drawings shall be submitted to the Engineer for approval prior to ordering the hardware. The Engineer shall have the right to request that sample of each type be provided for inspection prior to approval.

k. Lamp Outage Indicators. There shall be one lamp outage indicator for each light source. This indicator shall provide a positive means of determining if a backup bulb is in use and shall be visible to a person approaching the signal in an enclosed vehicle if the signal is 17 feet above the pavement surface. This indicator shall automatically reset upon replacement of the failed bulb.

l. Quality Control. A Certificate of Compliance shall be provided stating that testing of the optical fiber has been performed and that all fiber used in the signals meets the standards set forth in this document. A sample plug from every production run of fiber used in the sign fabrication shall be finished and processed at one end and tested for roundness of the fiber, core to clad fusion, fiber diameter, and optical transmission.

m. Maintenance. All serviceable components shall be accessible for repairs without the removal of other components. Routine maintenance shall require no equipment other than a standard screwdriver. A wiring diagram of the interior electrical connections shall be provided. The Contractor shall furnish a manufacturer-provided list of replacement parts, and a manufacturer's certification that replacement parts shall be stocked for five years.

n. Life Cycle Design. Life cycle design shall be fifteen (15) years minimum, exclusive of the lamps.

o. Shop Drawings and Prototype. Prior to production, shop drawings shall be submitted for approval of the Engineer. Upon approval of the shop drawings and prior to manufacture of the remaining signals, the Contractor shall submit for the Engineer's approval one complete and fully functioning prototype of a three-state fiber-optic lane-use control signal.

Q. FIBER OPTIC BLANKOUT SIGN

1. GENERAL DESCRIPTION (ONE WAY)

a. One Message - LC/1/1W. Signal shall be capable of displaying one message. This message must say NO RIGHT TURN or NO LEFT TURN.

b. Two Message -LC/2/1W. Signal shall be capable of displaying any two of the messages listed in Subsection “a” above.

2. GENERAL DESCRIPTION (TWO WAY)

a. Each side of a two-way signal shall be capable of displaying any of the combinations listed in Subsection 02890.2.02Q above.

b. Two way signals shall be serviceable from either of the two sides.

3. FUNCTIONAL REQUIREMENTS

a. All messages shall be clearly legible, attracting attention under any lighting conditions. At full intensity, the signal shall be highly visible anywhere with a 20 degree cone centered about the optic axis.

b. The signal shall consist of:

(1) Weatherproof housing and door.

(2) Fiber Optic module.

(3) Color filters for desired message colors.

(4) Light sources.

(5) Transformers.

c. The color of any message shall be changeable in the field by replacement of the supplied color filters without removing the signal from the case.

d. Two (2) 42 watt, 10.8 volt lamps with a rated life expectancy of 8,000 hours shall be used for each message. Lamps shall be mounted horizontally to prevent moisture collection.

e. Individual glass output lenses shall be fitted over the end of each fiber optic glass bundle to provide the 20 degree viewing angle. Lenses shall be 5/8" in diameter and arranged to form the appropriate message.

f. Transformer shall be used to reduce the incoming 120 VAC to 10.8 VAC. The transformers shall contain Class A insulation and weatherproofing and be rated at 48.5 volt-amps.

g. The signal shall be capable of continuous operation over a range in temperatures from -37℃ (-35℉) to +75℃(+165℉).

h. Power consumption shall be less than 100 watts per message Two lamps shall be used for burnout protection.

i. A separate transformer shall be used to isolate each light source to provide burnout protection.

j. Bundles shall be arranged so that in the event of a failure of one light source the other shall continue to provide a legible message. (Biofocated points are available on one and two message units)

4. FIBER OPTIC MODULES

a. The fiber optic module shall consist of the following components:
- A rigid aluminum message plate.

- Fiber optic glass bundles and spares.
- Fiber optic commons.
- Color chip/lamp socket holder (s)
- Color chip (s)
- Flat black Delron trademark lens holders.
- 5/8" glass lens (20 degree cone of focus).
- Protective back cover for fiber bundles.

b. The 5/8" glass lenses shall be mounted in black Delron trademark lens cells by heat-swedging the lens into the cell, onto a square shouldered seat to insure proper focus. The combined unit shall be mounted into the signal face by means of a plated snap ring on the interior. Number of cells varies according to message.

c. The finished lens cell assembly shall not protrude from the signal face by more than 5/16".

d. Door panels and lens holders shall be colored flat black to maximize legibility when activated. No color shall appear in the lenses when deactivated regardless of ambient light conditions.

e. Message color is provided by a tempered, optically correct glass color filter in conformance with I.T. E. specifications.

f. Electrical connection shall be made via barrier type terminal strip.

g. All fasteners and hardware shall be corrosion resistant stainless steel.

h. All components shall be readily accessible for maintenance when the door is open.

i. No special tools shall be required for lamp replacement.

5. MECHANICAL CONSTRUCTION, ALUMINUM HOUSING

a. One way housings shall be constructed of .080" or .125" extruded aluminum 8" deep with a .063” flat aluminum back welded into the housing.

b. Two way housings shall be constructed of .063” aluminum body, and a channel aluminum frame work structure inside .080” thickness. Housing body and inside frame work shall be permanently attached to form a single unit.

c. All corners and seams of one or two way housings shall heli-arc welded to provide a weatherproof seal around the entire case.

d. Continuous full length stainless steel hinges, .040 A X 1 1/6" open shall connect to the housing and the extruded aluminum door.

e. Signals shall have stainless steel 1/4 turn link-locks in sufficient number to tightly secure the door.

f. Door gaskets shall be 3/16 X 1" neoprene to provide a weatherproof seal.

g. 0.125" extruded aluminum doors have one side removable to gain access to signal face. (Not required for normal maintenance).

h. Signal face shall be 0.100” flat aluminum or equivalent, and shall have the entire fiber optic assembly mounted to it.

i. Each door shall be fitted with a sun hood of .063” thick aluminum.

j. Finish on signal housings shall be two coats of exterior signal enamel applied after surface material is acid-etched and primed with zinc-cromate primer.

k. The housing shall be fitted with a 1 2" mounting hub at the center of the top and bottom of the unit for side of pole mounting.

R. CLOSED CIRCUIT TELEVISION (CCTV) SYSTEM

1. CCTV CAMERAS

This subsection details furnishing, installing, integrating, and testing of closed circuit television (CCTV) cameras at locations shown in the Plans and as specified by these specifications.

a. Functional Requirements

All CCTV cameras shall have a minimum of 450 lines per frame, interlaced 2:1, per EIA-170A standard. No interlace jitter or line pairing on the viewing monitor shall be discernible. The frame frequency shall be 30 frames per second. The width to height aspect ratio shall be 4:3. The system shall be capable of providing clear, low-bloom and low-lag video pictures under all conditions from bright sunlight to nighttime scene illumination. Color quality shall be maintained by a continuous “through the lens” automatic white balance system.

Equipment supplied shall be identical at each field installation location and shall be completely interchangeable.

b. Electrical Requirements

All color video cameras shall be Digital Signal Processing (DSP) units of solid-state design, and shall meet or exceed the following requirements:

- Imager: Interline transfer Charge Coupled Device (CCD).
- Image Area: 3.6mm (H) x 2.7mm (V) [¼” Format]
- Resolution: NTSC - 450 horizontal; 350 vertical
- Picture Elements: 768 (H) x 494 (V)
- 22X optical zoom, 8X digital zoom
- Effective Zoom Range 176:1
- Horizontal Angle of View: Optical: greater than 47° at wide zoom, less than 4° at telephoto zoom.
- Auto Focus mode with manual override.
- Pan/Zoom/Focus Presets: Sixty-four (64) preset positions
- Auto or Manual shutter speeds of 1/60 – 1/10,000 second.
- Auto Iris with manual over ride.

- Automatic Gain Control (AGC): 0 to 14 dB
- Automatic White Balance with manual override.
- Signal to Noise Ratio greater than 46dB.
- Video Output: NTSC, 0.7 V p-p @ 75ohms, unbalanced.
- Sensitivity: greater than .125 lux @ 1/4 second shutter speed.
- Programmable I.D. Generator & Alarm Messages
- Camera Identification: Up to 20 characters long.
- Zone identification: Up to 20 characters long.
- Message Positioning: Can be placed at top or bottom. Left, right positioning accomplished by padding message with spaces.
- Communication and Camera Addressing Protocol: RS-422 Serial Communication.

c. Environmental Requirements

All CCTV field equipment shall perform to the stated specifications over an ambient temperature range of -29℃ (-20℉) to +54℃ (+130℉) and humidity range of 0 percent to 95 percent.

All camera enclosures shall be designed to withstand the effects of sand, dust, and hose-directed water. All connections shall be watertight.

Unless otherwise shown on the plans, all CCTV field equipment installed shall be operational in indicated weather conditions and shall be able to withstand a wind load (gust) of 90 mph without permanent damage to mechanical and electrical equipment.

d. Camera Housing

The camera housing shall withstand ambient outdoor temperatures from -34℃ (-30℉) to +60℃ (+140℉) and maintain interna l temperatures and humidity levels compliant with the camera equipment specifications. The internal humidity of the housing shall be less than 10 percent when sealed and pressurized through a Schraeder valve to 5psi using dry nitrogen gas. Desiccant packs shall be securely placed inside the housing to absorb any residual moisture and decrease internal humidity. A pressure relief valve shall be provided to prevent the internal pressure from exceeding 7psi.

The viewing window shall be constructed in such a way that unrestricted camera views can be obtained at all camera and lens positions.

The camera/lens/housing shall be assembled and factory tested only by the camera manufacturer at the camera manufacturer facility. The camera shall have been adjusted for color balance and lens tracking/focus, and all configurable items shall have been properly set per manufacturer's specifications. Each camera/lens/housing delivered to the project site shall be accompanied with a written certification of assembly and configuration from the camera manufacturer. This certification shall serve as manufacturer's documentation that the assembly and configuration of the camera/lens/housing equipment was performed in accordance with the manufacturer's specifications. A sample certification document shall be furnished as part of the materials submittal data.

The Contractor shall supply and install a dome type environmental enclosure designed to protect the camera, pan/tilt mechanism, and zoom lens from the harsh outdoor environment. The assembly must be supplied with an integral sun shield to reduce glare. The enclosure shall be fully weatherproof.

The camera and zoom lens shall be mounted to insure that the enclosure shall not obstruct the field of view of the camera. Sufficient clearance between the zoom lens extended to its furthest point of travel and the dome enclosure wall shall be provided to insure that mirroring on the window will not be obtained.

The top portion of the dome enclosure shall be manufactured of steel and have a white reflective acrylic coating. Enclosure dome shall be clear optically graded acrylic.

A gas-tight connector shall be required for all wiring entries into the housing. Wiring to the connector shall be sealed with silicon or functionally equivalent compound.

e. Pan-Tilt Unit

Drive motors shall be capable of instantaneous reversing and shall have overload protections. Braking shall be provided in both pan and tilt movements to enable fast stop and reversal and to prevent drifting.

The Dome enclosure shall include an integrated Pan/Tilt mechanism to control the camera angle of the camera. The pan/tilt motor units shall have the following (preset) potentiometers: The unit shall provide vertical movement from 0 degrees to -90 degrees and horizontal movement of 360 degrees. Tilt speed shall be in the range of approximately 3 to 4 degrees per second and the pan speed shall be approximately 8 to 9 degrees per second. The unit shall be capable of simultaneous pan-and-tilt movements.

f. Camera Control Receiver

The control receiver shall provide the ability to generate a camera identification message over the video display for text labeling of all 64 preset locations. Each identification line shall be programmable up to 20 characters. Two separate lines of text shall be provided for identification of the location, zone and camera I.D. number. The camera I.D. shall be programmable locally. The software, cables and any associated hardware to accomplish this task shall be supplied with the camera control receiver. Camera controls (e.g. pan/tilt/zoom, presets, preset character generation titles, AGC, iris control, etc.) shall be provided through the software protocol. On-screen programming shall not be acceptable.

The camera control receiver shall meet the following specific function requirements for the control and drive circuits:

- Electronic zoom in/out and step
- Electronic shutter selection
- AGC and manual gain selection
- Remote white balance control

- Pan left
- Pan right
- Tilt up
- Tilt down
- Manual and auto iris control
- Iris open/Iris close
- Sixty-four (64) Pan/tilt position presets stored in non-volatile memory
- Camera power (latching)
- Zoom and focus position preset
- One (1) auxiliary output (10 amp relay contact closure).

Each unit shall have a unique address, which is changeable by switch settings. The unit shall respond to the central command only if it is addressed.

The camera shall incorporate an integrated camera control receiver into the Dome Enclosure to control the camera, camera DSP functions and, pan/tilt and lens functions. The protocol and message structure for camera control shall be common for all cameras. No proprietary protocol and message structure shall be used.

The camera control receiver shall receive the command data from the local communications interface as EIA-422 control data. The camera control receiver shall provide the output signals to operate the camera accordingly. The control receiver shall retain up to 64 preset positions of all camera, pan/tilt, and preset text information when power is removed.

g. Power

All camera, pan/tilt, control receiver, and heater components shall operate from 115VAC 50/60 Hz. (±10 percent) as an input source of power.

All power supplies required to operate the integrated CCTV dome camera shall be included with the camera unit.

h. Communications Interface

A minimum 9600-baud data rate shall be used. Data shall be sent asynchronously as 8 bit with no parity. Each block of data shall include a camera identifier and be accompanied by a checksum calculated on the entire block. When the field unit must transmit data to the control unit at the TOC, it shall raise the Request To Send (RTS) line and keep it raised until all data has been sent. The field unit shall not transmit data unless the Clear to Send (CTS) line from the communications equipment interface has been acknowledged. Complete hardware interface and protocol description shall be supplied as part of the required documentation.

i. Cables and Connectors

Connectors shall be provided and installed that are compatible with the communications equipment interface. Connectors shall be used for connections at the control unit and at the camera, zoom lens and pan/tilt

mechanisms. Pressure tight multi-conductor ms-type cable connectors shall be used for camera, zoom lens, and pan/tilt connections.

The camera lead-in cables shall meet the manufacturer's specifications for NTSC video transmission, RS-422 communications, and power. Cables/adapters shall be supplied for connecting the NTSC, RS-422, and power from the camera/controller to the controller cabinet. CCTV lead in cables shall be routed as shown on the plans. Strain relief shall be provided for cables to keep cables from being damaged from over-strain or bending due to the vertical rise up the camera poles. Video and data lead-in cables shall be terminated at the respective ports of the video encoder and video decoder. Power cable shall be integrated into the signal controller cabinet grounding system. Furnish a CCTV lead-in cable that contains conductors for CCTV unit control, CCTV unit power, and CCTV unit video. Measure run between installed location of CCTV unit and the signal controller cabinet where the CCTV unit will receive power and connect to the communications cable. Furnished cable shall be constructed to conduct control signals, video signal, and power over the measured distance (plus 20%) with signal and voltage drops that allow the unit to operate in accord with these Technical Specifications. Furnished CCTV lead-in cable shall contain shielding to prevent interference and crosstalk between the data, video, and power conductors.

The NTSC shall feed into video input #1 on the encoder, and the pan-tilt-zoom EIA-422 interface shall terminate at an EIA-422 to EIA-232 opto-isolated converter. This converter shall connect to the camera control data port of the encoder.

2. VIDEO ENCODER AND DECODER

This subsection details furnishing, installing, integrating, and testing the video encoder pair for each CCTV camera deployed. The video encoder pair consists of a video encoder unit at each CCTV location in the field to convert analog NTSC video (30 fps) into digital video for transmission and a corresponding video decoder unit at the TOC to convert the digital video back to analog NTSC video for display on the TOC monitor system. The video encoder units shall be compatible with the video decoder units and be of the same manufacturer and model series.

a. Functional Requirements

The video encoder and decoder units shall support transmission of digitally-compressed video over single mode fiber optic cable when integrated with cabinet switches. The video compression algorithm shall be based on MPEG-2 and MPEG-4 standards. The video shall support resolutions up to a maximum of 720 x 640. The video encoder and decoder units shall provide a LCD display indicating diagnostic data including data rate, quality level, frame rate, video status, and board temperature. All supporting user interface software shall be provided with each encoder and decoder unit. The encoders and decoders shall be capable of streaming two separate streams of digital video simultaneously: one stream at 2Mbps D1 at 30fps, and one at 384kbps CIF at 15fps.

b. Electrical Requirements

The video encoder unit shall operate at 115VAC +/- 10 percent at 60 Hz and consume no more than 100 W. Encoder unit shall be provided with any necessary power adapters.

The video decoder unit shall operate at 115VAC +/- 10 percent at 60 Hz. Power is available from rack mounted power strips for the Contractor-provided equipment. The Contractor shall not be responsible for installation of additional power at the TOC. The Contractor shall be responsible for proper routing of all power cables within the new equipment rack.

c. Physical Requirements

The video encoder and decoder units shall consume no more than 2 rack units of mounting height in the CCTV equipment cabinet. Rack mounting kits shall be supplied for each video encoder and decoder unit.

d. Environmental Requirements

The video encoder and decoder units shall operate between -31℃ (-23℉) to +60℃ (+140F).

e. Communication Requirements

The video encoder unit shall provide a minimum of one (1) NTSC composite video input (BNC). Where multiple inputs are available, they shall be capable of being switched remotely to the single digital video output using software encoder switching controls. The encoder shall include an Ethernet interface port for compatible connection to the field cabinet switch.

The video decoder unit shall provide one (1) NTSC composite video output (BNC). The decoder shall include an Ethernet interface port for compatible connection to the LAN Switch at the TOC.

The video encoder and decoder units shall support a minimum of two (2) bi-directional data channels for camera control and other peripherals. The video encoders and decoders shall also support telnet access for administration of codec setup parameters. Data channels shall support RS-232/RS-422 communications up 19.2kbps per channel. Data ports shall be addressable. The video encoder and decoder units shall support encoding rates from 1.0Mbps to 6.0Mbps.

f. Cables and Connectors

An RJ-45 or DB-9 style connector shall be supplied with each video encoder and decoder unit that is compatible with the connection to the camera lead-in cables. Any adapter cables necessary to interconnect the CCTV camera and pan-tilt-zoom shall be provided. The units shall be supplied with programming cable assemblies and power supply assemblies.

3. TRAINING

Prior to the installation of any specified equipment, the Contractor's personnel shall have received training from the equipment suppliers on installation, operations, testing, maintenance, and repair procedures of all equipment.

S. TEST EQUIPMENT.

1. General.

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.

2. 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.

3. 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.

4. 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.

a. Construction. 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.

b. Connection to System. The Contractor shall furnish and install a suitable multi-mode fiber jumper cable to connect the ST connectors in an existing wall box with front panel ST connectors of the test controller. This cable shall incorporate a variable attenuator which shall provide a minimum range of adjustment of 5 dB to 15 dB. The minimum length of this jumper cable shall be twenty (20) feet.

5. Fiber Optic Test Equipment.

a. 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:

- o Interchangeable connector adapters,
- o Automatic measurement range selection,
- o Power measurements in Watts or Decibels,
- o Selectable measurements of absolute or relative power levels, and
- o 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°C (+165°F) and an operating temperature from a minimum of 0°C (+32°F) to +50°C (+122°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/adapter. 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/adapter which, as a minimum, is ST-compatible.

b. 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°F) to +50°C (+122°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°C (+73°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°C (+165° F) and an operating temperature from a minimum of 0°C (+32°F) to +50°C (+122°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/adapter. 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/adapter which, as a minimum, is ST-compatible.

c. 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℃ (-5ºF) to +52℃ (+125ºF) and an operating temperature from a minimum of 0℃ (+32 ºF) to +50℃(+122ºF) 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/adapter. 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℃ (+77ºF) in the pulsed-wave mode when fully charged.

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

d. Optical Fiber Clever. 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 1.0º from perpendicular a minimum of 95 percent of the time.

e. 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/adapters 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.

6. Other Test Equipment.

a. 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.

b. 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.

2.03 MISCELLANEOUS MATERIALS.

A. PAINT.

1. General.

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.

a. Types of Paint.

Types of paint to be used shall be as follows:

- 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.

b. 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.

c. 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. INDUCTIVE LOOP SAW-CUT SEALANT

1. Scope

a. This specification describes the minimum design, installation and functional performance requirements of a flexible traffic loop wire encapsulant intended for sealing and protecting vehicle detector loop wires installed in saw cuts 1/4" to 3/8" wide 1-1/2" to 2-1/2" deep.

b. The encapsulant is intended to provide compressive yield strength to withstand normal vehicular traffic as well as sufficient flexibility to withstand normal movement in asphaltic and concrete pavements, while protecting the loop wire from moisture penetration, fracture and shear.

2. General

a. Saw cuts for loops 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 permitivity 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.

b. Other sealants manufactured for embedding electrical wire or cable in bituminous or concrete pavement shall not be used unless approved by the Engineer.

c. The encapsulant shall be a one-part elastomeric compound requiring no mixing, measuring or application of heat prior to or during its installation.

d. The encapsulant shall, within its shelf life in original undamaged packing, cure only in the presence of moisture.

e. 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℃ (+75 □F) and completely cure to a tough rubber-like consistency in two (2) to seven (7) days after installation.

f. 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.

g. The cured encapsulant shall be temperature stable and exhibit no degradation in performance throughout the ambient temperature ranges experienced within the Continental United States.

h. The encapsulant shall exhibit minimal shrinkage during or after its installation, and in no manner affect the performance characteristics of the material.

i. 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.

j. The encapsulant shall have a minimum shelf-life in undamaged original containers when store in a cool, dry environment as follows: 12 months after receipt when packaged in 5 U.S. gallon pails.

k. The encapsulant shall be designed for roadway installation when the surface temperature is between +4℃ (+40 □F) and +60℃ (+140 □F).

3. Physical Properties

The encapsulant shall have the following physical properties in its cured and uncured states. (See Table 2-17 and Table 2-18)

Table 2-17 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 2-18 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

4. Certification

   The supplier shall provide a letter of certification from the manufacturer confirming the physical properties identified in Table 2-17 and Table 2-18 of this specification on each lot shipped.

5. Packaging, 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.

6. Retention Test

   The purpose of this test is to measure the non-flow properties of a one component sealant. Sealant shall obtain 70% retention when tested as follows:

   a. Put a strip of masking tape on both ends of the test fixture, completely covering.

   b. Weigh with the masking tape in place.

   c. Sample of sealant should be tested at 24°-26°C (75°-79°F) and stirred for one minute prior to testing.

   d. Fill a B-D 10cc syringe with the sample and inject the sample into the slot in the test fixture.

   e. Using a tongue depressor, scrape off any excess sealant from the top of the test fixture so that the sealant fills the test fixture slot and is level with the top of the fixture.

   f. Re-weigh the fixture with the sample material filling the slot.

   g. Put the fixture on top of two 2 ounce ointment cans and remove the masking tape from the ends.

h. Wipe off and discard any sealant on the pieces of the masking tape. Do not discard the pieces of masking tape.

i. The test period is for five minutes, starting when the two strips of masking tape are removed from the ends of the test fixture. During the test period, the sealant may flow out of the slot onto and down the sides of the test fixture.

j. After the five minute test period, using a tongue depressor, wipe off and discard any sealant that has run out of the slot onto and down the sides of the test fixture, so that the only remaining sealant is in the slot of the fixture.

k. Replace the same pieces of masking tape that were removed at the beginning of the test back onto the fixture.

l. Re-weigh the test fixture with the residual amount of sealant.

m. Weight formulas are given in Figure 2-2 below.

Final wt. of sample X 100 = % Retention **Original wt. Of sample**
Final wt. of sample = **(After test)** Wt. of fixture & residual sample Wt. of fixture w/masking tape
Original wt. of sample = **(Before test)** Weight of fixture & original sample Weight of fixture w/masking tape

Figure 2-2 Weight Formulas for Retention Test for Inductive Loop Saw-Cut Sealant

2.04 CONSTRUCTION EQUIPMENT.

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.

Part 3 CONSTRUCTION REQUIREMENTS

3.01 GENERAL.

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 Division 0 (Bidding and Contract

Requirements) and Division 1 (General Requirements) of this City of Memphis Standard Contract Documents Book.

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 Part 22, Part 23, Part 31, and Subsection 02890.3.023.02F of these 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.

New controllers and associated equipment shall be timed per the signal timing sheets provided by the City of Memphis. Signal timing shall be requested a minimum of ten (10) days prior to actual signal turn on. The actual setting of the dials on the traffic signal controller and all associated equipment is to be accomplished by the Contractor or his representative.

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 proceeding 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.

3.02 INSTALLATION OF TRAFFIC CONTROL EQUIPMENT AND MATERIALS.

A. SIGNAL HEADS.

The Contractor shall install the signal heads as required by the Plans 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.

B. CONTROLLERS AND CABINETS.

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.

Following the Field Tests indicated in Subsection 02890.4.03 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 Subsection 02890.3.02F 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.

C. VEHICLE DETECTOR AMPLIFIERS.

1. Inductive Loop Vehicle Detectors.

The Contractor shall install embedded vehicle loops and leads, shielded loop lead-in cable, and amplifiers according to these Specifications. All detector loops and lead-in cables shall be tested before and after they are sealed in the pavement to assure that there are no shorts to ground in the system and that loop plus lead-in inductance is within the operating range of the detector in accordance with the Design Standards.

2. Vehicle Loops and Leads.

Vehicle loops and leads shall be installed according to Subsections 02890.3.02D and 02890.3.02E of these Specifications.

3. Shielded Loop Lead-In Cable.

Shielded loop lead-in cable shall be installed according to Subsection 02890.3.02I of these Specifications.

4. Inductive Loop Vehicle Amplifier.

The Contractor shall install the amplifier in the Controller Cabinet and shall make the necessary connections between the controller and terminal blocks in the cabinet and the amplifier to render the detector system operational.

D. VEHICLE AND PEDESTRIAN DETECTOR SENSOR UNITS.

5. Inductive Traffic Detection Loops 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/S6).

6. Pedestrian Push Buttons.

The Contractor shall install pedestrian push buttons 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.

E. TRAFFIC DETECTOR LEAD WIRE.

The detector loop lead saw cuts shall be made with the appropriate pavement saw and cooling lubricant. The width and depth shall be as required in the Plans. Before placement of the wire, the saw cut shall be cleaned and dried with compressed oil free air. Traffic detector lead wire shall be installed as required in the Design Standards (T/S 6). The loop lead wire from the loop to the splice with the shielded loop lead-in cable in

the pull boxes, conduits, or pole base or the terminal in the controller cabinet shall be twisted in accordance with the Plans and Design Standards.

F. SIGN AND SIGNAL SUPPORT POLES.

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

G. CONDUIT AND RISERS

1. Trenched 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 Subsection 02890.4.02 of these Specifications. 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 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.

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 2 inch mandrel 1/2 inch smaller in diameter than the conduit shall be passed through the entire length of the conduit immediately before installation of cable.

2. Jacked Underground Conduits.

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.

3. 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.

H. PULL BOXES.

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.

I. ELECTRICAL CABLES AND CONDUCTORS.

1. General.

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. 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.

2. 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. A power outlet with a duplex outlet receptacle with U-type ground slot shall be provided in the cabinet.

3. 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 condulet. A cover kit shall be placed over splices as shown in the Plans or when directed by the Engineer.

4. 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, reuseable 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, condulet, or pull boxes.

J. SIGNAL SPAN WIRE ASSEMBLIES.

The signal span wire assemblies shall be installed by the Contractor in accordance with the Plans and Design Standards.

K. MESSENGER WIRE.

Messenger wire shall be installed by the Contractor in accordance with the Plans and Design Standards.

L. GUY ASSEMBLIES.

Guy assemblies shall be installed by the Contractor in accordance with the Plans and Design Standards.

M. CLEARANCE FROM UTILITY FACILITIES.

1. General.

   All traffic signal facilities shall provide the minimum clearance from all existing MLG&W electrical distribution facilities as required by the National Electric Safety Code unless otherwise approved by MLG&W. In addition, OSHA regulations may require further clearances.

2. Signal Pole and Foundation Clearances

   Traffic signal foundations shall maintain a minimum two feet of separation between the foundation and any underground electric, gas, or water distribution facilities. Traffic signal poles with heights at least 4 feet 6 inches below the lowest electrical cross arm shall maintain a minimum clearance of five feet from any electrical distribution pole. Traffic signal poles that are tall enough to be less than 4 feet 6 inches below the lowest electrical cross arm shall maintain a minimum clearance of 10 feet from any electrical distribution pole. Mast arms shall maintain a minimum clearance of four and a half feet from the lowest electrical conductor.

   During construction and installation of traffic signal facilities, OSHA regulations require that a crane may operate no closer than ten feet to an energized power line. If it is necessary to operate a crane closer to MLG&W power lines than ten feet, MLG&W shall be contacted to de-energize the power line during construction.

3. Traffic Signal Conductor Clearances

   Traffic signal conductor, span wires, messenger cables, and conductors or cables for any traffic signal devices shall be installed to be a minimum of two feet below any power conductor.

N. FIBER OPTIC COMMUNICATIONS SYSTEM.

1. General.

   The FO cable shall be installed in conduit or aerial as shown in the Plans. The FO cable shall meet the requirements of Subsection 2.02Q. The Contractor shall take every precaution to ensure the FO cable is not damaged during storage and

installation. The FO cable shall not be stepped on by workers nor run over by any vehicle or equipment. The cable shall not be pulled along the ground or over or around obstructions.

2. Required Support During Cable Installation by MLG&W.

If called for in the Plans, certain segments of the FO cable may be routed through ducts and manholes owned by Memphis Light Gas & Water (MLG&W). For these segments, the new FO cable shall be installed by MLG&W personnel under the terms of a separate force account agreement. In support of MLG&W's activities, the Contractor shall:

a. Provide on-site guidance to MLG&W's designated field supervisor regarding the number and types of cables required in each duct, the required ending points of each such cable segment, and the FO cable manufacturers recommendations regarding cable installation methods and allowable pulling tension;

b. Furnish the FO cable off the reel at the work site as needed by MLG&W;

c. Furnish all required pulling lubricants;

d. Furnish, on a loan basis, the required pulling grips and a dynameter (clutch device) to limit the pulling tension when the cable is pulled by mechanical means;

e. Determine and provide to MLG&W the number of meters of each FO cable to be coiled by MLG&W at each ending point (which typically will be a new Contractor-installed pull box); and

f. Provide all required traffic control.

Following the installation of each FO cable segment by MLG&W, the Contractor shall:

g. Perform, as soon as practical, an OTDR test of each fiber of each FO cable (using procedures set forth in Subsection 4.04B; and

h. Assuming that each fiber of the FO cable passes the attenuation test, extend the FO cable to the designated controller cabinet, splice cabinet, or aerial splice enclosure and terminate each fiber of the cable.

It shall be the responsibility of the Contractor to coordinate his construction activities on a continuing basis with each of the utility agencies which have facilities in the immediate vicinity.

The cable shall meet the requirements set forth in Subsection 2.02O. of these specifications.

The Contractor shall furnish all attachment hardware and installation guides necessary to install the fiber optic cable.

3. Allowable Splice Points.

   All splices shall be fusion splices made in housing-mounted splice trays which, as called for on the Plans, shall be located in traffic signal controller cabinets, stand-alone fiber splice cabinets, or aerial splice enclosures. Each aerial splice enclosure shall be weather-tight and shall be re-enterable for maintenance or expansion. The Contractor shall furnish and install the splice trays and tray housings.

   FO cable runs shall be continuous between allowable splice points. The Contractor shall carefully determine the length of FO cable necessary to reach from termination point to termination point. Splicing of FO cable shall be allowed only at the locations shown on the Plans.

4. Splicing Methods.

   All splicing shall be done by the fusion method. Maximum allowable splice loss shall be 0.10 dB for single mode splices and 0.20 dB for multi-mode splices. Splice losses shall be documented in tabular form and shall be provided to the Engineer upon completion of the project. Splice losses shall be measured using bi-directional OTDR measurements. Splices shall be protected in heat-shrink protective sleeves equivalent to FT-1 containing concentric heat-shrink tubing and a stainless steel stiffening rod. All splices shall be secured in splice trays or splice enclosures.

   The connector loss for the complete connection to the terminal equipment shall not exceed the sum of the allowable loss for the various components. For example, a prefabricated drop cable fiber fusion-spliced to the trunk cable and terminated in the controller cabinet shall not exceed 0.2 dB for the fusion splice plus 0.5 dB for the connector itself, or 0.7 dB plus the attenuation within the fiber. All such losses shall be as measured in one direction with an OTDR operating at the intended operating wavelength of the system.

   All optical fibers, including unspliced spares shall be securely fastened down inside a splice tray.

   At all aerial splice locations, sufficient unopened length of each cable shall be backlashed to enable the splice enclosure to be detached, lowered to ground level, and taken into a service vehicle (splice van) parked as much as twenty-five (25) feet from the point directly under the normal location of the splice enclosure. A radius controlling device, commonly referred to as a "Sno-Shoe", shall be used at each aerial splice point for securing cable slack. Each such radius controlling device shall be mounted directly to the strand.

   At all non-aerial splices, a minimum of minimum of six (6) feet of each spliced fiber shall be stored within the splice enclosure. Additionally, a minimum of thirty (30) feet of coiled slack shall be provided on the unopened portions of all cables.

5. Cabinet Entrance Requirements.

   Except as otherwise specifically called for on the Plans, FO cables shall enter the cabinets by means of a separate riser or conduit entrance:

a. For new and existing cabinets mounted on wood poles, or embedded steel poles, the Contractor shall install a new riser with sealing bushing. This new riser shall enter through the top of the cabinet.

b. For new cabinets mounted on the vertical shaft of existing steel mast arm poles, the Contractor shall install, as shown in the detail in the Plans, a new 90-degree conduit sweep from the pole into the bottom of the new cabinet. This conduit sweep shall conform to the detail shown on the Plans and shall accommodate the bending radius of the FO cables.

c. For base-mount cabinets and pedestal-mount cabinets, the Contractor shall, if called for on the Plans, install a new separate conduit entrance which, as called for on the Plans, shall either be a new entrance drilled into an existing foundation or formed into a new foundation.

6. Conduit Bends and Fittings.

Sealing bushings rather than weatherheads shall be used on all risers containing FO cable. Conduit bends and cabinet entrance fittings shall be designed to accommodate the bending radius limitations of the FO cable. Sealing bushings shall also be provided in new holes drilled into the sides of existing steel poles for entrance of FO cables.

7. Installation in Conduit.

Where shown on the Plans, FO cable shall be installed in new or existing underground conduit.

A minimum of ten (10) feet of each FO cable shall be looped in each new or existing oversized pull box and a minimum of thirty (30) feet of each FO cable shall be looped in each existing manhole or vault.

Before any FO cable installation in conduit is performed, the Contractor shall provide the Engineer with four copies of the cable manufacturer's recommended and maximum pulling tensions. Included with these pulling tensions shall be a list of the cable manufacturer's approved pulling lubricants. Only those lubricants in the quantity recommended by the FO cable manufacturer, shall be approved for use.

When installing the cable in underground conduit, the maximum allowable pulling tension for the cable installation by the Contractor shall not exceed 70 percent of the manufacturer's stated maximum pulling tension. If the cable is pulled by mechanical means, a dynameter (clutch device) approved by the Engineer shall be used to ensure that a maximum allowable pulling tension is not exceeded at any time during installation. Unless otherwise approved by the Engineer, the maximum pulling tension shall be 415 pounds during installation (short term) and 135 pounds long term installed.

FO cable shall not be pulled over edges or corners, over or around obstructions or through unnecessary curves or bends. Approved cable guides, feeders, shoes and bushings shall be used to prevent damage to the cable during installation.

FO cable shall not be pulled through any intermediate junction box, manhole, pull box, pole base or any other opening in the conduit unless specifically required by the Engineer in specific facilities. The necessary length of cable to be installed shall be pulled from one junction box, manhole, pull box, pole base, or cabinet to the immediate next downstream manhole, box, pole base, or cabinet. The remaining length of cable to be installed in the next conduit shall be carefully stored in a manner that is not hazardous to pedestrian or vehicular traffic yet ensures that no damage to the cable shall occur. The cable shall be stored in a manner that shall allow that length of cable to be safely pulled into the next conduit. The Engineer shall approve the storing methods to be used.

8. Aerial Installation.

Where FO cable is to be installed on overhead poles, the Contractor shall exercise care in temporary placement of installation equipment to provide safety to the public and to prevent damage to existing facilities. Should the Contractor cause damage to any existing cables and/or equipment, the Contractor shall immediately notify the Engineer and the affected owner and the Contractor shall repair or have the repair made at no additional cost to the City.

During installation, the Contractor shall provide cable blocks a maximum of every 50 feet to guide the cable and reduce pulling tension. Corner blocks, appropriately sized to ensure that the minimum bending radius of the cable is not violated, shall be provided whenever fiber optic cable must be pulled around a corner. Unless otherwise approved by the Engineer, the maximum pulling tension shall be 600 pounds during installation (short term) and 135 pounds long term installed.

Where the Plans call for aerial installation, the Contractor shall double-lash the FO cable to the designated supporting messenger, which in the majority of cases is new one-quarter inch messenger cable installed by the Contractor. Lashing shall comply with the detail sheets in the Plans.

Clearance from existing aerial utilities shall be as required in Subsection 3.02 M.

9. Fiber Optic Termination Facilities.

The Contractor shall install fiber optic splice enclosures and splice cabinets at locations shown in the Plans, or as approved by the Engineer. Each incoming and outgoing fiber shall be provided with 10 feet of slack.

Splicing of SMFO cable shall be done only in splice trays, which are located in fiber optic splice enclosures (installed either aerial or underground). The Contractor shall furnish and install the splice trays, drop cable assemblies, and cable storage baskets.

At splice locations, the incoming fiber shall be spliced in a splice tray to an outgoing fiber. All splicing shall be done by means of a fusion splice technique that induces less than 0.05dB attenuation.

Each spliced fiber shall be packaged in a protective sleeve or housing. Bare fibers shall be completely recoated with a protective RTV gel or similar substance

prior to application of the sleeve or housing to protect the fiber from scoring, dirt, or microbending. All splices shall be performed in accordance with the recommendations of the cable manufacturer and the splice manufacturer.

Enclosures that are shown in the Plans to be installed underground shall be attached to the side of the manhole or pull box with reusable, stainless steel bands. A sufficient amount of slack cable (minimum of 30 feet) shall be provided to enable the splice enclosure to be moved to a service vehicle parked near the controller cabinet, or other nearby site approved by the Engineer.

Enclosures that are shown on the Plans to be installed aerial shall be lashed to the messenger cable and shall not be located closer than 10 feet to the adjacent utility pole. Sufficient slack, minimum of 30 feet, shall be provided in the drop cable and trunk cables to allow the fiber optic splice enclosure to be moved to a service vehicle parked near the controller cabinet, or other nearby site approved by the Engineer.

Waterproof protection shall be provided at the splice enclosure ports using heat shrink cable seals.

At the conclusion of splicing, but prior to the final placement of the enclosure, all enclosures shall be subjected to a pressurization flash test in accordance with the manufacturer's recommended procedures.

10. Ruggedized Ethernet Field Switch

    The Contractor shall furnish and install one ruggedized Ethernet Cabinet Switch at the locations called for on the Plans. Integrate with single-mode or multi-mode fiber optic cable furnished or existing by others. Integrate with Ethernet cabinet equipment as required. Perform all coordination, setup, and configuration to integrate switch with the County traffic signal system fiber optic network. Video integration and demonstration testing shall be performed in accordance with the procedures for the Ruggedized Ethernet Hub Switch.

11. Ruggedized Ethernet Hub Switch

    The Contractor shall furnish and install one ruggedized Ethernet Hub Switch at each of the locations called for on the Plans. Integrate with single-mode or multi mode fiber optic cable furnished or existing by others. Integrate with Ethernet cabinet equipment as required. Perform all coordination, setup, and configuration to integrate switch with the City traffic signal system fiber optic network, and the attached digital video encoders/decoders and other Ethernet devices. The contractor shall test and demonstrate transmission and decoding all attached video simultaneously across the network. During this test, the contractor shall demonstrate automatic switching failover by unplugging one set of fiber connectors to one half of the network ring. Video quality for the high bandwidth video camera channels shall be demonstrated in accordance with their configuration requirements.

12. Serial Device Server

The Contractor shall furnish and install one serial device server at the locations called for on the Plans. Integrate with the controller and Ethernet cabinet equipment as required. Perform all coordination, setup, and configuration to integrate unit with the County traffic signal system fiber optic network. Set up IP addressing for communication with the traffic management system software at the traffic operations center.

13. Field Hub Cabinet

The Contractor shall furnish and install one field hub cabinet at the locations called for on the Plans. All field cabinets shall be furnished with mounting plates and other necessary hardware to mount the field cabinet on a pole or foundation. The field cabinet should be mounted in such a direction that if a person is looking at the devices inside the field cabinet he/she should be facing the traffic rather than facing away from the traffic as indicated in the Plans.

14. Central Hardware, Software and Communication Equipment

a. ACTRA Software Configuration

The contractor shall update the ACTRA traffic control database to reflect the changes to the traffic signal controller COM port or IP addressing requirements. All timing plans and other parameters in the database regarding the affected intersections shall be unmodified.

b. Hardware Integration

Fully integrate the communications server and fiber Ethernet switch with the existing Ethernet LAN switch to form a complete IP-based traffic signal control system between intersections on the fiber optic network and the TOC. The Contractor shall ensure that the final system is in compliance with the block diagram provided in the Plans.

Coordinate with City Information Technology representatives prior to configuration of remote terminal servers and ruggedized Ethernet switches to obtain IP addressing and LAN parameters prior to installation of Ethernet switch equipment.

Prior to installing and configuring the LAN, develop a LAN architecture and design document that shows the entire LAN topology, the bandwidth of the links, the IP addressing scheme to be used, and the actual network hardware that shall be used, listed by port number. Addressing scheme shall accommodate the expansion requirements described in these project special provisions. Submit draft report to the Engineer for approval. Respond to the Engineer’s comments and submit finalized version of the report. The report shall describe the network topology in text and using graphics.

Install and integrate port replication software on the communications server and configure to ensure communication with intersections on the fiber optic network is successful.

Final location and mounting of all equipment shall be approved by the Engineer.

Route all cabling in raised floor, drop ceiling, cable raceways, or as approved by the Engineer.

Effectively ground all provided equipment in accordance with City specifications and as approved by the Engineer.

Integrate KVM switch with rack-mounted servers and existing keyboard, pointing device, and display.

O. REVERSIBLE LANE SYSTEM.

1. General.

This section sets forth the requirements for the construction of reversible lane control systems. This work includes:

- Installation of reversible lane controllers;
- Installation of multi-state lane use control signals; and
- Installation of blank-out signs
- Installation of support gantries
- Installation of static signs
- Removal of the above items

2. Removal of Existing Gantry Structures.

The Contractor shall remove any structures designated for removal and transport the salvaged equipment as provided for in the Specifications. The Contractor shall also remove the foundations to a minimum depth of 6 inches below the surface and restore the surface to original conditions. If within the sidewalk, the Contractor shall restore the area with new sidewalk.

3. Installation of New Gantry Structures.

If called for on the Plans, the Contractor shall install new, steel gantry structures. The Contractor shall install new concrete footings, which shall be designed by the gantry fabricator and sealed by a Tennessee professional engineer. For both the structure and the foundations, the Contractor shall submit, for the Engineer's review and approval, shop drawings and design calculations sealed by a Tennessee professional engineer. Erection of the new gantry shall be done only during off-peak traffic hours, which specifically exclude the hours of 7 AM to 7 PM Monday through Friday and 10 AM to 6 PM on Saturday. The approximate placement of the lane control signals shall be as shown in the Plans . However, the Engineer shall approve the final placement based on the actual, installed locations of the gantry foundations and field measurement of the exact lane widths.

4. Reversible Lane Controllers and Cabinets.

The Contractor shall install the reversible lane controllers and cabinets 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 reversible lane controller cabinet shall be completely wired for service.

Following the Field Tests indicated in Subsection 02890.4.03of these Specifications, the Contractor shall install the reversible lane controller in the cabinet, making the necessary connections between the controller and the terminal blocks in the cabinet. The Contractor shall also install the conflict 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 Subsection 02890.3.02F 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.

5. Lane-Use Control Signals and Blank-Out Signs.

As called for on the Plans, the Contractor shall remove existing lane-use control signals and lane controllers, replace existing lane-use control signals and lane controllers with new signals, and/or install new lane-use control signals and lane controllers. As called for on the Plans, the Contractor shall remove existing blank-out signs, replace existing blank-out signs with new blank-out signs, and/or install new blank-out signs. For any equipment designated for removal, the Contractor shall remove and transport the salvaged items in accordance with these Specifications.

If called for on the Plans, the Contractor shall furnish and install a new disconnect box with circuit breakers. The line side of the disconnect shall be connected to the existing power source and the new lane control signals shall be connected to the protected side of the box.

When replacing existing lane-use control signals, the Contractor shall perform his removal and replacement activities in a pre-planned sequence that, to the extent practical, provides for continuous, uninterrupted operation of the reversible lane system. Generally, this shall involve beginning at one end of the project and working to the other. At least two calendar weeks prior to the intended beginning of work, the proposed sequence shall be submitted to Engineer for approval.

The existing signals shall be removed and replaced with new signals and new mounting hardware. The Contractor shall also remove the existing signal conductors and install new conductors. A separate, multi-conductor signal cable shall be used to connect each lane-use control signal with the new cabinet. A three-conductor cable shall be used to connect each single-state signal (or blank-out sign) and a five-conductor cable shall be used to connect each three-state signal.

The Contractor shall salvage the existing signals, mounting hardware, controllers and cabinets, and signal cable as called for in these Specifications.

The Contractor shall schedule his activities to begin the work at each gantry after the morning (inbound) peak and have the new signals in operation (using the new controller's internal time-base) by the beginning of the afternoon (outbound) peak. The work at one gantry shall be completed before work begins at the next gantry unless the Contractor can satisfy the Engineer that the work at more than one gantry can be successfully started and completed within the above-stated beginning and ending time constraints.

The Contractor shall furnish the appropriate hardware to mount each required lane-use control signal, blank-out sign, and/or static sign. When existing lane-use control signals are being replaced, the new mounting hardware shall be equal or better in design and quality to the existing hardware. The Contractor shall submit catalog cuts or shop drawings the Engineer for approval prior to ordering the hardware. The Engineer shall have the right to request that sample of each type be provided for inspection prior to approval.

The Plans may call for a blank-out sign to be illuminated only during railroad preemption. In that case, the Contractor shall program the controller and modify the controller cabinet as required such that each such sign shall be illuminated during railroad preemption but be dark at all other times.

The Plans may call for a blank-out sign to be illuminated on a time-of-day basis as controlled by the controller’s event scheduler. In that case, the Contractor shall program the controller and modify the controller cabinet as required such that each such sign shall be illuminated at the scheduled times but be dark at all other times.

P. CLOSED-CIRCUIT TELEVISION (CCTV) SYSTEM.

1. CCTV CAMERAS

Mount CCTV camera units at a height sufficient to adequately see traffic in all direction or as approved by the Engineer. The minimum height shall be 20 feet above ground level and the maximum height shall be 45 feet above ground level. Insure that the CCTV camera is mounted at a height greater than the traffic signal heads at the intersection.

Mount CCTV camera on side of pole nearest intended field of view and avoids occluding the view with the pole.

Electrically bond each camera and pan/tilt/zoom mechanism and its housing to the CCTV camera attachment assembly using a number 6 AWG braided copper conductor.

Integrate CCTV camera unit with video encoder unit, equipment cabinet, and equipment cabinet power supply.

Ground all equipment as called for in these Special Provisions.

Install surge protectors on all ungrounded conductors entering the CCTV enclosure. House the protectors in a small, ventilated weatherproof cabinet

attached near the CCTV attachment point in a manner approved by the Engineer. The air terminal ground wire shall not pass through this cabinet.

Install coaxial cable as required to video encoders with the CCTV units. Insure that all connections are tight and fully secure.

2. VIDEO ENCODER AND DECODER

The Contractor shall furnish and install one stand alone video encoder unit at each CCTV field location in either a new CCTV equipment cabinet or an existing signal controller cabinet as called for in the Plans. Integrate video encoder unit with the ruggedized Ethernet switch.

At locations where removal of unused equipment is called for in the Plans, identify unused signal cabinet components including but not limited to: unused NEMA TS-2 bus interface units (BIU); unused detector racks; and unused load switch racks. Following identification, obtain approval from Engineer to remove item(s) to allow for additional space in cabinet to install video encoder. Following removal of unused equipment, insure no cabinet functionality has been compromised and that the cabinet and intersection are functioning properly. Return all unused cabinet equipment that is removed to the Engineer.

3. CENTRAL VIDEO EQUIPMENT

Fully integrate the digital video server, the existing twisted pair based CCTV video stream, video control software, plasma monitor, video monitors, workstations, and video decoders with the Ethernet LAN switch to form a complete IP-based central video distribution and control system within the TOC. Ensure that the final system is in compliance with the block diagram provided in the Plans.

Coordinate with City Information Technology representatives prior to configuration of CCTV encoders and ruggedized Ethernet switch to obtain IP addressing and LAN parameters prior to installation of encoder, and Ethernet switch equipment.

The Contractor shall integrate workstations in the TOC and on the City LAN with the digital video server such that the workstation can receive and process streaming video from the server. Furnish all graphics cards, video cards, and software required to integrate the workstation.

The Contractor shall integrate and make fully available over the digital video network the existing analog twisted pair NTSC video stream currently installed at the TOC. The existing NTSC video stream shall be connected to the digital video network via digital video encoder called for in these special provisions and connection to the LAN switch. Pan, tilt and zoom control of the existing CCTV unit shall not be integrated into the system and shall remain via the existing joystick/control pad.

Prior to installing and configuring the LAN, develop a LAN architecture and design document that shows the entire LAN topology, the bandwidth of the links, the IP addressing scheme to be used, and the actual network hardware that shall

be used, listed by port number. Addressing scheme shall accommodate the expansion requirements described in these project special provisions. Submit draft report to the Engineer for approval. Respond to the Engineer's comments and submit finalized version of the report. The report shall describe the network topology in text and using graphics.

The contractor shall modify all IP addresses and configurations to achieve communications with all CCTV cameras on the fiber optic network via the Managed Fiber switch. The contractor shall update the CODEC IP addresses if required.

Final location and mounting of all equipment shall be approved by the Engineer.

Route all cabling in raised floor, drop ceiling, cable raceways, or as approved by the Engineer.

Integrate KVM switch with display monitor workstations, digital video server, and keyboard, pointing device, and LCD display furnished as part of the digital video server.

Q. COMPUTER APPARATUS.

1. Microcomputer Workstations.

The Contractor shall furnish and install each workstation as called for in the Plans. This shall include furnishing a cables and connectors to link each workstation with the existing TCC LAN and furnishing and installing a surge suppression power strip for each workstation that is not connected to a UPS.

2. Notebook Computers.

The Contractor shall furnish notebook computers as called for in the Plans.

R. 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.

3.03 PREPARATION OF TRAFFIC CONTROL EQUIPMENT.

A. PAINTING.

1. General

In general, the following materials and equipment require finishing:

a. New signal heads except plastic composition type, terminal compartments and framework, push-button housings, cabinets (except aluminum), and guard parts shall be painted.

b. New standards, posts, and pedestals shall be painted unless they are galvanized or aluminum or unless otherwise specified on the Plans.

c. Existing equipment and materials to be relocated and existing equipment altered in place shall be repainted, unless otherwise specified or approved.

2. New Equipment

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

a. 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.

b. 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.

c. When specified to be painted, standards and posts shall have at least two coats of Traffic Paint applied as follows:

(1) 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.

(2) 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.

d. 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.

e. 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.

f. 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.

3. 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.

4. Painting Procedures

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.

Part 4 TESTS, SERVICE CHECKS, INSPECTION, AND DOCUMENTATION

4.01 GENERAL.

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.

4.02 CONDUIT TESTS.

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.

4.03 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. FUNCTION 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.

4.04 SYSTEM COMPONENT TESTS.

A. CABINET/CONTROLLER TESTS.

1. Initial Testing by Contractor.

Each new controller and cabinet assembly (including both intersection controllers and reversible lane controllers) 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.

2. Pre-Installation Programming by the City.

Before any new controller is installed in the field, the Contractor shall delivered the both the controller and its conflict monitor to the City of Memphis Signal Shop. City personnel will then program the controller and monitor (including the timing data). To facilitate this process, the Contractor shall:

a. The Contractor shall provide one (1) or more controller cabinets, which shall be set up by the Contractor in the City's Signal Shop. The number to be provided, which shall be a function of the number of new controllers to be furnished in conjunction with the project, shall be one (1) cabinet per twenty (20) controllers up to a maximum of five (5) cabinets.

b. After successful completion of the required initial testing to be performed by the Contractor any required controller and cabinet assembly training required to be performed by the Contractor, the Contractor shall deliver to the City Signal Shop lots of not more than ten (10) controllers and conflict monitors, each labeled as to the intersection or lane control gantry for which it is intended.

c. The Contractor shall allow at least five (5) working days (excluding City holidays) per delivered lot of controllers and monitors for the City to perform the required programming and database entry, after which the Contractor shall pick up the controllers and monitors and install them at the locations for which they have been programmed.

B. COMMUNICATIONS CABLE TESTS

1. General.

Each fiber of each FO cable furnished and/or installed by the Contractor (including any Contractor-furnished cable that may be installed by MLG&W per Subsection 02890.3.02M) shall be tested by the Contractor, both on-the-reel prior to installation and after installation using a high-resolution optical time domain reflectometer (OTDR). All single mode measurements shall be conducted at the 1310 ± 30 nanometer wavelength. All multi-mode measurements shall be conducted at 850 ±30 nanometer wavelength. The Contractor shall record the identification, location, length, and attenuation measurements of each tested fiber and shall furnish all test reports to the Engineer.

2. On-Reel Testing.

Prior to the installation, the Contractor shall perform on-site, on-reel testing. This testing shall be for both attenuation and continuity. The tests shall be conducted at 850 nm for multi-mode fibers and at 1310 nm single mode fibers. The testing shall be performed using an OTDR by means of a pigtail splice. All test results shall be within ± 3 percent of factory-supplied attenuation measurements. Testing of each fiber of each FO cable is required but in one direction only. Hard copy or electronic copies (with applicable software) of the OTDR traces for the testing shall be furnished to the Engineer prior to installation of the cables. Except for the access to and the test preparation of any one end of the newly furnished cable to be tested, the Contractor shall preserve the cable in its originally-shipped condition. If any fiber of the cable fails the on-reel attenuation test, the cable shall be rejected and shall not be used on this project. The rejected cable shall be replaced at the Contractor's expense.

3. Cable Segment Testing.

a. Cable Installed by MLG&W. As described in Subsection 02890.3.02M, certain segments of the FO cable may be required to be installed in the MLG&W duct system by MLG&W personnel, in which case the cable is to be furnished to MLG&W by the Contractor. In such instances, the Contractor shall perform the on-reel testing described above prior to furnishing FO cable to MLG&W. As soon as practical after installation by MLG&W, the Contractor shall test each fiber of the unterminated FO cable using procedures identical to the on-reel test. If the cable segment passes this test, the Contractor shall accept it from MLG&W and extend and terminate it as called for on the Plans. If the cable segment fails this test, the Contractor shall furnish replacement cable for MLG&W to install. (Providing that it had passed its on-the-reel test, the Contractor shall be paid for all cable furnished to MLG&W whether or not it passes this post-installation test.)

b. All Cable. As each cable segment is terminated, the Contractor shall perform an end-to-end attenuation (power loss) test of each terminated fiber of each FO cable. This testing shall be performed using hand-held optical test sets and shall be tabulated and be included in the documentation package to be provided to the Engineer at the conclusion of the project. Overall loss for

each link shall not exceed the cumulative specified maximum losses of the components. For example, at 850 nm, a one kilometer link with two splices and a connector on each end shall not exceed 4.9 dB:

1.0 km x 3.5 dB/km:	3.5 dB
0.2 dB per splice x 2:	0.4 dB
0.5 dB per connector x 2:	1.0 dB
Maximum allowable loss:	4.9 dB

The cable segment shall be rejected for use on this project if any terminated fiber of the cable segment fails the attenuation test. Rejected cables shall be repaired or replaced by the Contractor at the Contractor's expense. The Contractor shall retest all fibers of any repaired or replaced cable segment.

C. CCTV SYSTEM INTEGRATION AND TESTING

Integration and testing shall be comprised of two subsystems: CCTV-Ethernet Communications and Central Video Display.

The Contractor shall furnish and install the CCTV- Ethernet equipment and Video Display equipment and assist as required to integrate them with the respective central software systems. Integration and testing is divided into three primary activities: Stand Alone Testing, System Operational Testing, and Acceptance Testing.

Testing of all equipment furnished and installed under this Contract shall be conducted by and be the responsibility of the Contractor. The City reserves the right to perform any inspections deemed necessary to assure that the equipment conforms to the requirements specified herein. The Contractor shall be required to successfully complete the Stand Alone Test, the System Operational Test, and the Acceptance Test.

The Contractor shall make arrangements for the witnessing of tests as requested by the Engineer. Full documentation of test results including problems experienced shall be prepared by the Contractor and submitted to the Engineer. Any equipment that fails the tests shall be replaced or repaired and re-tested at the Contractor's expense.

Unless otherwise noted, all test documents shall be submitted to the Engineer at least thirty (30) days prior to starting the applicable testing. Should the City require any revisions, the Contractor shall re-submit the document for further review prior to starting the test. The City’s review period shall not exceed 15 days.

The Engineer’s approval of any testing document or witnessing of tests shall not relieve the Contractor of his responsibility to provide a completely acceptable and operating system that meets the requirements of these Contract Documents.

1. Test Documentation

   The Contractor shall be required to supply written test procedures for the Stand Alone Test and the Acceptance Test. The City shall approve the test procedures before testing can be started. No testing shall commence without appropriate documentation approval.

The Contractor shall submit Test Reports for all testing levels. The Test Reports shall verify that the test procedures were conducted and the results of such testing. All Test Reports shall be presented and organized in logical groups of equipment and must be signed by the Contractor.

The Contractor shall compare the results of each test with the requirements specified in the Contract Documents, and with the test procedures. Failure to conform to the requirements shall be counted as a complete failure, and the equipment shall be rejected. Rejected equipment may be offered for retesting provided all non-compliant items have been corrected and retested by the Contractor. Any corrections deemed necessary by the Engineer shall be made by the Contractor, at no additional cost to the Department.

Failure analysis and corrective action reports shall categorize the cause of failure as material defect, quality/workmanship defect, design defect, or system defect. Failure analysis and corrective action plans shall, at a minimum, include the following items:

- Failure report form and numbering system.
- Applicability: Vendors, Suppliers, Contractor-Component Subsystem and System Levels
- Sign off authority at the different levels of activity
- Incorporation into the test report
- Correlation with configuration management
- Precise corrective action
- Confirmation of corrective action

Close out of the failure report, with accompanying charts, graphs, evidence, photographs, etc. (The failure analysis/corrective action report shall provide complete traceability and audit trail of each occurrence.)

2. Stand Alone Testing

The Contractor shall be required to perform a Stand Alone Test of each respective CCTV- Ethernet and Video Display installation to demonstrate that each site is fully operational prior to system integration. The Stand Alone Test shall be conducted at each location utilizing Contractor-supplied software and hardware. The Stand Alone Tests shall demonstrate the full control and display capabilities of CCTV cameras, and the full viewing configurations and distribution of video at the TOC.

The Contractor shall provide a test procedure for the Stand Alone Tests. The testing shall demonstrate all required functionality of CCTV- Ethernet units and Video Display units as specified within these Special Provisions. The Stand Alone test procedure document shall be submitted to the Engineer for review 15 days before testing is to begin.

3. System Operational Testing

The Contractor shall perform a System Operational Test for the entire system composed of the CCTV-Ethernet communications and Video Display subsystems. This test will demonstrate that users at the TOC can fully control

the CCTV cameras in the field over a fiber optic Ethernet network and can distribute the multicast video streams to any monitor or video display without using multiple software applications. Ethernet Hub Switch testing requirements and simultaneous video quality transmission demonstration requirements shall be met.

The Contractor shall provide a test procedure for the System Operational Test. The testing shall demonstrate all required functionality as described in these Special Provisions while maintaining all of the City's existing traffic signal system communications and operations. The System Operational test procedure document shall be submitted to the Engineer for review 15 days before testing is to begin.

4. Acceptance Testing

The Acceptance Test shall not commence until the System Operational Test is successfully completed. During this 30-day period, all aspects of the system features shall be tested. The intent of this test period is to fully utilize the cameras in real-world operation. The TOC operators shall use the CCTV cameras and display video daily in the operation of the TOC. The system shall not lockup and fail or crash due to operator entry of data. The operators shall record any deficiency as it occurs. Weekly test reports shall be gathered by the Contractor and submitted to the Engineer during the Acceptance Test.

Should any Contractor supplied equipment fail during the Acceptance Test, the current test period shall stop. The Contractor shall repair the problem, document the failure, and submit a detailed report to the City. The Contractor must then demonstrate that the system is fully operational. The City may request the Contractor to conduct the System Operational Test (or a portion thereof) once again based upon the extent of controller/firmware failures or system modifications identified and implemented during the Acceptance Test. Once the system is fully operational, the Contractor shall submit to the City for review and approval a new Acceptance Test schedule that conforms to the failure guidelines below. All aspects of repair and re-testing shall be done at no additional cost to the City.

Action in event of hardware failure: Failures of any Contractor supplied hardware item during the test period shall necessitate restarting the 30-day test period for full 30-day duration after its repair.

Action in event of controller/firmware failure: Any failure of Contractor supplied CCTV or Video Display equipment firmware or discovery of a firmware deficiency that causes a system malfunction shall cause the Acceptance Test to be halted and repeated in its entirety after correction of the firmware problem.

Intermittent failures: No intermittent failure shall be permitted to persist during the test period. If such problems are encountered, the test shall be terminated and restarted after the cause of the intermittent failure is identified and removed from the system.

System shutdown for testing/correction: The system may be shutdown for purposes of testing and correcting identified deficiencies. For each time period of

system shut down, the scheduled Acceptance Test shall be extended for the same period of time plus one day.

Maximum downtime: If the total number of system shutdowns attributable to Contractor provided software or hardware exceeds three during the Acceptance Test, the tests shall be re-performed for another full 30-day period.

4.05 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 Section 1112 of this 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.

4.06 MILL TEST REPORTS 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 4-1, 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 4-1.
- 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 4-1 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	

4.07 “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.

4.08 DOCUMENTATION.

A. CONTROLLERS AND CABINETS.

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, GTT Opticom vehicle preemption equipment and 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.

Three (3) copies of all the above information shall be provided with each controller unit for the controller and each piece of auxiliary equipment in the cabinet. In addition, three (3) copies of a cabinet wiring diagram, including all auxiliary equipment, shall be supplied with each controller unit. 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.

B. CABLE SEGMENT ATTENUATION.

The Contractor shall submit complete documentation of the cable segment on-reel and final attenuation tests required by Subsection 02890.4.04B. Such documentation shall be submitted in both hardcopy (written) form and in Engineer-approved electronic format on diskette.

C. SPLICE TABLES.

The Contractor shall prepare and submit as-built splice tables that depict the communications cable plant as constructed. The splice tables shall depict the splices made at each splice enclosure by identifying fiber spliced and buffer tube. The splice tables shall be in a format similar to those provided with the project Plans. All expressed fibers, spare fibers, used fibers and capped fibers shall be identified.

Original splice tables shall be provided in electronic format in a Microsoft Excel worksheet. Any changes to these tables shall be designated by using the underscore and strike-out method, or other method as approved by the Engineer. The as-built splice tables shall be furnished in Microsoft Excel format on a CD and in hard copy format.

D. CCTV SYSTEM.

Two (2) Operations and Maintenance (O&M) Manuals shall be supplied for each individual CCTV component. A reproducible form of each manual shall also be provided. The manuals supplied for the off-the-shelf items shall be those supplied by the equipment manufacturer. The Contractor shall also provide the Engineer with a Windows compatible CD-ROM containing the manuals developed by the Contractor. The manuals shall contain as a minimum the following operational and maintenance information:

- Installation and set-up procedures
- Functional descriptions
- Step-by-step system operating instructions
- Theory of system operation
- Recovery procedures to be followed in case of malfunction
- Procedures for updating all data base elements
- Electrical wiring diagrams
- Pictorial of components layout on chassis or circuit boards with parts identification
- Complete performance specifications (both electrical and mechanical) on each unit
- Instructions for gaining maintenance assistance from manufacturer
- Configuration parameters/settings shall be supplied for each site in both electronic and hard copy form.

E. Ruggedized Ethernet Field Switch and Hub Switch.

Two (2) Operations and Maintenance (O&M) Manuals shall be supplied for each individual ruggedized Ethernet field switch or hub switch. A reproducible form of each manual shall also be provided. The manuals supplied for the off-the-shelf items shall be those supplied by the equipment manufacturer. The Contractor shall also provide the Engineer with a Windows compatible CD-ROM containing the manuals developed by the Contractor. The manuals shall contain as a minimum the following operational and maintenance information:

- Installation and set-up procedures
- System operating instructions
- Theory of system operation
- Site-specific configuration programming parameters
- Recovery procedures to be followed in case of malfunction
- Complete performance specifications (both electrical and mechanical) on each unit
- Instructions for gaining maintenance assistance from manufacturer

Configuration parameters/settings shall be supplied for each site in both electronic and hard copy form.

4.09 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 Section 00710 (General Conditions) of this Contract Document Book. Upon completion of the project, warranties or guaranties 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 Engineer.

Part 5 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.

5.01 SIGNAL HEADS.

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.

5.02 CONTROLLERS AND CABINETS.

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.

5.03 TRAFFIC DETECTOR AMPLIFIERS

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

5.04 VEHICLE AND PEDESTRIAN DETECTOR SENSOR UNITS.

Accepted traffic detector sensor units, including inductive loop vehicle detectors of all sizes and shapes and pedestrian push buttons, shall be measured as one complete furnished and installed unit, per each.

5.05 INDUCTIVE LOOP LEAD WIRE.

Accepted detector 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). Any conduit shall be measured separately.

5.06 VIDEO DETECTION SYSTEM.

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

5.07 PRIORITY CONTROL SYSTEM.

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.

5.08 SIGN AND SIGNAL SUPPORT POLES.

Accepted sign and signal support poles shall be measured by the individual unit furnished and installed complete in place, per each.

5.09 CONDUIT AND RISERS.

Accepted furnished and field installed rigid conduit shall be measured in linear feet to the nearest foot for each size of conduit installed. Underground conduit shall be measured along the conduit by one of the following:

1. From the face of curb to the outside face of a pull box or outside edge of a pole foundation.
2. From the outside face of a pull box to the outside face of a pull box.
3. 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.
4. 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.

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:

1. From the ground to the weatherhead.
2. From the top signal head bracket to the weatherhead.
3. From the bottom of the controller cabinet to the weatherhead.

5.10 PULL BOXES.

Each pull box of the type required shall be measured as one complete installed unit, per each.

5.11 ELECTRICAL CABLES AND CONDUCTORS.

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.

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.

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:

1. The distance from the ground to the weatherhead (or mast arm).
2. The distance from the bottom of the controller cabinet to the weatherhead (or mast arm).
3. The distance from the bottom of the controller cabinet to the ground.
4. The distance from the ground to the bottom of the signal head or pedestrian push bottom.
5. 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.

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:

1. From outside face of pull box to outside face of pull box.
2. From outside face of pull box to the outside face of a pole.
3. From outside face of pole to outside face of pole.

Vertical measurements shall be made by one of the following:

1. From the ground to the weatherhead.

2. From the bottom of the controller cabinet to the weatherhead.
3. From the bottom of the controller cabinet to the ground.

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.

5.12 SPAN WIRE ASSEMBLIES.

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.

5.13 MESSENGER WIRE.

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.

5.14 GUY ASSEMBLIES.

Guy assemblies of all sizes shall be measured as one complete installed unit, per each.

5.15 FIBER OPTIC COMMUNICATIONS SYSTEM.

A. REMOVAL OF EXISTING TRAFFIC COMMUNICATIONS CABLE.

Removal of existing copper or fiber optic traffic signal and intelligent transportation system communications cables, if called for on the Plans, shall be measured as a lump sum. This item shall include removing and salvaging or disposing of the removed cable as called for in the Plans.

B. CABLES FURNISHED AND INSTALLED BY THE CONTRACTOR.

The accepted length of fiber optic cables of each type 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. Such measurements shall be made to the outside of the terminal facility (e.g., controller cabinet, splice cabinet, or splice enclosure) based on the meter marks printed on the cable jacket. At each terminal facility, the nearest meter mark shall be recorded and the total cable length (in meters) shall then be calculated. The resulting value in meters shall then be converted from meters to the nearest foot.

The above measurements include amounts coiled in manholes, vaults, and pull boxes and amounts coiled or stored aerially in coils or backlashes. No measurement shall be made of radius controlling devices (e.g., “Sno-Shoes”), for the cable lashing, or for any other hardware required to secure the cables within in manholes, vaults, and pull boxes.

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.

Splice cabinets and splice enclosures shall be measured separately. Messenger cable shall be measured separately.

C. CABLES FURNISHED BY THE CONTRACTOR FOR INSTALLATION BY MLG&W.

The length of fiber optic cables of each type and size (number of fibers) furnished by the Contractor for installation by MLG&W shall be measured in linear feet to the nearest foot from point to point along the routing for each cable. Such measurements shall be made at the inside edge of the pull box where the plans for MLG&W to coil an amount of cable for installation by the Contractor. At each pull box edge, the nearest meter mark shall be recorded and the total cable length (in meters) furnished and installed by MLG&W shall then be calculated. The resulting value in meters shall then be converted from meters to the nearest foot. No measurement shall be made of the support which the Contractor must provide, per Subsection 02890.3.02M, during MLG&W's cable removal and/or installation activities.

The remaining length of each cable between the point of this measurement and the point of termination by the Contractor shall be measured and paid for as cable furnished and installed by the Contractor in accordance with Subsection 02890.5.15B above.

D. CENTRAL FIBER TERMINATION FACILITIES.

Central fiber termination facilities shall be measured by the number of each furnished, installed, and accepted, in place and complete.

Each such item shall include the termination facility, all required patch cables (jumpers), the splicing and termination of the fiber optic cables inside of the facility, and any attachment hardware and other miscellaneous hardware and incidental items required to provide a complete installation.

E. FIELD FIBER TERMINATION FACILITIES.

Field fiber termination facilities shall be measured by the number of each furnished, installed, and accepted, in place and complete.

Each such item shall include the termination facility, all required patch cables (jumpers), the splicing and termination of the fiber optic cables inside of the facility, and any attachment hardware and other miscellaneous hardware and incidental items required to provide a complete installation.

F. RUGGEDIZED ETHERNET CABINET SWITCHES

Ruggedized Ethernet Cabinet Switches shall be measured in units of each furnished, installed, and accepted, in place and complete.

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.

G. RUGGEDIZED ETHERNET HUB SWITCHES

Ruggedized Ethernet Hub Switches shall be measured in units of each furnished, installed, and accepted, in place and complete.

Each such item shall include the switch, its integration into the hub 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.

H. SERIAL DEVICE SERVER

Serial device server shall be measured in units of each furnished, installed, and accepted, in place and complete.

Each such item shall include the serial device server, its integration into the field cabinet, its grounding and electrical isolation, 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.

I. FIELD HUB CABINET

Accepted Field Hub Cabinet shall be measured by the cabinet furnished and installed complete in place, per each. This item shall include the cabinet, foundation, splice enclosure, hardware, materials, labor, tools, equipment, and incidentals necessary to complete the work, and all testing and documentation.

J. COMMUNICATIONS SERVER

Communications server shall be measured in units of each. This item shall include the furnishing, installation, testing, and all materials, equipment, labor, tools, storage, shipping, and incidentals necessary to install and make the server fully operational.

K. PORT REDIRECTOR SOFTWARE

Port redirector software shall be measured in units of each. This price shall include installation on the communications server, testing, labor, and all incidental or third-party software required to make the software fully operational.

L. MANAGED FIBER ETHERNET SWITCH

Managed Fiber Ethernet Switches shall be measured in units of each furnished, installed, and accepted, in place and complete. Each such item shall include the switch, its integration into the TOC, 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, the LAN Architecture report to be submitted to the Engineer, to provide a fully operational IP-based communication system.

M. SOFTWARE AND HARDWARE INTEGRATION

Software and Hardware Integration shall be measured and paid on a lump sum basis. This item shall include all work, testing, and documentation required to fully integrate the central traffic control system. This includes all the construction requirements for the ACTRA software configuration and hardware integration, as described in this specification.

5.16 REVERSIBLE LANE SYSTEM.

A. REMOVAL OF EXISTING GANTRY STRUCTURES.

Removal of existing reversible lane control gantry structures shall be measured by the number of each removed and salvaged in accordance with the Plans and specifications. At each location, the unit of work shall include removal of both wood or steel poles, the steel gantry of cable spans and tethers, the lane control signals and/or blank-out signs, the existing lane controller and cabinet, and any down guys.

B. INSTALLATION OF NEW GANTRY STRUCTURES.

New fabricator-designed steel monotube gantry structures shall be measured by the number of each span length furnished, installed, and accepted, in place and complete. This item shall also include the concrete foundations.

C. REVERSIBLE LANE CONTROLLERS AND CABINETS.

New lane controllers and cabinets shall be measured by the number of each furnished, installed, and accepted, in place and complete.

D. REVERSIBLE LANE SIGNALS.

New reversible lane signals shall be measured by the number of each furnished, installed, and accepted, in place and complete. This item shall include the new mounting hardware and other miscellaneous hardware and incidental items required to provide complete installation.

5.17 FIBER-OPTIC BLANK-OUT SIGNS.

New blank-out signs shall be measured by the number of each furnished, installed, and accepted, in place and complete. This item shall include the new mounting hardware and other miscellaneous hardware and incidental items required to provide complete installation.

5.18 CLOSED-CIRCUIT TELEVISION (CCTV) SYSTEM.

A. CCTV CAMERA ASSEMBLIES

CCTV camera assemblies shall be measured in units of each and shall be paid for at the contract unit price per each. The price shall include furnishing and installing camera unit, camera lenses, control circuits, accessories, camera housing, pan and tilt units, camera

control receivers, cable harnesses, connectors, equipment for accommodating presets, source ID generator, all mounting brackets, mounting hardware (e.g., screws, nuts, bolts, etc.), power cords, transformers, delivery of all required software, installation and configuration of the CCTV unit, factory certification, and testing.

B. CCTV LEAD-IN CABLE

CCTV Lead-In Cable shall be measured in linear feet. The item shall include all terminations at the CCTV camera assemblies and the CCTV cabinets.

C. VIDEO ENCODER

Video Encoder shall be measured in units of each and shall be paid for at the contract unit price per each. The price shall include the video encoder unit, all mounting accessories, all cabling necessary for video communications and power, connectors, removal of unused controller cabinet equipment, all mounting brackets, mounting hardware (e.g., screws, nuts, bolts, etc.), power cords, delivery of all required software, installation and configuration of the Encoder Unit, factory certification, and testing.

D. VIDEO DECODER

Video Decoder shall be measured in units of each and shall be paid for at the contract unit price per each. The price shall include the video decoder unit, all mounting accessories, all cabling necessary for video communications to the video switch and all power cords, connectors, all mounting brackets, mounting hardware (e.g., screws, nuts, bolts, etc.), delivery of all required software, installation and configuration of the Decoder Unit, factory certification, and testing.

E. PLASMA VIDEO MONITOR

Plasma Video Monitor shall be measured in units of each for each monitor furnished, installed, tested, and accepted. All monitors, electronic chassis', mounting brackets, mounting hardware (e.g., screws, nuts, bolts, etc.), power cords, transformers, jumper cables and connectors shall be included under this item.

F. DIGITAL VIDEO SERVER

Digital video servers shall be measured in units of each and paid for at the contract unit price per each. This price shall include the furnishing, installation, testing, and all materials, equipment, labor, tools, storage, shipping, and incidentals necessary to install and make the server fully operational.

G. DIGITAL VIDEO CONTROL SOFTWARE

Digital video control software shall be measured in units of each and paid for at the contract unit price each. This price shall include installation on the video server, testing, labor, and all incidental or third-party software required to make the software fully operational.

H. HARDWARE INTEGRATION

Hardware Integration shall be measured on a lump sum basis. This item shall include all work, testing, and documentation required to fully integrate the central CCTV system. This includes hardware, software, and modifications required to install and make the CCTV client/server software fully functional.

I. ETHERNET LAN SWITCH

Ethernet LAN switches shall be measured in units of each and paid for at the contract unit price each. This price shall include all cables, adapters, or converters that are necessary to provide a fully operational IP-based video distribution system and the LAN Architecture report to be submitted to the Engineer.

J. DISPLAY MONITOR WORKSTATION

Display Monitor Workstations shall be measured in units of each and paid for at the contract unit price per each. This price shall include the furnishing, installation, testing, and all materials, equipment, labor, tools, storage, shipping, and incidentals necessary to install and make the display monitor workstations fully operational.

K. MONITOR SWITCH

Monitor Switch shall be measured in units of each and paid for at the contract unit price per each. This price shall include the furnishing, installation, testing, and all materials, equipment, labor, tools, storage, shipping, and incidentals necessary to install and make the monitor switch fully operational.

L. VIDEO AND COMMUNICATION RACK

Video and Communications Rack shall be measured in units of each and paid for at the contract unit price per each. This price shall include the furnishing, installation, testing, and all materials, equipment, labor, tools, storage, shipping, and incidentals necessary to install and make the rack fully operational.

5.19 COMPUTER APPARATUS.

A. FILE SERVERS.

New file servers shall be measured by the number of each type furnished, installed, and accepted, in place and complete.

B. MICROCOMPUTER WORKSTATIONS.

New microcomputer workstations shall be measured by the number of each type furnished, installed, and accepted, in place and complete.

C. NOTEBOOK COMPUTERS.

New notebook computers shall be measured by the number of each type furnished and accepted.

5.20 TEST EQUIPMENT.

Each item of test equipment shall be measured by the number of each type furnished and accepted.

5.21 SAW-CUT IN PAVEMENT.

Accepted saw-cut in pavement shall be measured in linear feet to the nearest foot along the saw-cut.

Part 6 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 subsection shall be made under the pay items listed at the end of this subsection.

6.01 SIGNAL HEADS.

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.

6.02 CONTROLLERS AND CABINETS.

Payment at the contract unit price, per each, shall be made for each accepted controller and cabinet of the type specified. This shall be payment in full for furnishing and installing the controller and cabinet with connection, providing the connection of the power service, and for connecting the signal cable and detector cable as required to render the installation operable.

6.03 VEHICLE DETECTOR AMPLIFIERS.

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.

6.04 TRAFFIC DETECTOR SENSOR UNITS

A. <u>VEHICLE DETECTOR SENSOR UNITS</u>

Payment will be made for each accepted, furnished and installed detector loop wire at field location at the contract unit price for each loop. This shall be payment in full for required saw cut, all turns of the color coded detector loop wire, sealant, and other incidentals required for a complete, tested, and operable installation.

B. PEDESTRIAN DETECTOR SENSOR UNITS.

Payment, at the contract unit price, shall be made for each accepted pedestrian push button. This shall be payment in full for furnishing and installing each push button with sign including banding or other mounting of the sign and pushbutton, wiring, and any necessary materials for a complete, tested, and operable installation.

6.05 INDUCTIVE LOOP LEAD WIRE.

Payment, at the contract unit price, per linear foot, shall be made for the accepted length of furnished and installed detector lead wire. This shall be payment in full for required saw cut, twisted wire, sealant, and other incidentals required for a complete, tested, and operable installation. Any conduit and trenching required shall be paid for separately.

6.06 VIDEO DETECTION SYSTEM.

Payment at the contract unit price, per each, shall be made for each accepted video detection system of the type specified. This shall be payment in full for furnishing and installing the video cameras, video detection processors, integration card, card rack, power supply unit, monitor, pointing device, 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 video detection 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 video detection system component such as cameras, processors, integration cards, card racks, power supply unit, monitors, and pointing devices. 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.

6.07 PRIORITY CONTROL SYSTEM.

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, 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.

6.08 SIGN AND SIGNAL SUPPORT POLES.

Payment, at the contract unit price, shall be made for each accepted and installed pole of each length and type. This shall be payment in full for excavation, reinforced concrete, concrete finishing and curing, anchor bolt installation, replacement in kind of sidewalks and pavement,

and other incidentals required for complete installation of pole foundations, furnishing and installing the pole (with mast arm, if applicable), plumbing, and other incidentals required for complete installation of the pole ready for attachment of traffic control equipment. The 6 inch deep, 3 foot square concrete top on the foundation is included in the payment for the pole.

6.09 CONDUIT AND RISERS.

Payment, at the contract unit price per linear foot for each size and type, shall be made for the length of accepted and installed conduit called for on the Plans, complete with 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.

Payment, at the contract unit price for each size of jacked conduit, shall be made for the accepted length of jacked conduit. This shall be payment in full for all labor, excavation, backfilling, conduit, and other incidentals required for complete installation.

Payment, at the contract unit price for each size of rigid conduit riser, shall be made for the length of accepted and installed rigid conduit riser of the sizes called for in the Plans. This shall be payment in full for required fittings, bushings, condulets, banding, clamps, weatherheads or sealing bushings, and other accessories necessary for complete installation and grounding at all conduit riser locations.

6.10 PULL BOXES.

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.

6.11 ELECTRICAL CABLES AND CONDUCTORS.

Payment, cable at the contract unit price for the cable type and size, shall be made for the accepted length of two-conductor power service. This shall be payment in full for 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.

Payment, at the contract unit price, shall be made for the accepted length of signal conductor cable of each size installed. This shall be payment in full for all terminations, splices, cable pulling, lashing, and other incidentals required for installation and hookup.

Payment, at the contract unit price for the cable, shall be made for the accepted length of two-conductor shielded loop lead-in cable installed. This shall be payment in full for splicing, pulling, lashing, and other incidentals required for a complete installation.

6.12 SPAN WIRE ASSEMBLY.

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.

6.13 MESSENGER WIRE.

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.

6.14 GUY ASSEMBLY.

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.

6.15 FIBER OPTIC COMMUNICATIONS SYSTEM.

A. REMOVAL OF EXISTING TRAFFIC COMMUNICATIONS CABLE.

Payment shall be made at the contract lump sum price, which shall be payment in full for all required work including disposal or salvaging of the removed cable.

B. CABLES FURNISHED AND INSTALLED BY THE CONTRACTOR.

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.

C. CABLES FURNISHED BY THE CONTRACTOR FOR INSTALLATION BY MLG&W.

Payment at the contract unit price shall be made for the accepted length of fiber optic cable of each type and fiber count furnished. This shall be payment in full for furnishing the cable and for providing all required support of MLG&W's activities.

D. CENTRAL FIBER TERMINATION FACILITIES.

Payment at the contract unit price, per each, shall be made for each accepted central fiber termination facility of the type specified. Such payment shall be payment in full the facility, patch cables (jumpers), the splicing and cable terminations within the facility, and any other hardware and incidental items required to provide a complete installation.

E. FIELD FIBER TERMINATION FACILITIES.

Payment at the contract unit price, per each, shall be made for each accepted field fiber termination facility of the type specified. Such payment shall be payment in full the facility, patch cables (jumpers), the splicing and cable terminations within the facility, and any other hardware and incidental items required to provide a complete installation.

F. RUGGEDIZED ETHERNET CABINET SWITCHES

Ruggedized Ethernet Cabinet Switches shall be paid for at the contract unit price per each. This shall be payment in full for 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.

G. RUGGEDIZED ETHERNET HUB SWITCHES

Ruggedized Ethernet Hub Switches shall be paid for at the contract unit price per each. This shall be payment in full for 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.

H. SERIAL DEVICE SERVER

Serial device server shall be paid for at the contract unit price per each. This shall be payment in full for the serial device server, its integration into the field cabinet, its grounding and electrical isolation, 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.

I. FIELD HUB CABINET

Field Hub Cabinet shall be paid for at the contract unit price per each. The price shall include the cabinet, foundation, splice enclosure, hardware, materials, labor, tools, equipment, and incidentals necessary to complete the work, and all testing and documentation.

J. COMMUNICATIONS SERVER

Communications server shall be paid for at the contract unit price per each. This item shall include the furnishing, installation, testing, and all materials, equipment, labor, tools, storage, shipping, and incidentals necessary to install and make the server fully operational.

K. PORT REDIRECTOR SOFTWARE

Port redirector software shall be paid for at the contract unit price per each. Such software is usually cost free from vendor. This price shall include installation on the communications server, testing, labor, and all incidental or third-party software required to make the software fully operational.

L. MANAGED FIBER ETHERNET SWITCH

Managed Fiber Ethernet Switches shall be paid for at the contract unit price, per each. This price shall include the switch, its integration into the TOC, 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, the LAN Architecture report to be submitted to the Engineer, to provide a fully operational IP-based communication system.

M. SOFTWARE AND HARDWARE INTEGRATION

Payment shall be made at the contract lump sum price, which shall be payment in full for all required work, testing, and documentation to fully integrate the central traffic control system. This includes all the construction requirements for the ACTRA software configuration and hardware integration, as described in this specification.

6.16 REVERSIBLE LANE SYSTEM.

A. REMOVAL OF EXISTING GANTRY STRUCTURES.

Payment at the contract unit price, per each, shall be made for each removed gantry once the work has been accepted. This shall be payment in full for removing and salvaging the existing gantry and guy assemblies, removing existing foundations to the specified depth, and for restoring the surrounding area to original or better condition including replacement in kind of sidewalks and pavement.

B. INSTALLATION OF NEW GANTRY STRUCTURES.

Payment, at the contract unit price, shall be made for each accepted and installed gantry structure of each span length. This shall be payment in full for excavation, reinforced concrete, concrete finishing and curing, anchor bolt installation, replacement in kind of sidewalks and pavement, and other incidentals required for complete installation of gantry foundations, furnishing and installing the gantry structure, and other incidentals required for complete installation of the gantry structure ready for attachment of lane-use control signals and/or blank-out signs.

C. REVERSIBLE LANE CONTROLLERS AND CABINETS.

Payment at the contract unit price, per each, shall be made for each accepted reversible lane controller and cabinet. This shall be payment in full for furnishing and installing the reversible lane controller and cabinet, providing the connection of the power service, and for connecting the signal cable as required to render the installation operable.

D. REVERSIBLE LANE SIGNALS.

Payment at the contract unit price, per each, shall be made for each accepted lane-use control signal of each specified type. This shall be payment in full for furnishing and installing the signal or sign including all connection of wiring, testing, and incidental materials for a complete and operable installation.

6.17 FIBER OPTIC BLANK-OUT SIGNS.

Payment at the contract unit price, per each, shall be made for each accepted blank-out sign of each specified type. This shall be payment in full for furnishing and installing the signal or sign including all connection of wiring, testing, and incidental materials for a complete and operable installation.

6.18 CLOSED-CIRCUIT TELEVISION (CCTV) SYSTEM.

Upon acceptance, payment for the item “Hardware Integration” shall be made at the contract lump sum price. This shall be payment in full for all work, testing, and documentation required to fully integrate the central CCTV system. This includes hardware, software, and modifications required to install and make the CCTV client software fully functional.

For CCTV Lead-In Cable, payment shall be made at the contract unit price per linear foot. The price shall include all terminations at the CCTV camera assemblies and the CCTV cabinets.

For CCTV camera assemblies, video encoder and decoders, plasma video monitors, digital video server, digital video control software, Ethernet LAN switch, display monitor workstations, Monitor switch, and video and communication racks, payment shall be made at the contract unit price for each accepted item. This shall be payment in full for furnishing, installing, and connecting each item and for furnishing any other cables, hardware, and incidental items required to provide a complete installation.

6.19 COMPUTER APPARATUS.

For microcomputer workstations and file servers, payment shall be made at the contract unit price for each accepted item. This shall be payment in full for loading the required software, for furnishing, installing, connecting, and integrating each item, and for furnishing any other cables, hardware, and incidental items required to provide a fully working operation.

For each notebook computer, payment shall be made at the contract unit price for each accepted item. This shall be payment in full for loading the required software, for furnishing the unit, and for furnishing any other cables, hardware, and incidental items required to provide a fully working operation

6.20 TEST EQUIPMENT.

Payment at the contract unit price, per each, shall be made for each accepted item of test equipment of the type specified. Such payment shall be payment in full for the item.

6.21 SAWCUT IN PAVEMENT

Payment shall be made for the accepted length of sawcut in pavement at the contract unit price. This pay item shall not include sawcut for traffic detector sensor units or detector loop lead wire, for which payment shall be made as described in Subsections 02890.6.04A and 02890.6.5 of these Specifications; this pay item shall include sawcut in pavement for any other purpose. Payment shall not include detector cable, or any other cable or wires, for which payment shall be separate. This shall be payment in full for required sawcut, sealant, and other construction incidentals required.

Part 7 PAY ITEMS

Item Number	Description	Pay Unit
02890-01	**SIGNAL HEADS**	
02890-01.01._._._._	Vehicle Signal Head	Each
	Number of Arrow Lenses	
	Number of Optically Programmed Lenses	
	Number of 12" Lenses	
	Number of 8" Lenses	
02890-01.02.08.00	Pedestrian Signal Head (8" Lenses)	Each
02890-01.02.12.00	Pedestrian Signal Head (12" Lenses)	Each
02890-01.02.12.10	Pedestrian Signal Head (12" Lenses, Optically Programmed)	Each
02890-02	**CONTROLLERS AND CABINETS**	
02890-02.01	4-Phase Traffic Signal Controller	Each
02890-02.02	8-Phase Traffic Signal Controller	Each
02890-02.03	Master Controller	Each
02890-02.11	Pole-mounted Cabinet	Each
02890-02.12	Base-mounted Cabinet	Each
02890-02.13	Fiber Optic Communication Interface (Type I)	Each
02890-02.14	Fiber Optic Communication Interface (Type II)	Each
02890-03	**TRAFFIC DETECTOR AMPLIFIERS**	**Each**

Item Number	Description	Pay Unit
02890-04	**TRAFFIC DETECTOR UNITS**	
02890-04.01	Inductive Loop Vehicle Detector Amplifier	Each
02890-04.02	Pedestrian Push Buttons	Each
02890-05	**TRAFFIC DETECTOR LOOP LEAD WIRE**	**Lin. Ft.**
02890-06	**VIDEO DETECTION SYSTEM**	**Each**
02890-06.01	Video Detection Camera (Master Arm Mounting)	Each
02890-06.02	Video Detection Camera (Pole Mounting – Long Arm)	Each
02890-06.03	Video Detection Camera (Pole Mounting – Short Arm)	Each
02890-06.04	Video Detection Processor (Single Channel)	Each
02890-06.05	Video Detection Processor (Dual Channel)	Each
02890-06.06	Video Detection Monitor	Each
02890-06.07	Video Detection Mouse	Each
02890-07	**PRIORITY CONTROL SYSTEM**	**Each**
02890-07.01	EVP Detector (Single Channel)	Each
02890-07.02	EVP Detector (Dual Channel)	Each
02890-07.03	EVP Phase Selector (2 Channel)	Each
02890-07.04	EVP Phase Selector (4 Channel)	Each
02890-07.05	EVP Confirmation Lamp	Each
02890-07.06	EVP Confirmation Beacon	Each

Item Number	Description	Pay Unit
02890-08	**SIGN AND SIGNAL SUPPORT POLES**	
02890-08.01._._	Steel Strain Poles	Each
	Pole Length (Feet)	
	Anchor Base Size (Inches)	
02890-08.02._._	Mast Arm Supports	Each
	Mast Arm Length (Feet)	
	Anchor Base Size (Inches)	
02890-08.03._	Pedestal Poles	Each
	Pole Length (Feet)	
02890-08.04._._	Wood Poles	Each
	Length (Feet)	
	Class	
02890-09	**CONDUIT AND RISERS**	
02890-09.01._._	Trenched Underground Conduit	Lin. Ft.
	Depth (Inches)	
	Size (Tenths of Inches)	
02890-09.02._	Jacked Conduit	Lin. Ft.
	Size (Tenths of Inches)	
02890-09.03._	Aboveground Conduit	Lin. Ft.

Item Number	Description	Pay Unit
	Size (Tenths of Inches)	
02890-09.04._	Conduit Riser	Lin. Ft.
	Size (Tenths of Inches)	
02890-09.05._	Conduit (Attached to Structure)	Lin. Ft.
	Size (Tenths of Inches)	
02890-10	**PULL BOX**	
02890-10.01	Standard Traffic Pull Box Type "A"	Each
02890-10.02	Standard Traffic Pull Box Type "B"	Each
02890-10.03	Fiber Optic Pull Box Type "A"	Each
02890-10.04	Fiber Optic Pull Box Type "B"	Each
02890-11	**CABLES AND CONDUCTORS**	
02890-11.01	Two-Conductor Power Service Cable	Lin. Ft.
02890-11.02._	Signal Conductor Cable	Lin. Ft.
	Number of Conductors	
02890-11.03	Two-Conductor Shielded Detector Cable	Lin. Ft.
02890-11.04	Coaxial Cable	Lin. Ft.
02890-11.05	Preemptor Detector Cable	Lin. Ft.
02890-11.06	CAT6 Ethernet Cable	Lin. Ft.
02890-11.07	Loop Wire	Lin. Ft.

Item Number	Description	Pay Unit
02890-12	**SPAN WIRE ASSEMBLY**	**Lin. Ft.**
02890-13	**MESSENGER WIRE**	**Lin. Ft.**
02890-14	**GUY ASSEMBLY**	**Each**
02890-15	**SAWCUT IN PAVEMENT**	**Lin. Ft.**
02890-16	**FIBER OPTIC COMMUNICATIONS SYSTEM**	
02890-16.01._	Single-mode Fiber Optic Cable	Lin. Ft.
	Number of Fibers	
02890-16.02._	Multi-mode Fiber Optic Cable	Lin. Ft.
	Number of Fibers	
02890-16.03._	Single-mode Fiber Optic Drop Cable	Lin. Ft.
	Number of Fibers	
02890-16.04._	Multi-mode Fiber Optic Drop Cable	Lin. Ft.
	Number of Fibers	
02890-16.05._	Single-mode Fiber Optic Cable (Installed by MLG&W)	Lin. Ft.
	Number of Fibers	
02890-16.06._	Multi-mode Fiber Optic Cable (Installed by MLG&W)	Lin. Ft.
	Number of Fibers	
02890-16.07	Removal of Existing Traffic Communication Cable	Lump Sum

Item Number	Description	Pay Unit
02890-16.08	Aerial Fiber Optic Splice Enclosure	Each
02890-16.09	Underground Fiber Optic Splice Enclosure	Each
02890-16.10	Fiber Splice Cabinet	Each
02890-16.11	Central Fiber Termination Facility	Each
02890-16.12	Fiber Distribution Box	Each
02890-16.13	Ruggedized Ethernet Cabinet Switch	Each
02890-16.14	Ruggedized Ethernet Hub Switch	Each
02890-16.15	Serial Device Server	Each
02890-16.16	Field Hub Cabinet	Each
02890-16.21	Communications Server	Each
02890-16.22	Port Redirector Software	Each
02890-16.23	Managed Fiber Ethernet Switch (Single-Mode)	Each
02890-16.24	Managed Fiber Ethernet Switch (Multi-Mode)	Each
02890-16.25	Software and Hardware Integration	Lump Sum
02890-16.25	KVM Switch	Each

02890-17	**REVERSIBLE LANE SYSTEMS**	
02890-17.01	Reversible Lane Controller and Cabinet	Each
02890-17.02	Multi-state Lane Control Signal	Each
02890-17.03._	Gantry Structure	Each
	Span Length (Feet)	

Item Number	Description	Pay Unit
02890-18._._	**FIBER OPTIC BLANK-OUT SIGN**	**Each**
	One way or two way (01 / 02)	
	Number of Messages (01 / 02)	
02890-19	**CLOSED-CIRCUIT (CCTV) SYSTEM**	
02890-19.01	CCTV Camera Assembly	Each
02890-19.02	CCTV Lead-in Cable	Lin. Ft.
02890-19.03	Video Encoder	Each
02890-19.04	Video Decoder	Each
02890-19.12	Plasma Video Monitor	Each
02890-19.13	Digital Video Server	Each
02890-19.14	Digital Video Control Software	Each
02890-19.15	Hardware Integration	Lump Sum
02890-19.16	Ethernet LAN Switch	Each
02890-19.17	Display Monitor Workstation	Each
02890-19.18	Monitor Switch	Each
02890-19.19	Video and Communication Rack	Each
02890-20	**COMPUTER APPARATUS**	
02890-20.01	Computer Workstation	Each
02890-20.02	File Server	Each
02890-20.03	Notebook Computer	Each