SECTION 902

TRAFFIC SIGNALS

902.1 Description. This work shall consist of furnishing and installing traffic signal equipment and material as shown on the plans. All work shall be in accordance with NEC, NESC and NEMA standards.

902.2 General. Existing traffic signals shall be maintained in effective operation by the contractor, except for shutdowns approved by the engineer for alterations or final removal. After any modifications have been made or after work is begun on an existing signal installation, the contractor shall maintain the signals in accordance with Sec 902.21. The contractor shall notify local traffic control agencies at least two days, excluding weekends and state holidays, prior to operational shutdown of any traffic signal. The contractor shall notify the engineer at least two days, excluding weekends and state holidays, prior to disconnecting existing vehicle or pedestrian detection. All traffic signal equipment that the contractor uses or installs on the project, whether furnished by the Commission or the contractor, either on a temporary or permanent basis, shall, upon installation or upon initial use by the contractor, be operated and maintained by the contractor until the project is complete and accepted. Any malfunction of an existing signal installation resulting from the contractor's operation, regardless of the nature of the work, shall be corrected at the contractor's expense in accordance with Sec 902.21. Signal timing will be provided to the contractor by the engineer. Programming of the controller will be the responsibility of the contractor, except when waived by the engineer. If any adjustments are required to the operation of an existing signal installation due to the contractor's operation, the contractor shall provide a minimum of two working days notice to the engineer.

902.3 Temporary Traffic Signals. Installation of temporary traffic signals shall consist of furnishing and installing poles for span wire signals, span and tether wires, control and power cable, power supply and connection to a power source, the controller, signal heads, detectors, luminaires, and all mounting hardware, unless specified otherwise. Maintenance of the installation and all other equipment and material necessary to provide the temporary installation will be the responsibility of the contractor. If the temporary traffic signal installation is not shown on the plans, the contractor shall submit a plan to the engineer for approval prior to the installation of temporary signals. Any existing or Commission furnished signal equipment to be used in the temporary signal shall be shown on the temporary signal plan. Temporary signals shall have the signal heads covered until placed in operation. A minimum of two signal faces, in accordance with Sec 1092, shall be oriented toward each street approach positioned a minimum of 8 feet apart, center to center, and a minimum of 16 feet above the surface of the traveled way to the bottom of the backplate. Existing signals shall not be taken out of operation until the temporary signals are ready for operation and approved by the engineer. A flashing operation shall be used during shutdown of the temporary signals.

902.3.1 All temporary signal equipment shall be removed by the contractor after the new installation is in operation, or as directed by the engineer. Contractor furnished equipment that will become the property of the Commission shall be of new stock and shall meet all applicable specifications. Contractor furnished equipment that will remain the property of the contractor may be new or used. Commission owned equipment will remain the property of the

Commission, unless specified otherwise, and shall be disposed of as shown on the plans or as directed by the engineer.

902.3.2 The contractor shall pay all electrical costs incurred by operation of the temporary signals and new signal systems until the signals are accepted for maintenance. For temporary signal installations where an existing signal power supply is not available, the contractor shall make any necessary arrangements to provide power to the temporary signals. Portable generators shall not be used to provide power to temporary signals. No direct payment will be made for power costs. All wire and cable for temporary signals shall be suspended overhead with proper clearance or buried a minimum of 18 inches underground.

902.3.3 Temporary signal installations shall be installed to meet the construction schedule. The contractor shall provide a minimum of two working days notice to the engineer prior to the signal turn-on. The contractor shall maintain the signals in proper operating condition, in accordance with Sec 902.21. Any damage to the traffic signal installation from any cause whatsoever shall be repaired by the contractor at the contractor's expense.

902.4 Material. All material shall be in accordance with Division 1000, Material Details, and specifically as follows:

Item	Section/Specification
Concrete	501
Galvanized Coating of Traffic Signal Posts and Appurtenances	712
High-Strength Bolts, Nuts and Washers	712
Low-Carbon Steel Bolts, Nuts and Washers	712
Structural Low Alloy Steel	712
Luminaires	901
Signs	903
Reinforcing Steel for Concrete	1036
Wood Poles for Power Supplies and Temporary Installations	1050
Electrical Conduit	1060
Electrical Conductors	1061
Pull and Junction Boxes	1062
Fiber Optic Interconnect	1092
Signal Equipment	1092
Nuts for Anchor Bolts	ASTM A 563, Grade C, D or DH or ASTM A 194, Grade 2 or 2H
Stainless Steel Bolts, Screws and Washers	ASTM A 193, Grades B5, B6, B7 or B16
Stainless Steel Nuts	ASTM A 194

902.4.1 Bolts, nuts and washers, except stainless steel, shall be galvanized in accordance with AASHTO M 232 (ASTM A 153), Class C or mechanically galvanized in accordance with AASHTO M 298 (ASTM B 695), Class 55. Except for anchor bolts, galvanizing thickness shall not exceed 6 mils. Anchor bolts shall have a minimum yield strength of 55,000 psi and a minimum elongation of 14 percent in 2 inches or 12 percent in 8 inches. For anchor bolts and nuts, and for high strength bolts and nuts, except those in accordance with AASHTO M 164, the contractor shall furnish to the engineer a test report certified to be the last completed set of mechanical tests for each size in each shipment. For high strength bolts and nuts in accordance with AASHTO M 164, the contractor shall furnish a copy of the manufacturer's inspection test report for each production lot or shipping lot furnished to the engineer and shall certify the bolts furnished are in accordance with the requirements specified. Bolts and nuts

specified to meet ASTM A 307 shall be accompanied by a manufacturer's statement that the bolts and nuts were manufactured in accordance with ASTM A 307.

902.4.2 Concrete shall be of the class specified in the contract. Material, proportioning, mixing, slump and transporting of concrete shall be in accordance with Sec 501 for the specific class specified. Concrete shall be placed, finished and cured, and the entire exposed surface, including sides and top, surface sealed in accordance with Sec 703.

902.4.3 Equipment and material shall be of new stock unless the contract provides for relocation of existing units or use of units furnished by others. New equipment and material shall be the product of reputable manufacturers, shall be in accordance with Caltrans 170 Specifications, ICEA, IMSA, ITE, MUTCD, NEMA, RETMA, NEC and the regulations of the National Board of Fire Underwriters, as applicable, and shall meet the approval of the engineer.

902.4.4 The configuration and installation of equipment mounted on substation and service poles shall be in accordance with the requirements of the utility company or municipality furnishing electrical power.

902.4.5 Three copies of the list of equipment and material to be installed will be furnished to the successful bidder, along with the contract for execution. The contractor shall complete the list by writing in the name of the equipment manufacturer and catalog number of each item listed. A list of pre-approved equipment and material is available through Traffic or MoDOT's web site. Only items on the latest revision of the pre-approved list will be accepted for use. Two copies of the completed list shall be submitted to the engineer and approved by the engineer in writing before items are installed. Approval of the items on the list will not relieve the contractor of responsibility for satisfactory performance of the installation.

902.5 Signal Heads. Each signal head of one or more signal faces shall be conventional or, if designated on the plans, optically limiting. The contractor may furnish aluminum or polycarbonate signal heads. The position of signal indications shall be as specified in the contract. Each traffic signal face shall consist of a number of identical signal section housings rigidly fastened together. Signal heads shall not be painted in the field.

902.5.1 Housing, Door and Visor. If existing housings are to be combined with new housings, the new housings shall be adaptable to the existing.

902.5.2 Louvers. Louvers, if specified in the contract, shall be installed in a tunnel visor with the fins or baffles in a vertical position.

902.5.3 Hardware. Fittings shall be secured to the signal housing by a closed threaded nipple and hex nut. Cast nipples shall not be used.

902.5.4 Backplates. Stainless steel bolts, nuts and flat washers shall be used to fasten the backplate to the head. Bolt lengths shall be selected to not interfere with maintenance operations. Any connection to the top of any signal section shall be watertight.

902.5.5 Optically Limiting Signal Heads. The signal section shall be a self-contained assembly consisting of an optical unit, section housing, housing door, terminal block and necessary gaskets to ensure a weatherproof unit. The optically limiting signal head shall be capable of separate mounting or inclusion in a signal face containing two or more signal sections. If existing housings are to be combined with new housings, the new housings shall be adaptable to the existing. Each signal section shall be installed and directed and the optical limiter masked in accordance with manufacturer's recommendations to provide indications in accordance with the plans or as directed by the engineer.

902.5.6 Painting and Finishing. All metal parts reused for modification of a signal installation shall be painted in accordance with the requirements for new material. If the painted surface of any equipment is damaged, the surface shall be repaired to the satisfaction of the engineer.

902.6 Signs. Signs for signal installations, including all material required for sign mounting, shall be furnished by the contractor. Signs shall be manufactured in accordance with Sec 903, and mounted as shown on the plans.

902.7 Posts and Mast Arms. Prior to installation, manufacturer and drawing numbers shall be submitted by the contractor to the engineer for approval in writing. Four copies of applicable pre-approved drawings shall be supplied with the poles.

902.8 Span Wire Assemblies. Span wire assemblies shall include 3/8-inch steel messenger wire, 1/4-inch tether wire, guy wire, all bolts, nuts, washers, clamps, cable straps, and other appurtenances shown on the plans or necessary for proper installation. Messenger wire shall be Class A galvanized, high-strength grade, seven-wire strand in accordance with ASTM A 475. Tether wire shall be seven-wire high-strength steel cable. Splicing of messenger and tether wires will not be permitted. Clamps shall be fabricated from low alloy steel. Steel posts for span wire assemblies shall have wire inlets and cable guides with 1-1/2 inch raintight insulator bushings and other features specified in the contract, and shall be in accordance with Sec 1092. Wood poles and steel posts for span wire assemblies shall be as specified in the contract and as shown on the plans. Luminaire bracket arms, if specified, will be at the contractor's expense. Conduit, junction boxes, service entrance caps, attachment hardware or other appurtenances on the wood poles or steel posts as shown on the plans will be at the contractor's expense.

902.9 Power Supply Assembly. The power supply assembly shall be in accordance with Sec 901.

902.10 Luminaire Control. If luminaires are specified as part of the signal conduit and wiring system on the signal posts or on separate light poles, a lighting control cabinet shall be provided and installed as shown on the plans.

902.11 Traffic Controller Assemblies.

902.11.1 Wiring. All wiring shall be insulated, stranded copper wire and shall be neatly bundled and secured with plastic cable ties. For double controller cabinets, all wiring for each intersection shall be terminated in the same compartment of the cabinet as the signal controller for that intersection. Incoming field circuits shall be routed horizontally from the conduit to the back of the cabinet, then vertically to the terminal block. All terminals shall be labeled and not be visibly obstructed. All field leads shall be identified by means of round aluminum identification tags with a minimum thickness of 0.1 mil attached to the cables with a copper wire to correspond with the plans. The outgoing signal circuits shall be of the same polarity as the line side of the power supply, and the common return of the signal circuits shall be of the same polarity as the ground side of the power supply. The power supply shall be provided through three single conductor cables. The ground side of the power supply shall be carried throughout the controller in a continuous circuit, and shall be secured to a ground bus bar in an approved manner. All field conductors shall be terminated in the controller cabinet.

902.11.2 Back Panel Wiring. All wiring on the backside of the controller back panel shall be neatly bundled and secured with plastic cable ties. Any multi-conductor cable between the controller or auxiliary equipment and the back panel shall be contained in an expandable

braided sleeve. All wiring shall be discrete insulated wires and shall be soldered directly to lugs on the back of terminal blocks and sockets. Printed circuit boards shall not be used.

902.12 Interconnect Types. The interconnect type shall be as shown on the plans.

902.12.1 Programming. The contractor shall install the system software in all computers to be used with the system as directed by the engineer, and shall program the local intersection controllers and the system master with all operating parameters and timing provided by the engineer.

902.12.2 Telephone Cable and Conduit. The telephone connection for the closed loop system will be coordinated by the engineer. The contractor shall contact the engineer a minimum of two weeks prior to the installation of the power supply assembly. The telephone network interface block shall be located on the power supply assembly. Two separate one-inch rigid conduits shall be installed for the telephone cable and shall be encased in the concrete base of the power supply and the base of the controller cabinet. One conduit shall be for the telephone cable from the telephone company pedestal to the power supply assembly, and the other conduit shall be from the power supply to the controller cabinet. Trenched telephone conduit may be installed parallel in the same trench as the conduit containing power cable. If telephone company cables cannot be installed at the same time as the telephone conduit, then a nylon pull string shall be installed in the conduit. Telephone cables shall not be exposed, except to facilitate connection to the telephone interface block. Telephone cables shall not be installed in the same conduit as the power cables. Any exposed conduit openings shall be filled with pliable duct sealant. The contractor shall supply the telephone cable between the telephone interface on the power supply and the telephone interface in the controller cabinet. The cable shall be a four-twisted-pair, shielded cable in accordance with local telephone company recommendations.

902.12.3 Closed Loop Interconnect. This work shall consist of furnishing, installing and testing a complete arterial master closed loop system comprised of intersections as shown on the plans. The system shall include all equipment listed or shown on the plans, and shall include any incidental items necessary for the satisfactory operation of the system.

902.12.4 Twisted Pair Interconnect. This work shall consist of furnishing, installing and testing a complete twisted pair interconnect system comprised of intersections shown on the plans. The twisted pair system shall include all equipment listed or shown on the plans and shall include any incidental items necessary for the satisfactory operation of the system.

902.12.4.1 Twisted Pair Interconnect Cable. Splices will not be permitted between controllers.

902.12.4.2 Twisted Pair Interconnect Installation. Twisted pair interconnect cable and the system shall be installed in accordance with the manufacturer's recommendations and as shown on the plans.

902.12.5 Wireless Telemetry Interconnect System. This work shall consist of furnishing, installing and testing a complete wireless interconnect system comprised of intersections shown on the plans. The wireless interconnect system shall include all equipment listed or shown on the plans and shall include any incidental items necessary for the satisfactory operation of the system. Telemetry radios and antennas shall be installed and set up in accordance with the plans, these specifications, and the manufacturer’s recommendations for a fully functioning system.

902.12.5.1 Antenna System. Antennas shall be positioned to receive maximum signal strength by adjusting the antenna direction while monitoring signal strength through the

telemetry radio. Antenna mounts shall be securely fastened to the poles as shown on the plans. Antenna cable shall be installed inside metal poles and conduit as shown on the plans. External cable on poles shall not exceed 3 feet unless approved by the engineer. Approved external cable runs exceeding 3 feet shall be secured using manufacturer specified hangers at a maximum spacing of 3 feet. Cable terminations shall be made in accordance with the manufacturer's recommendations. Connectors shall be installed after cable has been pulled into place. Connectors outside of cabinets shall be sealed in accordance with the manufacturer's recommendations. Any holes made in metal poles shall be deburred and protected with grommets. Drip loops shall be provided between the antenna connector and the metal pole entrance or first pole clamp. Cable bends shall be in accordance with the manufacturer's specified bending radius. Antenna cable shall be continuous without splice between the antenna and the antenna surge protector in the controller cabinet.

902.12.5.2 Grounding. A separate ground rod shall be installed for each pole with an antenna. The ground rod shall be as shown on the plans and shall be installed in a pull box adjacent to the pole, where available. Ground wires shall be No. 2 AWG minimum, and shall be securely attached to the ground rod by cadwelding. The ground wire shall be attached to the ground lug in metal poles. For wood pole mounting, the ground wire shall be attached directly to the antenna mount and securely fastened to the pole with wire clamps at 3 feet maximum spacing. Copper compression lugs shall be used to attach the ground wire to ground lugs in poles or on antenna mounts.

902.12.6 Fiber Optic Interconnect System. All system equipment shall be installed in accordance with the plans, standard specifications and the manufacturer's recommendations, and shall result in a fully functioning system.

902.12.6.1 Splice Cabinet. The splice cabinet will be required only when shown on the plans. The splice cabinet shall be installed adjacent to controller cabinets and shall be a Type 336 cabinet with an Electronic Industries Alliance (EIA) 19-inch rack cage and a fiber distribution unit. Splice cabinets shall be installed on a separate concrete base as shown on the plans and in accordance with Sec 902.15.

902.12.6.2 Fiber Optic Closed Loop System Components. The principal components of the fiber optic closed loop system, including but not limited to, the local intersection controller(s), the on-street system master and the system software, shall be supplied by the contractor and shall be compatible with any existing systems.

902.12.6.2.1 System Master Controller. The system master controller shall consist of a fiber-ready NEMA or Type 170 controller as shown on the plans, prom module, Type 170 only, and all necessary connectors and cables. The system master shall include a fiber optic data link. The system master controller shall be installed in the local controller cabinet designated on the plans. A separate cabinet will not be required.

902.12.6.2.2 Local Controller Assembly. The local controller assembly shall consist of a fiber-ready NEMA or Type 170 actuated traffic controller assembly in accordance with Sec 1092 and the plans. The local controller shall include a fiber optic data link.

902.12.6.3. Fiber Optic Interconnect Cable.

902.12.6.3.1 The contractor shall provide trained and experienced personnel to supervise the installation of the fiber optic cable. Fiber optic cable shall be installed by trained personnel having a minimum of one-year current installation experience in fiber optic systems. The contractor shall provide a certification for each person installing fiber cable. The certification shall show the amount of experience, the company or companies where experience was obtained and fiber optic training received. Methods of fiber optic installation, connections,

splicing or other types of work with fiber optic cable shall be approved by the engineer before implementation by the contractor.

902.12.6.3.2 Installation of the fiber optic cable shall also be in accordance with the manufacturer's recommendations and practices. If the manufacturer's recommendations or practices appear to conflict with this specification, the matter shall be brought to the attention of the engineer for resolution.

902.12.6.3.3 Fiber optic interconnect cable shall be installed in continuous runs for each system, in conduit, pull boxes, splice cabinets or traffic signal controller cabinets. Splices outside of the splice cabinets or controller cabinets will not be permitted. Only those fiber tubes to be accessed in splice cabinets, controller cabinets and distribution units shall be opened, and only active fibers in that tube or tubes shall be cut and spliced. The manufacturer's recommended procedures for a mid-span access shall be followed. Continuous fiber tubes shall be neatly coiled, ensuring that the minimum bend radii are not violated, and shall be organized in the fiber distribution unit. The continuous fibers in the fiber tube(s) that have been opened shall be coiled in the appropriate splice tray. The fibers to be spliced shall be connected by fusion splicing methods with a maximum loss of 0.10 decibels, and the splice shall be held and secured in a fusion splice organizer on the trays. The dark fibers in the 6-fiber cable shall be secured to the splice organizer on the appropriate tray, but will not need to be spliced.

902.12.6.3.4 The contractor shall document the location and termination of all fibers in the appropriate cabinet. Written documentation shall be left in the cabinet and one copy shall be provided to the engineer.

902.12.6.3.5 Each end of the interconnect cable shall be sealed with a manufacturer approved end cap or pulling grip for use during installation. These caps or grips shall be removed only after complete installation of the cable and for the cable acceptance testing. End caps shall be installed to remain in place where fibers are not to be terminated.

902.12.6.3.6 The minimum bending radius and the maximum pulling force of the interconnect cable, as defined by the fiber optic cable manufacturer, shall not be exceeded during installation. Pulling of the cable shall be hand assisted at each pull box, splice cabinet and controller cabinet. The cable shall not be kinked, crushed or forced around a sharp corner. Pulling equipment may be used, however, all pulling equipment and hardware shall maintain the cable's minimum bend radius. Equipment that may contact the cable, such as sheaves, bending shoes, capstans and quadrant blocks, shall be designed for use with fiber optics. Where pulling equipment such as a winch is used, cable tension shall be continuously monitored. This may include use of a winch with a calibrated maximum tension or a dynamometer or in-line tensiometer.

902.12.6.3.7 If a lubricant is used, the lubricant shall be of the water based type as approved by the cable manufacture and shall be compatible with the pre-lubricated polyvinyl chloride conduit. Prior to use, the lubricant type and manufacturer’s name shall be supplied to the engineer for approval.

902.12.6.3.8 Sufficient slack shall be left at each splice cabinet and controller cabinet to allow proper termination. Each pull box adjacent to a signal cabinet or a splice cabinet shall contain a minimum of 60 feet of coiled cable. Mid-block pull boxes shall contain a minimum of 10 feet of coiled cable. Stored cable shall be neatly coiled as per the manufacturer's minimum bending radius specification. Where the size of the box precludes the coiling of cable above the minimum bending radius, the cable shall pass straight through the pull box.

902.12.6.3.9 The conduit containing only fiber optic interconnect cable shall be polyvinyl chloride or high density polyethylene conduit in accordance with Sec 1060 and shall be orange in color. A No. 14 AWG stranded copper tracer wire or a pull tape with a tracer wire shall be installed in the conduit.

902.12.6.3.10 At each pull box and controller cabinet, the interconnect cable shall be visibly marked "Caution - Fiber Optic Cable" by self-adhesive, weatherproof tags.

902.12.6.4 Testing. After the fiber optic cable installation, each fiber in each section shall be tested for attenuation and continuity, as a minimum. The contractor shall provide all personnel, equipment, instrumentation and supplies necessary to perform all testing. Any sections that fail the testing shall be replaced at the contractor's expense, and retested. All testing shall be performed in an accepted manner and in accordance with the testing equipment manufacturer's recommendations. All data shall be recorded and submitted to the engineer.

902.12.6.4.1 Attenuation. The end-to-end attenuation shall be measured for each link after installation by insertion loss testing.

902.12.6.4.1.1 The launch cable shall be connected to the light source and the receive cable to the power meter. The two reference cables shall then be connected via a termination hub. A reference power reading (P1) shall then be taken and recorded.

902.12.6.4.1.2 The system link to be tested shall then be inserted between the launch and receive cables using two termination hubs. A test power reading (P2) shall then be taken and recorded.

902.12.6.4.1.3 The link attenuation (A) in decibels shall be recorded as the mathematical difference between the reference power (P1) and the test power (P2).

902.12.6.4.1.4 Insertion loss testing shall be performed in both directions along the link. The direction of the test shall be recorded in the documentation.

902.12.6.4.2 Transmitter/Receiver Power Levels. The output power levels at the network hardware transmitters and receivers shall be measured and recorded for system documentation. The power meter shall be connected to the transmitter side of the equipment with a system jumper. The transmit power level shall then be read and recorded. The transmitter shall then be re-connected to the cable link and the power meter connected to the receiver side of the equipment. The receiver power level shall then be read and recorded.

902.12.6.4.3 Continuity. Continuity tests shall be used to determine whether a test or system jumper does or does not pass light. A continuity test shall also be used to assure the fibers have not been crossed over in the jumper and to assure that the transmit fiber goes to the receiver fiber. To perform the continuity test, a high-intensity flashlight shall be aimed into the connector at one end, while an observer watches for a flicker of light at the other end.

902.12.6.4.4 Optical Time Domain Reflectometer. An Optical Time Domain Reflectometer (OTDR) shall be used to evaluate the quality and length of cable reels prior to use. The fiber loss in decibels/km and the length of each reel shall be recorded in the documentation. The maximum attenuation of the cable shall be 3.5 decibels/km nominal, measured at room temperature at 850 nanometers, equivalent for single mode. A hard copy of OTDR signature traces for all system links shall be made and provided in the documentation.

902.12.7 System Acceptance Test. In addition to the standard testing requirements, the contractor shall successfully complete and document a four-part system acceptance test, in the presence of the engineer, unless approved otherwise, as follows:

(a) System Master Acceptance Test

(b) Office Computer Acceptance Test

(c) Notebook Computer Acceptance Test

(d) System Operational Test

902.12.7.1 System Master Acceptance Test. The system master acceptance test shall be conducted after all traffic signal improvements and the initial eight-hour training session has been completed. The test shall include the following:

(a) The contractor shall simulate a fault at a local controller and verify that the fault is recorded in the permanent log in the master and that the master automatically dials the office computer and transmits the same information.

(b) The contractor shall verify that scheduled timing plans change based on time of day.

(c) The contractor shall change one offset at a local controller and verify the change has been made and implemented at the local controller.

(d) The contractor shall verify a traffic responsive plan change is made at the appropriate time. This shall be demonstrated with simulated detector data.

(e) The contractor shall verify all programming data for the master and all locals can be downloaded/uploaded via the front panel RS-232 connection on the system master.

902.12.7.2 Office Computer Acceptance Test. The office computer acceptance test shall be conducted after successful completion of the system master acceptance test and shall include the following:

(a) A simulated fault at a local controller shall be recorded in the office computer log. The contractor shall verify the entry by printing a log report.

(b) The contractor shall reschedule a timing plan change and verify that the event happens at the new time.

(c) The contractor shall make a timing plan change and verify the change has been made at the local controller.

(d) The contractor shall print a report that shows all plan changes for the previous 24 hours.

(e) The contractor shall print a report showing volume and occupancy values from all system detectors for the previous 24 hours.

(f) The contractor shall call up a real-time intersection display.

902.12.7.3 Notebook Computer Acceptance Test. The notebook computer acceptance test shall consist of the same tests performed for the office computer acceptance test, except all reports shall be displayed on the screen. This test shall be conducted only after the office computer acceptance test has been successfully completed. In addition, a complete local controller database shall be uploaded and downloaded from one controller to another using only the notebook computer, the cable provided and the two controllers.

902.12.7.4 System Operational Test. The system operational test shall be conducted after the system master, office computer and notebook computer acceptance tests have been successfully completed. The system operational test shall consist of a 30-day operational period, during which system failures are recorded. Any failure or malfunction of equipment during the test period shall be corrected at the contractor's expense, and the signal or system shall be tested for an additional 30 consecutive day period. This procedure shall be repeated until the signal equipment has operated to the engineer's satisfaction for 30 consecutive days. System failures will be defined, as a minimum:

(a) Local intersection controller failing to respond to the system master.

(b) System master failing to respond to either the office or notebook computer.

(c) A system detector failure.

902.12.8 Thirty-Day System Operational Test. The 30-day test shall replace the 15-day test period outlined in Sec 902.21. Liquidated damages will only be accumulated between the end of working days and the start of the final 30 consecutive day test period.

902.12.9 Documentation. Complete system documentation shall be provided. Documentation, as a minimum, shall include the results of all testing and shall be recorded along with date of test, name of person performing the test, brand name, model number, serial number of equipment used during test, and any other pertinent information and data.

902.13 Detectors.

902.13.1 Induction Detector Probes. Detector probes installed under bridge decks shall be protected by completely encapsulating the probe in a conduit system. Probes shall be oriented such that the detection zone is above the bridge deck, and shall be installed in gasketed junction boxes anchored to the bottom of the deck. The junction boxes shall have a minimum size of 6 x 6 x 4 inches and the probes shall be rigidly anchored in the box. The probes shall be no more than 18 inches below the top of the bridge deck. Conduit shall be sized such that the probe and cable can be pulled through the conduit. Any conduit bends shall be such that the probe and cable can be pulled through the bend. External conduit on the structure shall be in accordance with Sec 902.16.

902.13.2 Induction Loop Detectors. A slot for the installation of induction loop cable shall be sawed in the pavement as shown on the plans. Slots shall not be sawed until seven days after placement of Portland cement concrete. Each loop shall have a separate lead-in slot to the conduit. A separate conduit shall be installed between the sawed loop slot and the first pull box for each loop. The conduit opening at the end of the lead-in slot shall be at the bottom of the sawed slot. The slot shall be clean. The cable shall be pushed into the slot without damaging the insulation. After the loop cable is spliced to the lead-in cable, and before the slot is sealed, the resistance of the loop and lead-in cable to ground shall be checked. The resistance test shall be performed by the contractor in the presence of the engineer and documented. After a satisfactory test, showing a resistance no less than 10 megaohms, the slot shall be sealed. The conduit opening at the end of the lead-in slot and any drilled conduit holes in the pavement shall be sealed with a pliable duct sealant prior to the application of loop sealant. All sawed slots shall then be sealed with an approved detector loop sealant. All detector cable between the loop and detector amplifier shall be twisted at least three turns per foot.

902.13.3 Microwave and Ultrasonic Detectors. Microwave and ultrasonic detectors shall be mounted at the locations shown on the plans in accordance with manufacturer's

recommendations. All wiring shall be continuous and unspliced from the detector unit to the controller. The contractor shall make any necessary adjustments for proper operation of the detector.

902.13.4 Video Detection Systems. This work shall consist of furnishing, installing and placing into operation a vehicle detection system that detects vehicles by processing video images and providing detection outputs to a traffic signal controller. The system shall include all equipment shown on the plans and described in these specifications, and shall include any incidental items necessary for the satisfactory operation and maintenance of the system. The video detection system shall be installed per the manufacturer's recommendations. All cable runs shall be continuous without splice from the cabinet to the camera. If requested by the engineer, a factory certified representative from the supplier shall be available for on-site assistance for a minimum of one day during installation.

902.13.4.1 Camera. The bottom of the video camera shall be mounted a minimum of 30 feet above the pavement.

902.13.4.2 Extra Service Outlet. A separate grounded service outlet shall be provided in the controller cabinet for supplying power to the video detection system. Use of the grounded service outlet located on the cabinet door will not be permitted.

902.13.4.3 Monitor. The monitor shall be installed to automatically power on when the cabinet door is opened and automatically power off when the cabinet door is closed. A manual on/off switch shall also be provided.

902.13.5 Detector Loop Sealant. Loop sealant shall be proportioned, mixed and installed per the manufacturer's specifications and recommendations. After the loop slots are cut into the pavement, the surface shall be thoroughly cleaned, and all loose debris shall be removed. After application of the sealant, the roadway shall be tack-free and capable of being open to the motoring public within four hours without tracking. Loop sealant shall fully encapsulate the loop wires as shown on the plans. Backer rods shall be placed to ensure a one-inch depth coverage of loops. Excessive overfill will not be permitted.

902.14 Pull and Junction Boxes. Pull and junction boxes shall be installed at locations as shown on the plans. Pull boxes placed in traveled ways, auxiliary lanes, shoulders and low profile islands shall be concrete.

902.14.1 Conduit shall enter the pull box in the side of the box and shall extend a minimum of 2 inches and a maximum of 4 inches as shown on the plans. If it becomes necessary to increase the excavation depth and extend the pull box, no direct payment will be made. The excavated opening outside the pull box shall be wide enough to allow compaction of the backfill material. Cinders, broken concrete, broken rock or other hard or undesirable material shall not be used for backfilling. The backfill material shall be placed in layers not to exceed 6 inches deep, and each layer shall be thoroughly compacted before the next layer is placed. Where preformed pull boxes are used, the holes for the conduit shall be drilled as recommended by the manufacturer. The holes shall be round and no more than 1/2 inchlarger than the conduit.

902.14.2 Drains for pull boxes shall be constructed as shown on the plans.

902.14.3 The top surface of all pull boxes shall be flush with surfaced areas and approximately one inch above earth or sodded areas.

902.14.4 If preformed pull boxes are specified, the contractor may use standard concrete pull boxes in lieu of the Class 1 or 2 preformed pull boxes, or the Type A double concrete pull box in lieu of the Class 3 preformed pull boxes. For installations requiring different voltages for

lighting and signal applications, the Type B double concrete pull box may be used in lieu of two preformed pull boxes at the contractor's expense. If the Type B double concrete pull box is specified, no substitutions will be permitted.

902.14.5 Class 5 preformed pull boxes shall be in accordance with all requirements in the contract documents. Installation of Class 5 pull boxes shall be as shown on the plans and in accordance with the manufacturer's recommendations.

902.15 Concrete Bases. Excavation for bases shall be made in a neat and workmanlike manner. While concrete is being placed, forms shall be level and sufficiently rigid to prevent warping or deflection. Concrete shall be Class B or concrete of a commercial mixture in accordance with Sec 501. Conduit, ground rods and anchor bolts shall be held rigidly in place before and during concrete placement. Tops of all bases shall be finished level and the perimeter edged to a radius of 1/2 inch. Exposed surfaces of bases shall be finished in a workmanlike manner as soon as practical after removing forms. Concrete shall be placed, finished and cured in accordance with Sec 703.

902.15.1 Post Bases. Concrete bases for posts shall be in accordance with the dimensions shown on the plans. Metal forms no less than 26 inches high shall be used for all Type A bases. The top 12 inches of Type F bases shall be formed. Reinforcing steel for concrete bases shall be in accordance with Sec 706. Anchor bolts for steel posts and mast arms shall be as shown on the fabricator’s approved shop drawings. Conduit shall extend above all post bases a nominal 4 inches.

902.15.2 Controller Bases. Concrete bases for controllers shall be constructed as shown on the plans. Aprons will be considered part of the controller base. A minimum of four anchor bolts shall be used for single controller cabinets and a minimum of six anchor bolts shall be used for double controller cabinets. The size of anchor bolts for controller cabinets shall be as specified by the cabinet manufacturer. A ground rod shall be placed into the ground with a minimum of 8 feet of earth contact as shown on the plans. Bases for double controller cabinets shall have two ground rods, one positioned in each compartment. Conduit shall extend above all controller bases no more than one inch. Bases for double controller cabinets shall have two conduits to the first pull box, one positioned in each compartment. All conduit openings in the controller cabinet or controller cabinet base shall be sealed with a pliable duct sealant in accordance with Sec 901.15 after wiring is completed.

902.16 Conduit Systems. The contractor may furnish and install rigid steel, intermediate metal, polyvinyl chloride (PVC) schedule 40 or high-density polyethylene (HDPE) conduit. Conduit shall be placed a minimum of 18 inches below finished grade and shall slope to a pull box at a minimum rate of 0.5 percent unless otherwise shown on the plans. A change in direction of conduit shall be accomplished by bending the conduit uniformly to a radius that will fit the location, or by the use of standard bends or elbows. The minimum radius of the bend shall be six times the internal diameter of the conduit. Nipples shall be used to eliminate cutting and threading where short lengths of conduit are required. If it becomes necessary to cut and thread steel conduit, exposed threads will not be permitted. All conduit and fittings shall be free from burrs and irregularities. All conduits shall be cleaned and swabbed before cables are installed. All fittings shall be tightly connected to the conduit. Open ends of conduit placed for future use shall be capped or plugged. If approved by the engineer, conduit may be installed either by trenching or pushing; however, payment will be made by the method specified in the contract for that conduit. Functionally equivalent English measure items may be substituted by the contractor for metric items specified or shown on the plans in accordance with Sec 901.15 upon approval from the engineer.

902.16.1 Metal Conduit. All metal conduit ends shall be provided with a bushing to protect the cable from abrasion. All metal conduits shall be electrically bonded by conduit clamps

and bare No. 6 AWG stranded copper wire. All metal conduits in the controller base shall be electrically bonded to the power company ground.

902.16.2 Polyvinyl Chloride Conduit. A bare No. 6 AWG stranded copper ground wire shall be installed in each conduit and attached to the ground lug in signal posts, except as otherwise specified in this section. All bare ground wires shall be electrically bonded. All bare ground wires in the controller base shall be electrically bonded to the power company ground. PVC containing only fiber optic cable shall contain a bare or green-jacketed No. 14 AWG stranded copper tracer wire instead of a bare No. 6 AWG copper ground wire. Tracer wire shall not be pulled into the controller cabinet or bases. An additional 6 feet of tracer wire shall be coiled in each pull box through which the fiber optic cable passes. Tracer wire in pull boxes shall be capped, not electrically bonded to any ground wires labeled "TRACER" and tagged in accordance with Sec 902.19. Ground wire and tracer wire shall be at the contractor's expense.

902.16.3 Conduit in Trench. Trenches shall be excavated to the width and depth necessary for conduit installation. All trenches shall be backfilled as soon as practical after the installation of conduit. Cinders, broken concrete and other hard or objectionable material that might cause mechanical damage to the conduit shall not be used for backfilling within 6 inches of the top of the conduit. The bottom of the trench shall be free of such material before the conduit is placed. Conduit shall not be placed without approval of the trench from the engineer. Backfill material shall be deposited in the trench in layers not exceeding 6 inches deep and each layer shall be compacted to the approximate density of the adjacent material by an approved method before the next layer is placed. Red burial tape imprinted with "CAUTION - BURIED CABLE BELOW" shall be installed in all trenches at approximately one-third to one-half of the depth of the trench. All disturbed areas shall be restored to the satisfaction of the engineer.

902.16.4 Pushed Conduit. If pushed conduit is specified, the conduit shall be installed without disturbing the existing surface. Pushed conduit may be placed by jacking, pushing, boring or other approved means.

902.16.5 Conduit in Median. If conduit in median is specified, the conduit shall be placed on the existing pavement prior to construction of the raised median. If conduit is to be placed in concrete traffic barrier, the conduit shall be held rigidly in place before placement of concrete.

902.16.6 External Conduit on Structure. For existing structures, or if provisions are not made in the plans for providing a conduit raceway in new structures as described in Sec 707, the conduit shall be external conduit on structure. Conduit on structure will include conduit on bridges, retaining walls or other structures, and shall be installed as shown on the plans or as directed by the engineer. The final location of all conduit and junction boxes shall be approved by the engineer before installation begins. Conduit shall not be attached to prestressed concrete girders or prestressed, precast concrete deck panels. The conduit shall be secured to the concrete with clamps at no more than 5-foot intervals. Concrete anchors shall be in accordance with federal specification FF-S-325, Group II, Type 4, Class I, and shall be galvanized in accordance with ASTM A 153, B 695-91 Class 50, or constructed of stainless steel. The minimum embedment in concrete shall be 1 3/4 inches. The supplier shall furnish a manufacturer's certification that the concrete anchors meet the required material and galvanizing specifications. If necessary to anchor the conduit to steel bridge members, the attachment method shall not involve drilling, grinding or welding. Attachment method to steel members shall be approved by the engineer. Junction boxes shall be installed as shown on the plans or as directed by the engineer. Junction boxes shall be surface-mounted and installed such that covers are accessible. If the conduit crosses a bridge expansion joint, a conduit expansion fitting shall be used. The expansion fitting shall provide a minimum movement in

either direction as shown on the plans or as specified by the engineer. Junction boxes, expansion fittings and any hardware or material required for conduit installation shall be at the contractor's expense.

902.17 Signal Faces. Vehicle and pedestrian signal faces shall be covered or turned away from approaching traffic until placed in operation. When ready for operation, the signal faces shall be securely fastened in position facing approaching traffic. Incandescent lamps installed by the contractor shall be installed horizontally with the open segment of the filament facing up. Vehicle and pedestrian signal faces shall be aimed laterally at the approximate center of the lane or lanes the signal face controls. Signal faces shall be aimed at a point behind the stop line a distance corresponding to the following requirements:

Approach Speed, mph	Distance, feet
30	160
40	240
50	330
60	430
70	560

902.18 Post Erection. Post bases shall be securely anchored to concrete bases. Pedestal posts shall be erected vertically without the use of leveling nuts. Metal posts for span wire and cantilever mast arms shall be adjusted by leveling nuts. All posts for span wire and cantilever mast arms shall be raked as directed by the engineer. All signal posts shall be grounded by a bare No. 6 AWG stranded copper wire running from the ground lug inside the post to a clamp fastened on metal conduit at the top of the concrete base to a ground rod or through nonmetallic conduit to the ground bus in the controller.

902.19 Wiring.

902.19.1 All cable runs shall be continuous and unspliced from the connections in the terminal block of the signal head or disconnect hanger to the terminal strip in the controller cabinet, from the signal terminal block to another signal terminal block or as shown on the plans. When a terminal compartment is provided, all cable runs shall be continuous from the terminal compartment to the terminal strip in the controller cabinet. When parallel connections are required from an overhead signal head on a mast arm to a side-mounted signal head, cable shall be routed from the controller to the terminal compartment of the signal on the mast arm and then parallel-circuited back to the side mounted signal. All other conductor cable combinations to signal heads shall be as shown on the plans or as directed by the engineer. Where double controller cabinets are specified, wires shall be sorted between the controller and first pull box such that field wires enter the associated controller compartment.

902.19.2 Power cable runs shall be continuous and unspliced from the power disconnect switch located on the power supply to controller cabinet terminals. Power cable shall be encased in conduit of the size shown on the plans. Energized power cables shall run to circuit breakers. The neutral cable shall be terminated on the neutral bus bar and the equipment ground conductor shall be terminated on the ground bus in the controller cabinet.

902.19.3 Where luminaires are required, pole and bracket cable shall be installed between the luminaire and the power source at the base of the post. Each luminaire shall be connected to the power source by No. 12 AWG conductors with suitably sized equipment grounding conductor. A premolded fused connector assembly shall be installed on each conductor carrying current between the source cable and the pole and bracket cable. The assembly and cable shall be insulated with a protective rubber boot designed for the premolded connector.

902.19.4 Induction loop dimensions shall be as shown on the plans. The engineer will determine the exact location of loops. Each induction loop shall be connected to the detector by a separate lead-in cable. Single-conductor No. 14 AWG cable shown on the plans is an approximation of cable quantity required to construct the induction loop. If the number of turns shown on the plans is not in accordance with the manufacturer's recommendation for the sensing units furnished, the plans will be revised, the induction loop cable will be field measured and quantities adjusted accordingly. Induction loop detector cable shall be installed in accordance with manufacturer's recommendations. Induction loop detector lead-in cable will be shown on the plans as two-conductor No. 14 AWG cable. Should the manufacturer recommend a different type of cable, the two-conductor cable shall be revised to the manufacturer's specification, but will be considered completely covered by the contract unit price for loop detector lead-in cable. Cable for loop detectors shall be continuous from the terminal strip in the controller cabinet to a splice with the detector leads in the pull box adjacent to the detector. The conductor splice shall be soldered without an open flame. The soldered splice shall then be capped and inserted into a direct buried splice kit.

902.19.5 Where practical, color codes shall be followed such that the red insulated conductor connects to the red indication terminal, orange to yellow and green to green. Circuits shall be properly labeled in the controller cabinet and all pull boxes by means of round aluminum identification tags with a minimum thickness of 0.1 mils, attached to the cables with a copper wire. Information stamped on the tags shall identify equipment served by the conductor cable in accordance with designations used on the plans.

902.19.6 Cables shall be pulled through conduit by a cable grip providing a firm hold on exterior coverings. Cable shall be pulled with a minimum of dragging on the ground or pavement. Frame-mounted pulleys or other suitable devices shall be used for pulling cables out of conduit into pull boxes. Lubricants may be used to facilitate pulling cable. Polyester rope will not be permitted to facilitate pulling of cable. Slack in each cable shall be provided by a 6-foot loop coiled in each pull box and a 3-foot loop coiled in each junction box. All signal posts and controllers shall be grounded by bare No. 6 AWG stranded copper wire.

902.20 Test Equipment. During installation of equipment and material, the contractor shall furnish to the engineer suitable equipment to test all or part of the completed facility to establish compliance with requirements of the contract. Minimum test equipment shall be a voltmeter, ohmmeter and ammeter. For testing induction loop detectors, the contractor shall also provide a suitable 500-volt, direct current, 0 to 100- megaohm range, hand-operated, resistance measuring device.

902.21 Test Period. After the project is open to normal traffic, the contractor shall notify the engineer in writing the date the signal or signal system will be ready for testing. Upon concurrence from the engineer, the contractor shall place the signal or signal system in operation for a 15 consecutive day test period. A signal operated independently of other signals or signal systems shall be tested as a single installation. A signal operated as part of a system shall not be tested until all signals in the system are ready to be tested. A system shall be tested as a unit. Any failure or malfunction of equipment during the test period shall be corrected at the contractor's expense, and the signal or signal system tested for an additional 15 consecutive day period. This procedure shall be repeated until the signal equipment has operated to the engineer's satisfaction for 15 consecutive days. The contractor shall, in the presence of the engineer, demonstrate the proper action of the controller's monitor as part of the testing system, if applicable.

902.21.1 When the test period is initiated and until the test period is completed, following the turn on of temporary traffic signals or after work is begun on an existing signal installation, the contractor shall provide at least one service technician to remain in the area and be available for day, night and weekend trouble calls. The contractor shall furnish the name,

address and telephone number where each designated technician can be reached at all times. In the event of a malfunction, the contractor shall provide adequate traffic control for the intersection until the signals are restored to normal operation. Adequate traffic control shall be as shown on the plans or as directed by the engineer. If the signal or signal system malfunctions and a designated technician cannot be reached or cannot arrive at the intersection in a reasonable time in the judgment of the engineer, then the engineer may exercise the option to direct MoDOT personnel or a third party to correct the malfunction in the presence of the engineer. If this option is invoked, the entire cost of the work performed by MoDOT personnel or the third party will be computed as described in Sec 108.9 and deducted from the payments due the contractor.

902.21.2 Whether or not the engineer elects to correct the signal malfunction, nothing in this specification shall be construed or interpreted to relieve the contractor of any liability for personal injury or property damage that results either directly or indirectly from a signal malfunction during the test period. The contractor and surety shall indemnify and save harmless the State, the Commission, the Commission's agents, employees and assigns for any legal liability incurred for such a signal malfunction.

902.22 Maintenance Information. Before acceptance of the work, the contractor shall furnish the engineer with three copies of the manufacturer's instructions for maintenance and operation of all signal equipment including, but not limited to, controllers, conflict monitors, load switches, detectors, software, interconnect and auxiliary equipment. At a minimum, the manufacturer's instructions shall include organized written instructions, wiring diagrams, diagrams showing component layouts and parts lists with part numbers and serial numbers, where applicable. Serial numbers listed by the supplier will be verified with the shipping invoice and on the controller and conflict monitor received for installation. The contractor shall furnish three copies of wiring diagrams of the installation or system. The cabinet wiring diagrams shall include labeling for all field terminal connections and shall provide an orientation of the terminal layout that conforms to the intersection information specified.

902.23 Final Clean Up. .Final clean up of right of way shall be in accordance with Sec 104.

902.24 Method of Measurement.

902.24.1 Measurement of temporary traffic signal installations will be made per lump sum.

902.24.2 Measurement for the following items will be made per each:

(a) Signal heads and luminaires.

(b) Posts.

(c) Power supply assemblies, including all specified equipment.

(d) Traffic controller assemblies, including all specified equipment.

(e) System software, including installation.

(f) System master, including all specified items.

(g) Telemetry radios and antennas for wireless interconnect systems, including all specified equipment.

(h) Video detection systems, including all specified equipment.

(i) Pull boxes, including all specified material.

(j) Training, including all specified training.

(k) Modems, including all specified equipment.

(l) Splice cabinet, including all specified items.

All necessary material, hardware, equipment and specified incidental items.

902.24.3 Measurement of push button detectors, microwave detectors and induction probe detectors will be made per each. Measurement of two-channel card rack mounted detectors will be made per each detector card.

902.24.4 Final measurement of concrete for bases will not be made, except for authorized changes in construction or where appreciable errors are found in the contract quantity. Where required, measurement of concrete for bases, including all specified material, will be made to the nearest 1/10 cubic yard as shown on the plans. The revision or correction will be computed, and added to or deducted from the contract quantity.

902.24.5 Final measurement of conduit will not be made, except for authorized changes in construction or where appreciable errors are found in the contract quantity. Where required, measurement of conduit will be made to the nearest linear foot as shown on the plans. The revision or correction will be computed, and added to or deducted from the contract quantity.

902.24.6 Final measurement of conductor will not be made, except for authorized changes in construction or where appreciable errors are found in the contract quantity. Where required, measurement of conductor will be made to the nearest 10 linear feet as shown on the plans. The revision or correction will be computed, and added to or deducted from the contract quantity.

902.25 Basis of Payment. Accepted traffic signals will be paid for at the contract unit price for each of the pay items included in the contract. No direct payment will be made for any incidental items necessary to complete the work unless specifically provided as a pay item in the contract.

902.25.1 Temporary traffic signals will be paid for at the contract unit price. No direct payment will be made for guys, conduit and junction boxes on poles, hardware, lighting bracket arms, or any other item for which separate payment is not provided.

902.25.2 Accepted post bases will be paid for at the contract unit price. Payment will be considered full compensation for all labor, equipment and material to complete the described work, and will include all excavation, removal and disposal of all material encountered within the limits of the work.

902.25.3 Luminaire bracket arms, if specified, will be at the contractor’s expense.

902.25.4 No direct payment will be made for cable, conduit and any additional work required to connect the power supply assembly to the utility company facilities.

902.25.5 No direct payment will be made for the card rack assembly and card rack power supplies.

902.25.6 Payment for the telephone cable and associated pushed or trenched conduit will be considered fully covered under the contract unit price for the power supply assembly.

902.25.7 Furnishing and installing the system master controller, including all connectors and cables to provide a fully functioning system, will be paid for at the contract unit price per each. Payment for furnishing and installing telephone interface panels, an extra service outlet, door alarm, dial-up modem and all aspects of the system acceptance test, including all incidental items required to provide a fully functioning system, will be considered completely covered by the contract unit price for the system master.

902.25.8 For closed loop systems, if the Commission does not furnish the system software, the system software will be paid for at the contract unit price per each. If the Commission furnishes system software or has committed to purchase system software in another contract, no payment will be made for the software. This shall include versions of previously supplied software. Installing and programming local intersection controllers and the system master will be at the contractor's expense.

902.25.9 Accepted video detection systems will be paid for at the contract unit price. Payment will be considered full compensation for all labor, equipment and material to complete the described work, and for placing the specified equipment into operation to the satisfaction of the engineer.

902.25.10 No direct payment will be made for junction boxes.

902.25.11 Furnishing and installing telemetry radios, power supplies, interface cables, diagnostic pads and other items necessary for the proper operation of the radios will be paid for at the contract unit price for the Spread Spectrum Telemetry Radio.

902.25.12 Furnishing and installing antenna cable, including connectors, surge arrestors and other items necessary for proper operation, will be paid for at the contract unit price of RG-8/U Coaxial Cable.

902.25.13 If training is specified in the contract documents, training will be paid for at the contract unit price. Payment will be considered full compensation for all labor, equipment and material to conduct the training.

902.25.14 The accepted quantities of fiber optic cable, including installation, termination and testing of the fiber optic interconnect cables, all connectors, hardware, tags and other incidentals needed to provide a fully functioning system, will be paid for at the contract unit price per linear foot. The installation, termination and splicing of fibers in splice cabinets and fiber distribution units, including all connectors and other incidentals, will be considered fully covered under the contract unit price.

902.25.15 The fiber optic data link in the system master, including all incidental items required for proper operation, will be paid for at the contract unit price per each for the system master.

902.25.16 Furnishing and installing the dial-up modem including all connectors and cables necessary for proper operation will be paid for at the contract unit price per each.

902.25.17 Furnishing and installing the local controller assembly, including all connectors and cables to provide a fully functioning system, will be paid for at the contract unit price per each.

902.25.18 Furnishing and installing the fiber optic data links (modems) in the local controllers including all incidental items required to provide a fully functioning system, will be paid for at the contract unit price per each for controller assembly.

902.25.19 Furnishing and installing the fiber distribution unit for controller cabinets, including all mounting hardware and incidentals, will be paid for at the contract unit price per each for controller assembly.

902.25.20 Furnishing and installing the splice cabinet, including the rack cage, fiber distribution unit, grounding and other incidental items will be paid for at the contract unit price per each.

902.25.21 Payment for the telephone cable and associated pushed or trenched conduit will be considered fully covered under the contract unit price for the power supply assembly.

902.25.22 No direct payment will be made for warranties.

SECTION 1061

ELECTRICAL CONDUCTORS

1061.1 General. This specification covers electrical conductors and associated material for use on highway construction projects. Contractor furnished equipment that will become the property of the Commission shall be of new stock unless stated otherwise in the contract documents. Electrical conductors and associated equipment shall be in accordance with applicable requirements of ICEA, IMSA, NEMA, EIA, NEC, NFPA and regulations of the National Board of Fire Underwriters and shall meet the approval of the engineer.

1061.2 Conductors. Except as noted, all conductors shall be soft drawn, Class B or C stranded copper wire in accordance with NEMA WC70/ICEA A-95-658. Solid conductors may be used only for grounding where connected to a ground rod.

1061.3 High Voltage Power Cable. The voltage rating for high voltage power cable supplying primary electrical power shall be 5 KV for primary voltages less than 5,000 volts, and 15 KV for voltages of 5,000 volts and greater. The specific type of cable shall be as recommended and approved by the utility company or municipality supplying power.

1061.4 Low Voltage Power Cable. Low voltage power cable shall be 600-volt, single conductor cable and thermoplastic or thermosetting cross-linked polyethylene insulated. All cable shall be plainly marked on the outside with the manufacturer's name and identification in accordance with industry practice. Insulation type shall be THHN/THWN-2 orXHHW-2. Average thickness of insulation shall be no less than specified in the following table, with a minimum thickness of 90 percent thereof.

Size (AWG or kcmil)	**Thickness, Mils THHN/THWN-2)**
14-12	15
10	20
8-6	30
4-2	40
1-4/0	50
250-500	60
501-1000	70
Size (AWG or kcmil)	**Thickness, Mils THHN/XHHW-2)**
14-10	30
8-2	45
1-4/0	55
213-500	65
501-1000	80

1061.5 Cable-Conduit. Cable-conduit shall consist of one to four low voltage power cables with an insulated sized electrical neutral and a bare safety ground, factory installed in black polyethylene conduit intended for direct burial. The conduit shall be plainly marked on the outside with manufacturer's name and identification in accordance with industry practice and

shall be in accordance with ASTM D 3485. Cable-conduit shall be accompanied by the manufacturer's certification stating the conduit is in accordance with the requirements of this specification.

1061.6 Pole and Bracket Cable. Pole and bracket cable located in the lighting or signal pole that supplies electrical power to highway lighting shall consist of two single conductors. Wire size shall be No. 10 AWG in accordance with the requirements of low voltage power cable. Insulation type shall be THHN/THWN-2 or XHHW-2. Average insulation shall be in accordance with Sec 1061.4.

1061.7 Multi-Conductor Cable. Multi-conductor cable for traffic signals shall be No. 16 AWG, rated at 600 volts. The cable shall be in accordance with IMSA Specification No. 19-1 or No. 20-1.

1061.8 Induction Loop Detector Cable. Induction loop detector cable shall be single-conductor No. 14 AWG wire, with Type XHHW insulation, marked as such, rated at 600 volts. The cable shall be in accordance with IMSA Specification No. 51-7.

1061.9 Loop Detector Lead-In Cable. Lead-in cable used between the loop detector and the controller shall be two-conductor, twisted, shielded No. 14 AWG wire rated at 600 volts. The cable shall be in accordance with IMSA Specification No. 50-2.

1061.10 Certification. All cables and conductors shall be accompanied by certification from the supplier indicating: (1) the supplier is familiar with the requirements of these specifications and, (2) cable furnished was from a lot manufactured by (manufacturer's name) whose test results are in accordance with these specifications.

SECTION 1062

PULL AND JUNCTION BOXES

1062.1 Scope. This specification covers pull and junction boxes intended for use on highway lighting and traffic signal projects.

1062.2 Pull Boxes. Pull boxes may be cast-in-place concrete, precast concrete, preformed polymer concrete or preformed fiberglass reinforced polymer concrete. Pull box dimensions shall be as shown on the plans. Each pull box shall be equipped with cable hooks as shown on the plans. Cable hooks shall be galvanized steel or brass with a minimum diameter of 3/8 inch and a minimum length of 5 inches.

1062.2.1 Cast-in-place concrete pull boxes shall be constructed of Class B or B-1 concrete, or a commercial mixture in accordance with Sec 501. Material, proportioning, mixing, slump and transporting of concrete shall be in accordance with Sec 501. Placing, finishing and curing shall be in accordance with Sec 703. Pull boxes shall be cast in a neat and workmanlike manner. Forms will be required for the inside surfaces of the pull box walls; and if the excavation is irregular, forms will also be required for the outside surfaces of the walls. An outside form shall be installed across all trenches leading into the pull box excavation. The ends of all conduits through the walls shall fit tightly against the form.

1062.2.2 Precast concrete pull boxes shall be constructed of Class B or B-1 concrete, or a commercial mixture in accordance with of Sec 501. Material, proportioning, mixing, slump and transporting of concrete shall be in accordance with Sec 501. Concrete for precast pull boxes shall be placed, finished and cured in accordance with Sec 703.

1062.2.3 Preformed pull boxes shall withstand a wheel load of 20,000 pounds. Pull box walls may be either flared or vertical. Metal conduit, if used in preformed pull boxes, shall be electrically bonded to one another inside each pull box.

1062.3 Pull Box Covers. Each pull box shall be equipped with a bolt down cover. The threaded hole that receives the cover lock-down bolt shall be open at the bottom to allow the cleanout of sand, dirt and other debris. Lock-down bolts shall be stainless steel or brass with a penta-head. Frames and covers for cast-in-place and precast concrete pull boxes shall be cast iron in accordance with AASHTO M 105, Class 30, and shall be of the dimensions and weights shown on the plans. Preformed pull box covers shall be polymer concrete and shall have a minimum wheel load rating of 20,000 pounds. A lift opening shall be provided on all covers. Covers for pull boxes to be used for highway lighting or sign lighting shall be embossed with "STATE LIGHTING". Covers for pull boxes to be used for traffic signals, or a combination of traffic signals and 120 volt intersection lighting, shall be embossed with "STATE SIGNALS". Covers for pull boxes to be used for fiber optics shall be embossed with “STATE FIBER OPTICS”.

1062.4 Junction Boxes. Junction boxes shall be flanged and designed for flush mounting if encased in concrete, or designed for surface mounting if external mounting is specified. Junction boxes shall be drilled or tapped for all conduit connections. Junction boxes shall be installed such that covers are removable. Junction boxes shall be stainless steel, fiberglass or PVC watertight NEMA 4 enclosures. PVC junction boxes shall have a minimum wall

thickness of 1/4 inch. Junction boxes shall be in accordance with the following minimum sizes unless otherwise specified:

Maximum Entering Conduit Size, Inches	Minimum Box Size, Inches
2	12 x 12 x 4
4	16 x 12 x 6

1062.4.1 PVC and metal conduit shall be joined to junction boxes to make a rigid and waterproof connection. If metal conduit is used, an insulated bushing shall be provided at the end of the metal conduit on the inside of the junction box to prevent scuffing of the cable insulation.

1062.4.2 The junction box cover shall be made watertight with a suitable gasket and secured with stainless steel or cadmium plated screws or bolts.

SECTION 1092

SIGNAL EQUIPMENT

1092.1 Signal Heads. Signal heads shall meet the following requirements:

(a) All signal heads shall be weatherproof and black in color in accordance with Sec 1092.1.1. All indications shall be 12 inches unless specified otherwise.

(b) All signal indications in conventional signal heads shall be illuminated with LED modules. All LED modules, , shall be in accordance with ITE Vehicle Traffic Control Signal Heads: Light Emitting Diode (LED) Circular Signal Supplement dated Jun 27, 2005, shall be Intertek ETL verified and shall be in accordance with the following:

(1) The lens of each green indication shall be clear. If a polymeric lens is supplied, a surface coating shall be applied to provide abrasion resistance.

(2) The LED modules shall not contain Aluminum Gallium Arsenide (AlGaAs).

(3) The LED modules shall provide constant light output under power. Modules with dimming capabilities shall have the option disabled or shall be set on a non-dimming operation.

(4) Module shall be labeled with “Manufactured in conformance with the ITE LED Circular Signal Supplement”.

(5) Provided with spade adapters.

(c) All yellow and green arrow LED modules shall be in accordance with ITE Vehicle Traffic Control Signal Heads. Light Emitting Diodes (LED) Vehicle Arrow Traffic Signal Supplement dated July 1, 2007, shall be Intertek ETL verified and shall be in accordance with the following.

(1) Be omni-directional
(2) The lens of each green arrow indication shall be clear
(3) Provided with space adapters

1092.1.1 Housing, Door and Visor. All new signal sections shall be clean, smooth and free from imperfections. The connection between signal housings shall be weatherproof. Housings shall be rigidly fastened together by a three- or four-bolt assembly or other connectors approved by the engineer. Doors that will exclude dust and moisture shall be used to ensure a weatherproof unit. A tunnel visor shall be supplied with each signal section and each door shall have provisions for attachment of the tunnel visor. All visors shall be held in place by four stainless steel fastening screws or bolts and shall be capable of being removed without opening the signal head door. Internal bosses or inserts shall be provided, in each housing, for mounting a terminal block and for the attachment of back plates. The top and bottom exterior of the housing shall be flat to ensure perfect alignment of assembled sections. The housing of each section shall be one piece with sides, back, top and bottom integrally molded. The design of the housing shall be such that, with the aid of simple tools and the

addition of standard parts, it shall be possible to make any assembly consisting of one or more signal sections and, with the addition of standard bracket assemblies, assemble signal faces into multi-way traffic signal head configurations. The housings shall be polycarbonate. All material used in construction of polycarbonate signal heads shall be of ultraviolet stabilized color-impregnated polycarbonate resin. The housing shall have a minimum thickness of 0.09 inch and shall be ribbed or plated to produce added strength. If signal housings are not ribbed, minimum 0.10-inch aluminum plates shall be furnished and installed inside and outside the section housing at all points of attachment of the pipe bracket.

1092.1.2 Louvers. The degree of cut-off shall be stamped on the louver or printed on a decal on the front of the louver and shall be visible after installation.

1092.1.2.1 Fixed louvers shall be formed of 0.025-inch sheet aluminum. The top and bottom bends of each fin shall be securely fastened to the inside of the supporting ring. The angles of cut-off from either side of the center axis of the light beam shall be provided by six types of louvers: Type A - 3 degrees, Type B - 7 degrees, Type C - 10 1/2 degrees, Type D - 14 degrees, Type E - 18 1/2 degrees and Type F - 26 1/2 degrees.

1092.1.2.2 Adjustable louver units shall be composed of an acrylonitrile butadiene styrene (ABS) plastic housing and polycarbonate baffles. The unit shall be designed to prevent light leakage between the housing and the visor, and shall have an adjustable view range of 7 to 42 degrees. All plastic material shall be ultraviolet stabilized. All hardware shall be brass or stainless steel.

1092.1.3 Hardware. Hardware shall be 1 1/2-inch galvanized steel or unfinished aluminum, except aluminum pipe brackets and side mount brackets. Aluminum pipe brackets shall have a spun finish. Side mount brackets may be constructed of molded, glass-impregnated polycarbonate no greater than 12 inches in length. Elbows, tees and crosses shall be straight threaded and furnished with a square head set screw at each connection point to ensure rigid mounting. Fittings attached to the signal housing shall incorporate serrations or, by the use of an adapter ring, shall be compatible with the serrations on the signal housing.

1092.1.4 Backplates. Backplates shall be provided on all signal heads as shown on the plans. Backplates shall be black in color and constructed of flat pre-cut or preformed thermoplastic. Flat pre-cut thermoplastic backplates shall have a minimum thickness of 0.250 inch. Preformed thermoplastic backplates shall have rolled out edges and a minimum final thickness of 0.10 inch.

1092.1.5 Optically Limiting Signal Heads. All signal sections shall meet the following:

(a) Each signal housing shall be die cast aluminum having a chromate preparatory treatment. The signal housing and lens holder shall be predrilled for backplates and visors. All access openings shall be sealed with weather resistant gaskets. Hinge and latch pins shall be non-ferrous metal or stainless steel. The lens holder and interior of the housing shall be optical black. The housing shall mount to standard 1 1/2-inch fittings as a single section, as a multiple section face or in combination with conventional signals. The signal housing shall be provided with an adjustable connection that permits incremental tilting from zero to 10 degrees above or below the horizontal while maintaining a common vertical axis through the mounting assembly. The housing connection shall permit external adjustment about the mounting axis in 5-degree increments. Attachments such as visors, backplates or adapters shall readily fasten to mounting surfaces without affecting the weatherproof characteristics and light integrity of the signal.

(b) The optical system shall consist of an objective lens, optical limiter-diffuser, lamp, lamp fixture and optical masking tape.

(1) The objective lens shall be a high-resolution planar incremental lens, hermetically sealed within a flat laminate of weather-resistant acrylic or approved equivalent. The lens shall be symmetrical in outline and if rotated to any 90-degree orientation about the optical axis, shall not displace the primary image.

(2) The optical limiter-diffuser shall provide an accessible imaging surface at focus on the optical axis for objects up to 1,200 feet distant and shall permit an effective veiling mask to be applied as determined by the desired visibility zone. The optical limiter-diffuser shall be provided with positive positioning and shall be composed of heat resistant glass.

(3) The lamp shall be in accordance with Sec 1092.1, and shall have an integral reflector. The lamp shall be attached to the diffusing element with a collar having a specular inner surface.

(4) The lamp fixture shall consist of a separately accessible housing and integral lamp support, an adjustable ceramic socket and a self-aligning, quick release lamp retainer. Electrical connection between section housing and lamp housing shall be accomplished with an interlock assembly that disconnects the lamp holder when the door is opened.

(5) A signal lamp intensity control shall be supplied in each signal section to provide dimming of the signal lamp as the ambient light intensity drops below approximately 3 footcandles.

1092.1.6 Pedestrian Signal Heads. Pedestrian signal heads shall be in accordance with ITE specifications and standards for Pedestrian Traffic Control Signal Indications, adopted March 1985 and the following:

(a) Pedestrian signal head housings shall be constructed of a black, one-piece, 0.250-inch thick, polycarbonate material as shown on the plans. The housing shall include an integral mounting bracket designed for mounting on the side of the pole on all makes of signal poles with a terminal compartment and minimum 5-position, double-row terminal block.

(b) The door, lens and any openings in the housing shall have gaskets or seals to exclude dust and moisture from the inside of the compartment.

(c) Lenses shall be constructed of polycarbonate material and reduce glare.

(d) Pedestrian signal head units shall be provided with a manufactured, preformed rectangular visor or screen-type louver.

(e) All plastic material shall be ultraviolet stabilized.

(f) Indications shall be ITE Class 3 symbol messages. The "UPRAISED HAND" symbol shall be illuminated with a filled, Portland Orange LED module. The "WALKING PERSON" symbol shall be illuminated with a filled, White LED module. The LED modules shall be in accordance with ITE Pedestrian Traffic Control Signal Indications – Part 2: Light Emitting Diode (LED), Pedestrian Traffic Signal Modules, adopted March 19, 2004, shall be Intertek ETL verified and be in accordance with the following:

(1) The lens shall use transparent film or materials with similar characteristics

(2) Modules, conforming to this specification, shall be labeled with

the following statement, “Manufactured in Conformance with the Pedestrian Traffic Control Signal Indications – Part 2: Light Emiting Diode (LED) Pedestrian Signal Modules”.

(3) Modules with dimming capabilitites shall have the option disabled or shall be set on a non-dimming operation.

(4) Supplied with space adapters.

(g) Pedestrian traffic control signal faces shall be constructed such that both messages are displayed from the same message-bearing surface and rectangular in shape. The "WALKING PERSON" symbol shall be located to the right of the "UPRAISED HAND" symbol. The illumination of one message shall not result in the illumination of the other message.

1092.1.7 Finishing. Mounting brackets and hardware, except the aluminum pipe brackets and polycarbonate side mounted brackets, shall be galvanized steel or unfinished aluminum. Aluminum pipe brackets shall have a spun finish. Painting of the mounting brackets and hardware will not be permitted.

1092.2 Posts and Mast Arms. A grounding lug shall be provided for all units. A grounding conductor shall provide grounding continuity for all metallic, noncurrent carrying poles in one circuit.

1092.2.1 Steel Pedestal Posts. Steel pedestal posts shall be 4 1/2-inch outside diameter schedule 40 steel pipe. The base shall be cast iron, free from imperfections, and shall be provided with a suitable plastic, fiberglass or cast door for wiring access. The grounding lug shall be inside the base. The bolt circle and hole diameter shall be as shown on the plans. After fabrication, posts and bases shall be fully galvanized.

1092.2.2 Aluminum Pedestal Posts. Aluminum pedestal posts shall be schedule 80 straight tubing of 6063-T6 aluminum alloy in accordance with ASTM B 210, with a 4 1/2-inch outside diameter. The pedestal base casting shall be either permanent mold casting of Alloy 356.0 F, in accordance with ASTM B 108, or sand castings of Alloy 356.0 F, in accordance with ASTM B 26. The base shall be free from imperfections and shall be provided with a suitable door for wiring access. The base and post shall be joined by a threaded connection. Welded connections will not be permitted. The grounding lug shall be provided inside the base. All hardware shall be non-ferrous metal or stainless steel.

1092.2.3 Signal Post and Mast Arm Pre-Approval. Fabricators shall submit six copies of shop drawings and supporting calculations to Traffic. Submittals shall be approved by Traffic in writing prior to fabrication of the signal posts and mast arms. Shop drawings shall indicate complete design details required for post and mast arm fabrication, including material grades and thicknesses, welding and orientation of any longitudinal seams. The projected areas and weights of signs and signals used in the design of the post and mast arms shall be shown on the shop drawings. Design details for all possible post and mast arm combinations shown on the plans may be submitted. Shop drawings shall provide post and mast arm installation and hardware details. All welding procedures shall be prepared by the manufacturer as a written procedure specification and shall be submitted with the shop drawings for approval. Approval of the weld procedures will be required before approval of the shop drawings. Shop drawings shall indicate the specific approved welding procedure to be used for each joint. Shop drawings and supporting stress calculations shall be signed and sealed by a registered professional engineer in the State of Missouri. Manufacturers shall submit all required documentation, in accordance with Sec 1092.2.4.3. Upon written approval, pre-approved drawings may be used on any project where the design conditions of the shop drawings are not exceeded.

1092.2.4 Steel Posts and Mast Arms. Steel posts and mast arms shall be continuously tapered, hollow shafts fabricated as one continuous shaft or as individual segments at least 10 feet long, joined together using electrically welded, intermediate, transverse, full penetration, circumferential joints. Steel posts and mast arms shall be fabricated from basic oxygen or open-hearth steel sheet. The continuous, tapered, hollow shafts or individual segments shall be manufactured from one or two lengths of steel sheet, with one or two continuous, welded, longitudinal seams. The longitudinal seams in the mast arm shall be located outside of the upper half of the cross section of the member. Where transverse, full penetration, circumferential welds are used, the fabricator shall furnish to the engineer written certification that 100 percent of all such welds have been radiographed or ultrasonic tested by an independent testing agency using a qualified non-destructive testing technician, as described in Section 6.14.7 of ANSI/AWS D1.1 Structural Welding Code-Steel and equipment calibrated annually. The testing agency shall be approved by the engineer prior to fabrication. Post base and mast arm attachment plates shall be plate steel attached to the larger end of the shafts by continuous welds on the inside and outside of the shaft. After manufacture, the material shall have a minimum yield strength of 48,000 psi.

1092.2.4.1 A handhole equipped with a suitable metal cover shall be provided in the post near the base, and 12 inches above the mast arm connection if luminaire mounting is specified. A grounding lug or connector shall be provided inside the post near the handhole. A removable raintight metal pole cap shall be provided on the top of the post and on the small end of each mast arm. All handhole covers and metal caps shall include a galvanized steel chain. The chain shall be capable of supporting at least six times the weight of the cover or cap and be securely attached to the inside of the post or arm, with sufficient length to allow removal of the cover or cap for maintenance access.. The pole caps and handhole covers shall be securely attached to the post with screws that penetrates through the cap or cover and the post or arm. An aluminum or stainless steel identification tag shall be provided with all posts and mast arms as shown on the plans. The letters and numbers on the tag shall be embossed or engraved. The post tag shall be attached to the pole 6 inches above the top of the handhole. The mast arm tag shall be attached 3 inches from the base of the end cap. The base plate shall be equipped with four cast steel or cast iron nut covers in accordance with AASHTO M 103 or M 105, or four aluminum nut covers and shall have four galvanized or stainless steel screws for securing covers to the pole. All poles, shoe bases, base plates and cast steel or cast iron nut covers shall be fully galvanized after fabrication. All anchor bolt nuts shall be completely covered by nut covers. Luminaire bracket arms, when specified, shall be included with the post and mast arm. The contractor may furnish posts with the shape, gage and dimensions meeting or exceeding those required by the plans and specifications, provided shop drawings are submitted and approved in accordance with Sec 1092.2.3.

1092.2.4.2 Welding and fabrication of the assemblies shall be in accordance with the ANSI/AWS D1.1 Structural Welding Code-Steel. All requirements of the welding code for tubular structures will apply to the fabrication for the post and mast arm shafts and shall include any welds used to attach these members to plates or other hardware. The manufacturer shall employ qualified personnel to perform all visual and nondestructive testing (NDT) required. In addition to the visual inspections and NDT that may otherwise be required by the welding code, the manufacturer shall perform 100 percent magnetic particle (MT) testing of circumferential fillet welds used to attach the flange plate to the larger end of the mast arm shaft. NDT personnel shall be qualified as set forth in paragraph 6.14.7 of ANSI/AWS D1.1 Structural Welding Code-Steel. Qualifications of NDT personnel shall be submitted to the engineer for approval.

1092.2.4.3 The post and mast arm manufacturer shall be certified under the AISC certification program, Conventional Steel Building, or higher category. Evidence of current AISC

certification will be required prior to the approval of shop drawings, and lapsing of the certification will be cause for the manufacturer's removal from the approved list of suppliers.

1092.2.4.4 Steel posts, luminaire bracket arms, mast arms, nut covers and plate steel bases shall be hot-dip galvanized inside and out after fabrication, visual inspections and NDT testing. Galvanized material shall be handled in such a manner to avoid damage to the surface. Any galvanized material on which the coating has been damaged will be rejected or may, with approval from the engineer, be repaired in accordance with Sec 1081.

1092.2.5 Fabricator's Certification. Prior to erection of the posts and mast arms, the contractor shall furnish to the engineer a fabricator's certification. The certification shall specifically state the fabricated posts and mast arms have been quality control inspected by the fabricator and all material and manufacturing processes used were in full compliance with the specification requirements and the approved shop drawings and weld procedures. Certification shall be accompanied by supporting documentation, including the results of the visual inspections and NDT in accordance with Sec 1092.2.4.2 and copies of the pre-approved drawings required by Sec 1092.2.3.

1092.3 Lighting Control Cabinet. The lighting control cabinet shall contain a control panel constructed of the same material as the cabinet. Circuit breakers, the photoelectric switch, a contactor, if specified, and any other specified equipment for luminaire control shall be installed on the panel. Control cabinets shall be of sufficient size to house all equipment shown on the plans. Cabinets shall be dust tight, watertight, NEMA 4 and constructed of aluminum or stainless steel. All hinges, catches and other hardware shall be stainless steel. Cabinets shall have a No. 2 Corbin cabinet lock. Photoelectric switches and contactors shall be in accordance with Sec 901. Circuit breakers shall be Type B circuit breakers in accordance with Sec 901.

1092.4 Traffic Controller Assemblies. Traffic controller assemblies will be defined as the complete assembly of all required equipment and components for control of traffic signal indications. The type of controller assembly required for each location shall be as specified in the contract documents.

1092.4.1 NEMA TS1. Each NEMA TS1 controller assembly shall consist of a controller cabinet, signal controller, back panel, conflict monitor, card rack assembly, all required wiring, switches and connectors and all other equipment as defined in these specifications and as shown on the plans. Double controller assemblies to control two intersections shall consist of a controller cabinet, two signal controllers, two back panels, two conflict monitors, two card rack assemblies, all required wiring, switches and connectors and all other equipment as defined in these specifications and as shown on the plans.

(a) Each controller and associated equipment shall be designed to operate on 120 volts, 60 hertz, single phase, alternating current.

(b) Variations in the voltage of the power supply of ± 10 percent or sustained temperatures inside the cabinet between -20 and 165 F shall not change the total time cycle of pretimed controllers or the length of any interval, portion, period or unit extension of actuated controllers by more than five percent or cause electrical or mechanical damage. Heater elements shall not be used to attain compliance with these requirements.

(c) Vibration shall not affect normal operation of any equipment.

(d) All controllers and other specified auxiliary equipment shall be properly protected with fuses on each applicable unit. Fuses shall be installed in 1/4-twist or screw-in type fuse holders. Pop-out fuse holders will not be permitted.

1092.4.1.1 Controller Cabinets. Controller cabinets shall be cast aluminum or 0.125 inch reinforced sheet aluminum alloy and shall be of clean-cut design and appearance. The cabinet shall provide ample space for housing all equipment and components. Controller cabinets housing solid state controllers shall be furnished with unused cabinet space measuring 18 inches wide by 12 inches high by 12 inches deep, unless coordination equipment is specified on the plans. For pretimed and actuated NEMA controllers, the cabinet shall support a sixteen-position back panel. Double controller cabinets for two controllers shall support two sixteen-position back panels. All double cabinets shall have two doors that are hinged on the outside corners of the cabinet such that the doors open away from each other. Double cabinets shall have a divider between the two halves of the cabinet with an 8-inch opening between the compartments at the bottom of the divider for wiring between the compartments. The cabinet shall contain a rigid mounting table, sliding ways or hinged support of such construction that the controller and auxiliary equipment may be withdrawn from the cabinet without breaking any electrical connections or interrupting normal controller operation. Hinged supports shall be welded to the controller cabinet. Electrical connectors on the controller and auxiliary equipment to all circuits shall be NEMA 1/4 twist or MS type. Components of controller cabinets shall meet the following requirements.

(a) A hinged door or doors shall provide complete access to the interior of the cabinet. Door holds shall secure the door in an open position at least 90 degrees from the closed position and shall be furnished with each cabinet. The doors shall fit against a raintight gasket. Each door shall have a stamped or raised outside designation, "Traffic Control" or other approved identification. Each main cabinet door shall have a No. 2 Corbin cabinet lock and provisions for locking with a padlock. The handles for each door shall swing outward. An auxiliary door, positioned on each main cabinet door, equipped with a raintight gasket, shall allow access to a police panel and shall be equipped with a lock whose key will not unlock the main door. Two keys shall be furnished for each type lock used. The door hinges and pins shall be of corrosion-resistant metal. Pins shall be rolled or solid rod, at least 1/8 inch in diameter, except if continuous hinges are furnished, the pins shall be continuous the full length of the hinges, and shall be no less than 1/16 inch in diameter.

(b) The back panel in all controller cabinets shall be hinged at the bottom to permit the top of the panel to be rotated forward and down to an angle of no less than 45 degrees with all components, including load switches, attached for maintenance purposes. The bottom of the back panel shall be no less than 6 inches above the bottom of the cabinet.

(c) Cabinets housing solid state controllers shall have a thermostatically controlled ventilating fan with exhausting capability in an enclosure of at least 150 cubic feet per minute for cabinets up to 30.5 cubic feet and at least 250 cubic feet per minute for cabinets 30.5 cubic feet and more, installed in the top of the cabinet. Cabinets shall be supplied with a replaceable furnace-type fiberglass filter of at least one square foot area mounted behind louvers in the lower one-fourth of the door.

(d) Each controller cabinet shall be furnished with a clearly labeled switch mounted in the access or police panel to place the signals on flash. Operation of this switch shall not affect the electrical power supply to the controller. This shall be the only control switch accessible from the police panel.

(e) Each cabinet shall be provided with a grounded service outlet and a switch-controlled lamp receptacle.

(f) Each cabinet shall contain a separate aluminum power panel containing the following equipment.

(1) Two Type B circuit breakers in accordance with Sec 901. One breaker shall interrupt power to the controller and signals. The frame size and trip rating will be shown on the traffic signal plans or designated in the contract. The second Type B circuit breaker shall be an auxiliary breaker that interrupts power to the cabinet lamp and receptacle. The frame size and trip rating shall be 15 amperes.

(2) One mercury contactor controlling power to the signal bus.

(3) One radio frequency line filter.

(4) One line surge protector.

(5) One terminal block for alternating current power input.
(6) One ground bus terminal block.

(7) One isolated neutral bus terminal block.

(g) If specified, a manual operation push button shall be installed in the police panel. The push button shall be wired for manual operation of the signals. The push button shall be water-resistant, designed to protect the user against electrical shock, and shall be supplied with a coiled cord with a nominal 6-foot stretched length. A clearly labeled switch shall also be installed in the police panel to switch between manual or automatic operation of the controller.

1092.4.1.2 Flasher Unit. Each controller, through terminal options, shall permit yellow-red or red-red flash operation. Indications shall be flashed at no less than 50 or more than 60 flashes per minute, with approximately 50 percent dwell time. A two-circuit flasher, alternate flash and three flasher field circuits for each of the two flasher circuits will be required. A separate flasher shall provide flashing pedestrian indications when required by the contract. The timing of flashing pedestrian intervals shall be separately adjustable from all other timed intervals. The flasher shall be solid state with ratings of at least 15 amperes per circuit and shall comply with the latest revision of NEMA Standards Publication TS. The flasher units shall have a 150-volt metal oxide varistor (MOV) placed on each output flash terminal. Uniform code flash circuitry will be required for each controller. Flashing operation shall be in accordance with the MUTCD.

1092.4.1.3 External Time Switches. External time switches shall be solid state, keyboard entry and shall contain filtering and shielding circuitry to protect the unit's operation against electrical interference. Timing shall be based on the 60-hertz power supply frequency. Each unit shall contain a programmable automatic central daylight time compensation feature and a back-up power source to maintain time and memory functions during loss of alternating current power. Each unit shall provide a weekly program with at least 20 event changes per week.

1092.4.1.4 Wiring. The controller cabinet shall be equipped with a 600-volt heavy-duty one-piece mechanical screw connector offset tang assembly attached to a barrier terminal strip for terminating field conductors. Each mechanical screw connector shall accommodate up to four No. 12 AWG conductors. The connector shall be mounted horizontally on the inside back of the cabinet, approximately 6 inches from the bottom of the cabinet. All wiring to the terminal strips, except the incoming field circuits, shall be performed by the controller manufacturer. The terminal strips shall accommodate at least:

(a) Two terminals for the power supply.

(b) An unfused terminal for neutral side of power supply line.

(c) One terminal for each signal lamp circuit and one terminal for the common return from each signal face.

(d) If detectors are used:

(1) Two terminals for each detector.

(2) Screw terminal strips mounted vertically on the side of the cabinet approximately 6 inches from the bottom of the cabinet.

(3) All inductive loop detector inputs shall be protected with two 30-volt MOVs with a 30-j rating. An MOV shall be connected between each field terminal and cabinet ground.

(e) Terminals for interconnect cable when the controller is to be hard-wire interconnected shall be fused and provided with a 150-volt MOV with an 80 j rating.

(f) Terminals for closed loop system interconnect cable shall be fused and provided with a 30-volt MOV with a 30 j rating.

1092.4.1.5 Back Panel Wiring. Regardless of the number of phases specified on the plans, all load switch positions shall be completely wired for use. If pedestrian phases are not specified, twelve-position back panels for actuated NEMA controllers shall be configured for operation of eight phases and four overlaps. If pedestrian phases are specified, 12-position back panels shall be configured for operation of eight phases and four pedestrian phases or a combination of overlaps and pedestrian phases if specified on the plans. If flashing yellow arrow operation is called for, the appropriate load switches shall be configured as specified on the plans. Twelve-position back panels for pretimed controllers shall be configured for operation of 36 circuit outputs from the controller unless otherwise specified on the plans. A flash transfer relay socket shall be provided for each pair of load switch positions. Flash circuit one shall be wired to positions one, 3, 5, 7, 9 and 11. Flash circuit 2 shall be wired to positions 2, 4, 6, 8, 10 and 12. All flash transfer relay sockets shall be fully wired for operation. All controller harness wiring shall be connected to labeled terminals on the front of the panel.

1092.4.1.6 Solid State Controllers. This section describes the general specifications for actuated solid state controllers. If requested by the engineer, the contractor shall provide a prototype controller for testing and evaluation.

(a) Each controller shall be solid state keyboard entry and the circuit design shall use microprocessor techniques.

(b) Timing shall be accomplished in a digital manner by counting the 60 hertz power supply frequency. Timing circuits, interval and phase switching functions shall be accomplished by solid state circuitry. Removing, changing wires or using any tools to make timing interval adjustments shall not be necessary. The controller shall indicate the right of way conditions of the phase timing interval in effect, detector or actuation on each phase and memory conditions or demand on each phase for vehicles and pedestrians by use of status lights or display panels. The controller shall be capable of flashing yellow arrow operation without any external devices or special software upgrades.

(c) Opening and closing of signal lamp circuits shall be performed by plug-in solid state load switches, rated at no less than 10 amperes and loaded at a maximum of 6.7 amperes, located external to the controller. All load switch jacks shall be completely wired to field

output terminal strips. Actuated and pretimed controllers shall have a minimum of twelve load switch jacks. Each load switch shall provide three independent circuits with "on" indicator lamps and shall comply with the latest revision of NEMA Standards Publication TS.

(d) Each controller assembly shall contain a conflict monitor external to the controller circuitry conforming to NEMA Standards Publication TS and be capable of monitoring flashing yellow arrow operation on any channel. The monitor shall cause immediate transfer to flashing operation when conflicting or absent indications occur or when a voltage fault occurs. When the conflict monitor actuates flashing operation, the controller shall freeze or stop timing in the condition causing the actuation until manually reset. A single lamp failure in any signal head shall not cause the monitor to actuate.

(e) For double controller cabinets, two sets of switches shall be provided, one set for each controller installed in each compartment. Each controller cabinet shall be furnished with the following switches:

(1) Power Interrupt Switch - A switch located inside the main cabinet shall interrupt electrical power to the controller during maintenance on the controller. Operation of this switch shall not affect the flash operation. This switch shall not be accessible via the police panel.

(2) Flash Switch - A switch mounted in the police panel shall place the signal on flash. Operation of this switch shall not affect the electrical power supply to the controller. When the signals are returned to normal operation the external start shall be activated causing the controller to revert to the programmed initialization phase(s).

(3) Stop Time Switch - A three-position switch mounted inside the main cabinet shall provide the following functions:

(i) Stop Time - Causes the controller to stop time.

(ii) Normal - Allows the controller to cycle all phases, but during conflict monitor flash causes the controller to stop time.

(iii) Run - Allows the controller to cycle all phases and during any flashing operation allows the controller to continue cycling all phases without displaying them on the signal heads.

(f) During all direction flash condition, controller operation shall permit the cycling of all signal phases without an external load being connected to the field terminals.

(g) Solid state controllers shall have electronic filters to prevent interference caused by the opening and closing of circuits in electro-mechanical auxiliary equipment.

(h) The controller shall be of modular design constructed for individual removal and replacement in the controller by multiple prong jacks or outlets without modifying wiring. Hand operable positive locking devices shall be used to hold the modules securely in the controller.

(i) The functional operating circuits and associated components shall be grouped in plug-in printed circuit assemblies. Similar assemblies shall be interchangeable between controllers manufactured by the same company.

(j) The controller shall contain the necessary phase sequence, interval sequence timing, power supply and monitoring equipment required to supervise the operation for the

phasing shown on the plans, including any future controller expansion. If future phases are specified, the controller shall be completely configured to accept the future phases.

(k) Controllers that are interconnected shall have a coordinated/free operation switch to allow the controller to operate in coordination with the system or run free.

(l) High energy transient surge protection shall be provided on all solid state controllers to minimize damage to the controller and auxiliary equipment. This device shall be located on the incoming 120 volts, 60 hertz power service between the controller and signal circuit breaker and the power inputs to the controller and auxiliary equipment. The arrestor shall meet the latest NEMA specifications for surge protection.

(m) Every all direction flash operation called from a source external to the controller shall occur through the flash transfer relay.

(n) Any multi-conductor cable shall be contained in an expandable braided sleeve.

(o) Switches or relays that completely interrupt power to the signal heads other than the protective circuit breaker shall not be installed in the cabinet.

(p) All controllers shall be capable of downloading all programming data to a printer via a front panel RS-232 connection. The controller shall be capable of printing directly to a printer or via an external computer. If an external computer is required, the required software shall be provided with the controller.

(q) All controllers shall be provided with internal pre-emption functions and circuitry.

1092.4.1.6.1 Solid State Actuated Controller. Each solid state actuated controller shall meet the latest revision of NEMA Standards Publication TS. Actuated controllers shall meet the following requirements:

(a) Recall by keyboard entry shall be provided for each phase to furnish continuous recall. With the recall function in the "OFF" position, the controller shall operate normally with the right of way being transferred only upon pedestrian or vehicle actuation or external force-off control.

(b) Controllers shall be furnished with provisions for external maximum control for each signal phase complete with wiring to permit installation of a coordination unit. All wiring to facilitate coordination shall be terminated on terminal strips and complete information stating the function of each terminal shall be shown on the controller-wiring diagram.

(c) All phases shall contain a non-locking memory feature that can be energized or de-energized by keyboard entry.

(d) All phases shall be capable of being activated or inactivated by keyboard entry.

(e) On the cabinet inside door test panel, an external push button switch for each vehicle and pedestrian phase shall be provided. Each switch shall provide call to the phase assigned and ability to extend the phase. This detector input shall be independent of the circuitry between the amplifier and back panel.

(f) A MoDOT D-plug shall be provided between the D-plug on the controller and the interconnect panel on the cabinet. In the absence of the sync signal, the coordination

interface shall be configured to cause the controller to default to free operation. Configuration of the MoDOT D-plug shall be as follows:

Pin	Assignment	Pin	Assignment	Pin	Assignment
D1	Cycle 1	D10	Split 4	D19	Future (Pre-empt 4)
D2	Cycle 2	D11	Offset 1	D20	Flash
D3	Cycle 3	D12	Offset 2	D21	Hardware Interconnect[a]
D4	Cycle 4	D13	Offset 3	D22	Future
D5	Future (Cycle 5)	D14	Future (Offset 4)	D23	Future
D6	Future (Cycle 6)	D15	Future (Offset 5)	D24	Future
D7	Split 1	D16	Pre-empt 1	D25	Future
D8	Split 2	D17	Pre-empt 2		
D9	Split 3	D18	Pre-empt 3		

[a]Omit when activated through the cycle, split or offset inputs.

(g) The MoDOT D-Plug shall be a Cinch TRW Super D Connection as follows:

1 - Part #TB 25 P	Plug	1 - Part #SHD-25GL	Hood with Latch
1 - Part #TB 25SLB-1	Socket	1 - Part #SHD-25GFCS	Hood with Filler Ends

(h) Actuated controllers shall be fully configured for operation of a minimum of eight vehicle phases, four pedestrian phases and four overlaps, regardless of the number of phases shown on the plans.

1092.4.1.6.2 Timing Function. Timing intervals or periods shall be set by means of keyboard entry. Each timing interval shall be adjustable to any value within the following minimum ranges for each phase. Zero may be satisfied by a time increment of up to 100 milliseconds.

Interval	Range (seconds)
Minimal Initial	0 - 99
Unit Extension or Passage Time	0 - 9.9
Yellow Clearance	0 - 9.9
Red Clearance	0 - 9.9
Maximum I Green	0 - 99
Maximum II Green	0 - 99
Walk	0 - 99
Pedestrian Clearance	0 - 99
Seconds per Actuation	0 - 9.9
Maximum Initial	0 - 99
Time Before Reduction	0 - 99
Time to Reduce	0 - 99
Minimum Gap	0 - 9.9

1092.4.2 Type 170. Except as herein modified, the Microcomputer 170E controller, cabinet and equipment shall be in accordance with the Caltrans Transportation Electrical Equipment Specifications, Chapter 2, dated August 16, 2002, which shall form a part of these specifications. A copy of the Caltrans specifications is available upon request. In case of conflict, MoDOT specifications will govern. Certification that the equipment proposed is included on the most current Qualified Products List of Caltrans and MoDOT Approved Products List shall be provided. A list of pre-approved equipment and material is available

through Traffic or MoDOT's web site. Department-specific equipment not defined in the Caltrans specification will be exempt from this Qualified Product List requirement.

1092.4.2.1 Type 170 Controllers.

(a) The controller shall be fully compatible with the software specified on the plans.

(b) The C2, C20, C30 and C40 connectors shall be amp standard.

(c) One spare set of internal printed circuit boards shall be furnished with each controller unit. This shall include, but is not limited to, the power supply, front panel, I/O, central processing unit and modem, if specified.

1092.4.2.1.1 Master Controller. If a master controller or master coordination unit is specified in the plans, the master controller shall be a Type 170 controller. This controller shall be in addition to the intersection controller and shall be installed in the same cabinet unless otherwise specified on the plans.

1092.4.2.1.2 Diagnostic Test Program. For each ten or fewer Model 170E controllers purchased, a Diagnostic Test Program Prom Chip shall be provided. The Diagnostic Test Program Prom Chip shall test the operation of the Model 170E controller units including, but not limited to, internal memory, the program module, the real-time clock, input-output circuitry, the modem, the display and keyboard. The program shall be capable of operating with an external monitor and controller keypad. Full documentation on the program shall be included. The software shall be configured to work on a 412C prom module.

1092.4.2.1.3 Prom Module. Each Model 170E controller unit shall be furnished with one prom module, Model 412C, including a back up lithium battery and real time clock adjuster circuit, one Dallas 1225 chip and two 6264 ram chips.

1092.4.2.2 Type 170 Controller Cabinets. Type 170 controller cabinets, including the auxiliary door, shall be cast aluminum or 0.125 inch reinforced sheet aluminum alloy and be of clean-cut design and appearance. An auxiliary door equipped with a raintight gasket, shall allow access to a police panel and shall be equipped with a lock whose key will not unlock the main door. The doors shall be louvered to direct the incoming air downward. The cabinet shall be supplied with a replaceable furnace-type fiberglass filter mounted behind the louvers and shall cover the vent openings. A filter shell shall be provided to fit over the filter to provide mechanical support. Each cabinet door shall have a No. 2 Corbin cabinet lock and provisions for locking with a padlock. Two keys shall be furnished for each type of lock used. The handles for each door shall swing outward. Components of the Type 170 controller cabinets shall meet the following requirements:

(a) The cabinet shall contain a pull out, hinged-top drawer, including sliding tracks, with lockout and a quick-disconnect feature, such as a Vent-Rak Retractable Writing Shelf, #D-4090-13, or equivalent. The pull out drawer shall extend a minimum of 14 inches to facilitate removal of the processor by providing an aluminum platform covered with a formica-type, chemical-proof plastic sheet while the rear connector is being removed. The interior of the drawer shall be accessible. Minimum interior dimensions of the drawer shall be one inch high, 13 inches deep and 16 inches wide. The drawer shall be capable of supporting 40 pounds when fully extended and shall be mounted immediately below the controller assembly.

(b) All cabinet assemblies shall be supplied with a power distribution assembly Number 2, (PDA#2). If an auxiliary output file is specified, C5 connections shall be included.

(c) Each Type 336S cabinet shall include two fluorescent lighting fixtures mounted inside the front and back portion of the cabinet. The fixtures shall include a cool white lamp with protective cover and shall operate by a normal power UL listed ballast. The fixtures shall be installed to automatically power on when the cabinet door is opened and automatically power off when the cabinet door is closed. A manual on/off switch shall be provided for each fixture. Each switch should work each individual light. The Type 332 cabinet will require only one lighting fixture meeting the above requirements.

(d) Each controller cabinet shall be furnished with a clearly labeled switch, mounted in the access or police panel to place the signals on flash. Operation of this switch shall not affect the electrical power supply to the controller. The switch shall be labeled FLASH/AUTOMATIC. This shall be the only control switch accessible from the police panel.

(e) All output field conductors shall be terminated in the cabinet on a one-piece copper 600-volt heavy duty mechanical screw connector offset tang assembly. Each mechanical screw connector shall accommodate up to four No. 12 AWG conductors. Each clamp shall be captive to the contact screw and the screw captive to the contact. Field wiring shall not be spade lugged. The alternating current neutral bus and chassis ground bus shall be a 17-position solid copper neutral bar with set screws that allow the wires to be attached without tang or spade assemblies.

(f) The output file shall be hand wired and printed circuit boards will not be allowed, except for red fail monitoring. The back of the load switch bay and the conflict monitor bay shall be enclosed to prevent wires interfering with plugging in of components.

(g) A 420 auxiliary output file will be required when specified on the plans or if more than 12 load switches are required.

(h) I and J input files shall be provided unless otherwise specified.

(i) All cables shall be located and secured such that the cables do not interfere with removal of the controller or the opening of the controller front panel.

(j) A diagnostic cabinet test program, including documentation, shall be provided with each ten or fewer cabinets.

1092.4.2.3 Surge Protection. Each cabinet shall be provided with devices to protect the control equipment from surges and over voltages. This shall include incoming power lines, the input and output files and communication lines.

1092.4.2.3.1 All input file inputs shall be protected with a 30-volt MOV with a 30-j rating. All load switch outputs shall be protected with a 150-volt MOV with an 80-j rating. Each MOV shall be connected from the alternating current positive field terminal to the chassis ground. Each output MOV shall be mounted on the field terminal side of the output assembly.

1092.4.2.3.2 For the 332A cabinet, appropriate input surge protection shall be mounted on the lower input termination panel (LIP). The PDA#2 of each controller cabinet shall include a surge protection unit on the alternating current service input. The protector shall be installed between the applied line voltage and earth ground. The surge protector shall be capable of reducing the effect of lightning transient voltages applied to the alternating current line. The protection device shall be a two-stage series parallel device. The device shall include the following features and functions:

(a) Maximum alternating current line voltage shall be 140 volts during 20 pulses of peak current, each of which shall rise in 8 microseconds and fall in 20 microseconds to one half of the peak of 20,000 amps.

(b) The protector shall be provided with the following terminals:

(1) Main line (alternating current line first stage terminal).

(2) Main neutral (alternating current neutral input terminal).

(3) Equipment line out (alternating current line second stage output terminal, 10 amps.).

(4) Equipment neutral out (neutral terminal to protected equipment).

(5) GND (earth connection).

(c) The main alternating current line in and the equipment line out terminals shall be separated by a minimum 200 microhenry inductor rated to handle 10-amp alternating current service. The first stage clamp shall be between the main line and ground terminals.

(d) The second stage clamp shall be between the equipment line out and equipment neutral.

(e) The protector for the first and second stage clamp shall have an MOV or similar solid state device rated at 20 kiloamps and shall be of a completely solid stage design. Gas discharge tubes will not be allowed.

(f) The main neutral and equipment neutral out shall be connected internally and shall have an MOV similar solid state device or gas discharge tubes rated at 20 kiloamps between the main neutral and ground terminals.

(g) Peak clamp voltage shall be 350 volts at 20 kiloamps measured between the equipment line out and equipment neutral out terminals. Current shall be applied between the main line and ground terminals. Ground and main neutral terminals shall be externally tied together. The voltage shall not exceed 350 volts.

(h) The protector shall be epoxy-encapsulated in a flame retardant material.

(i) Continuous service current shall be 10 amps at 120 volts alternating current root means squared (RMS).

(j) The equipment line out shall provide power to the Type 170 controller and to the 24 volt power supply.

(k) Communications line protector for incoming and outgoing communication lines shall be EDCO part #PC642C-008 or equivalent with mounting connector #PCB1B or equivalent. If fiber or radio communications are specified, these communications line protectors will not be required.

1092.4.2.4 Cabinet Accessories. Each cabinet shall be equipped with the following, unless specified otherwise:

(a) A minimum of one direct current isolator.

(b) Load switches, quantity as specified in the contract documents.

(c) Two flashers.

(d) Alternating current isolators, quantity as specified in the contract documents.

(e) Four flash transfer relays. Two additional flash transfer relays shall be provided when a 420 auxiliary is shown on the plans.

(f) Modem, quantity as specified in the contract documents.

(g) SM modem, quantity as specified in the contract documents.

(h) Fiber optic modem, quantity as specified in the contract documents.

(i) Computer cable. The computer cable shall consist of both male and female amp connectors. The female connector shall be located in the front of the cabinet and shall extend past the front edge of the rack a minimum of 0.5 inches and a maximum of 1 inch. The male connector shall be located in the back of the cabinet. The cable shall extend 14 inches along the side of the rack with a minimum of 12 inches free that can be used to plug into any of the controller's four ports. The cable shall consist of one wire connecting the like pin in the other connector starting with A and ending with R. The wire shall be 20 AWG. One cable shall be supplied for each cabinet. The mounting of this cable shall not interfere in any way with the installation or removal of the controller. If the cable is mounted within the pull out drawer, any hole that is drilled in the drawer shall be equipped with a rubber grommet to protect the cable and the cable shall have enough slack to prevent binding.

(j) Conflict monitor.

(1) The conflict monitor shall be external to the controller circuitry in accordance with the Caltrans specifications. The monitor shall cause immediate transfer to flashing operation when conflicting or absent indications occur or when a voltage fault occurs. When the conflict monitor actuates flashing operation, the controller shall freeze or stop timing in the condition causing the actuation until manually reset. A single lamp failure in any signal head shall not cause the monitor to actuate.

(2) A connector and terminal assembly designated as P20 ,Magnum P/N 722120 or equivalent, for monitoring the absence of red shall be an integral part of the output file. The connector shall terminate and shall be compatible with the cable and connector of the conflict monitor unit. The pin assignments of the P20 connector and terminal assembly shall be provided with the cabinet plans. The P20 connector shall be designed such that the cable may only be inserted into the P20 connector in one direction. Unused red channels shall be programmed through jumpers. These jumpers shall cause 115 volts alternating current to be applied to any and all unused red monitoring channels. These jumpers and the respective attachment points shall be part of the output file.

1092.4.2.5 Software. Software shall be provided with each Type 170 controller unless otherwise specified. Requirements for software will be as follows.

1092.4.2.5.1 District 4 - Kansas City Area. The 412C prom module shall be configured for Wapiti software. For intersection controllers, the most recent revision of Wapiti W4IKS shall be mounted on the prom module. For master controllers, the most recent revision of Wapiti W70SM shall be mounted on the prom module.

1092.4.2.5.2 District 8 - Springfield Area. The 412C prom module shall be configured for Bi-Trans software that will be provided by District 8.

1092.4.2.6 Testing Requirements. All equipment shall be tested for conformance to these specifications. Testing may be done by an independent laboratory if the manufacturer does not have sufficient facilities to conduct the testing. A copy of the test results for all equipment shall be supplied by the manufacturer to the engineer.

1092.4.2.6.1 Conflict Monitor Test Cable. To facilitate testing of the conflict monitor, one additional 4-foot connector cable shall be furnished by the manufacturer and installed in each cabinet. The cable shall utilize an 18 AWG wire to connect a 36-pin plug to the back panel terminals as specified below. The connector cable shall utilize a 36-circuit polarized nylon Waldon Molex type receptacle, P/N 03-06-1361, using a 0.062-inch female terminals made of 70/30 spring tempered 0.010 inch thick tin-plated brass with contact of resistance 0.0025 ohm millivolts, drop of 2.5 millivolts at one amp with 250 volts, 4 amps maximum per circuit. This connector cable shall "free float" in the bottom front 6 inches of the cabinet and shall not be used in the normal operation of the controller. A moisture-proof cap shall be provided to prevent the accumulation of moisture on the plug terminals. The cap shall remain attached to the connector when the cable is in use.

Receptacle Circuit	Terminal Phase
1	1 G
2	1 Y
3	2 G
4	2 Y
5	3 G
6	3 Y
7	4 G
8	4 Y
9	5 G
10	5 Y
11	6 G
12	6 Y
13	7 G
14	7 Y
15	8 G
16	8 Y
17	2 WALK
18	6 WALK

Receptacle Circuit	Terminal Phase
19	4 WALK
20	8 WALK
21	1 AUX G[a]
22	1 AUX Y[a]
23	3 AUX G[a]
24	3 AUX Y[a]
25	5 AUX G[a]
26	5 AUX Y[a]
27	6 AUX G[a]
28	6 AUX Y[a]
29	I14-W STOP TIME
30	DC GROUND
31	MONITOR RESET
32	DC GROUND
33	2 AUX G[a]
34	2 AUX Y[a]
35	4 AUX G[a]
36	4 AUX Y[a]

[a]Circuits used only in a 332A cabinet with an auxiliary output file

1092.4.2.6.2 Controllers. Each Model 170E controller unit shall be tested over a temperature range of -29 to 165 F. Proper operation of the unit shall be verified at both temperature extremes and at ambient temperature. Testing shall be conducted prior to final inspection, and will not constitute a substitute for any quality control testing or final inspection testing normally performed.

1092.4.2.6.2.1 The environmental chamber(s) shall have provisions for remotely operating the Model 170E controller under test. Front panel displays shall be visible from a window in the environmental chamber. Signal outputs shall be brought out of the chamber to display board if controllers cannot be directly observed. Cold and hot soak times shall be sufficient to allow

all components in the device to reach the specified temperatures. A minimum soak time of three hours shall be used for all testing.

1092.4.2.6.2.2 The manufacturer shall submit to the engineer a proposed testing procedure and schedule 30 days prior to testing for evaluation. Test procedures, environmental chambers, automatic test equipment, display boards, power supplies and controls shall be described in detail.

1092.4.2.6.2.3 The controller shall pass the following test at least five times at each temperature extreme and ambient:

(a) Recovery from a short power interruption of approximately 500 milliseconds.

(b) Recovery from a long power interruption of approximately 5 seconds.

1092.4.2.6.2.4 The vendor shall provide a method of testing controller inputs and outputs. Diagnostic software and wraparound connector for controller harnesses may be used. If diagnostic software is not used, outputs shall be brought out to a display board. Inputs may be paralleled to each controller.

1092.4.2.6.3 Cabinet Testing. Cabinets shall be tested at ambient conditions only. An automatic or semi-automatic method of checking cabinet wiring between equipment harnesses and field connections will be required.

1092.4.2.6.4 Card Rack Assemblies. Card rack assemblies shall be in accordance with Caltrans.

1092.4.3 Auxiliary Equipment and Interfaces for Controllers. Interface panels shall be aluminum panels installed in the controller cabinet containing the required terminals and equipment. Interface panels shall be neatly laid out, neatly wired and easily accessible. Each auxiliary unit shall be enclosed in a suitably finished metal case and shall be mounted in the controller cabinet unless otherwise specified. The function of each auxiliary unit shall be indicated by an identification plate on the case. Auxiliary equipment cases shall be ventilated. Temperature, voltage and frequency shall be in accordance with Sec 1092.4.

1092.4.3.1 Pre-Emption Interface. The pre-emption interface shall consist of internal pre-emption functions in the controller, any field wire termination panels, relays, wiring and connectors required for proper operation. The pre-emption interface shall be wired to transfer control of the signals to the pre-emption sequence when actuated and shall provide the color sequence specified. After release of pre-emption, normal controller operation shall be automatically resumed except that actuated controllers shall be on recall for one complete cycle.

1092.4.3.2 Master and Local Coordination Interface. The coordination interface shall consist of internal coordination functions in the controller, and of any field wire termination panels, wiring and connectors required for proper operation. The master coordination interface shall supervise the actuated controller operating the signals in the intersection at which the actuated controller is located. Local coordination interfaces shall be supervised by the master coordination interface and shall in turn supervise the actuated controllers operating the signals at the intersections where the controllers are located. Coordination interfaces shall be connected to one another or to a telephone interconnection unit by a multi-conductor cable. The master coordination interface shall be furnished with internal time-based functions in the controller. The coordination interface shall provide the following:

(a) Fully actuated operation.

(1) Cycle length of the actuated controller may vary with traffic demand, but shall not exceed the cycle length set on the coordination interface.

(2) Vehicle and pedestrian detectors shall remain energized.

(3) During periods of light traffic, the actuated controller shall respond to detector demand on any signal phase.

(4) When there is continuous demand for all signal phases, the coordination interface shall cause termination of each signal phase in accordance with the time intervals set on the coordination interface for each signal phase.

(5) The actuated controller shall not be forced to transfer right of way to a signal phase if there is no demand.

(b) Semi-actuated operation.

(1) Signal phases, controlling the street on which signal progression is desired, shall be placed on maximum recall.

(2) Vehicle and pedestrian detectors shall remain energized.

(3) Transfer of right of way from the coordinated signal phase(s) shall not occur until there is detector actuation for a non-coordinated signal phase and only after the coordination interface has terminated the coordinated signal phase(s).

(4) The right of way interval awarded the coordinated signal phase(s) shall be governed by the time interval set on the coordination interface.

(5) If detector actuations for a non-coordinated signal phase(s) causes the phase(s) to time to maximum, the phase(s) shall be forced off and the coordinated phase(s) awarded right of way.

(6) If demand for the non-coordinated signal phase(s) is not sufficient to extend the phase(s) to maximum, right of way shall transfer to the coordinated phase(s) and remain there until demand for the non-coordinated phase(s) occurs and the coordination interface times the coordinated phase(s) to maximum.

(7) Detector actuation on a non-coordinated signal phase(s) occurring during the coordinated phase(s) right of way interval shall cause a call to be placed and retained for the non-coordinated signal phase(s).

(c) Fixed cycle length operation.

(1) All signal phases shall be placed on maximum recall.

(2) Vehicle and pedestrian detectors shall remain energized.

(3) The coordination interface shall control the time interval that each signal phase is awarded right of way.

(d) Free operation.

(1) When permitted by internal time-based functions, the coordination interface shall provide free operation of associated actuated controllers. During this

operation the actuated controller shall operate without supervision by the coordination interface.

(2) Pretimed controllers, in a signal system supervised by a master coordination interface, shall revert to dial 1, reset 1 or internal time based coordination during free operation at the user's option.

1092.4.3.2.1 Each coordination interface shall have the following minimum operational characteristics:

(a) Three cycles.

(b) Eight splits.

(c) Eight force off periods per split.

(d) Three offsets per cycle.

(e) Selectable recall by signal plan.

1092.4.3.2.2 Each coordination interface shall have all of the following methods of synchronizing to the master sync pulse:

(a) Dwell. The coordinator shall establish a new offset by stopping the cycle timer in the coordinated phase(s) green, until the new offset value is reached.

(b) Dwell with Interrupt. The coordinator shall establish a new offset by stopping the cycle timer in the coordinated phase(s) green. The maximum time the coordinator can dwell shall be adjustable from 1 to 99 seconds.

(c) Shortway. The coordinator shall establish a new offset by the shortest route possible.

1092.4.3.2.3 Each master coordination interface shall be furnished with necessary relays and internal functions in the controller to provide the following supervisory functions:

(a) Semi-actuated operation.

(b) Fixed cycle length operation.

(c) Free operation.

(d) Cycle Transfer (cycle 1 to cycle 2, cycle 3 or cycle 4 and vice versa; cycle 2 to cycle 3 or cycle 4 and vice versa; cycle 3 to cycle 4 and vice versa).

1092.4.3.2.4 Each controller shall be capable of permitting the manual selection of the following:

(a) Cycle Length 1, 2, 3, 4 or System.

(b) Offset 1, 2, 3, 4 or System.

(c) Semi-actuated operation, fixed cycle length operation or free operation.

1092.4.4 Remote "ON - OFF" Switch (Pedestrian Interval Sequence). The following type of "On - Off" switches shall be furnished as specified:

(a) Type I. Type I switches shall consist of one manually operated heavy-duty switch in a circuit not exceeding 18 volts. Necessary relays shall be located in the controller cabinet for including or excluding the pedestrian phase in the phasing sequence or switching signals between flashing and sequence operation. This shall be accomplished by energizing or de-energizing the pedestrian signal indications and push-button detectors. The switch shall be enclosed in a weatherproof, cast aluminum housing equipped for post mounting. The housing shall have a suitable lock, the key of which shall not unlock the controller cabinet. The housing shall be tapped for conduit.

(b) Type II. The Type II switch shall be operationally identical to the Type I, except the switch may be 120 volts and shall be located inside the police panel of the controller cabinet.

1092.4.5 Interconnect Types.

1092.4.5.1 Time Base Coordination Interface. The time base coordination interface shall consist of internal time base coordination functions in the controller.

(a) Timing base shall be the 60-hertz power line frequency. Timing error due to power failure or low voltage shall not exceed ± 0.005 percent during these conditions. Changes to and from standard time and daylight time shall be programmed to automatically occur at the specified times. Memory and timing shall be maintained for at least 48 hours during an alternating current power failure. A power failure indicator shall be provided.

(b) The interface shall have a multi-digit security access code or key and lock security access.

(c) The interface shall be zero time based, settable to the second, programmable for 52 weeks, accommodate at least three weekly programs, twelve day programs and no less than twelve exception day programs. Total event changes shall be a minimum of 160. Interrogation of the interface to determine the year, month, day, hour, minute, second, a.m. and p.m., as well as program information programmed in the unit, shall be possible. Indicators shall show the condition of all outputs.

(d) The interface shall permit the controller to operate free or in coordination. When in coordination, all maximum green limits shall be inhibited. The interface shall be capable of continuously generating no less than four cycle lengths from 40 to 255 seconds.

(e) The interface shall be capable of continuously generating eight individual force-off commands in each cycle length even though the use all of the force-off commands may not be necessary. The interface shall also place a continuous call to the detector inputs of the coordinated phases. Position of the force-off and continuous call functions shall be settable at any percentage point or seconds in any selected cycle length.

(f) The first program of the day shall be implemented at the beginning of the minute selected. When changing from one cycle length to another while in the coordination mode, the change to the new cycle length shall not occur until the present cycle length has terminated. If the controller is operated in the free mode between cycle lengths, the next cycle length programmed shall begin at the beginning of the minute selected.

(g) The interface shall be furnished with the capability of generating a daily reference point at which time all cycles are resynchronized. This daily reference point shall be

either 12:00 midnight or a selectable time of which 12:00 midnight could be selected. The resynchronization reference time is an arbitrary point in time that marks the beginning of all cycles on a daily basis.

(h) When designated, the interface shall be capable of generating an absolute reference point at which time all cycles are resynchronized. This absolute reference point shall be a selectable time by date and hour and minute that marks the beginning of all cycles.

(i) While under coordination, the designated coordinated phase(s) shall be capable of releasing from a hold status and operating in the actuated mode. The controller unit shall operate in actuated mode from a designated hold release point to the corresponding force-off point(s) of the coordinated phase(s).

(j) Three instruction manuals covering operational information shall be furnished with each interface.

1092.4.5.2 Closed Loop Systems.

1092.4.5.2.1 Equipment. New systems shall be compatible with any existing components in the system.

1092.4.5.2.1.1 System Software. The system software shall be designed to operate a traffic-responsive signal system with two-way communications between all local controllers and the system master. The software shall be capable of time-of-day system operation and a mix of time-of-day and traffic responsive operation. The software shall also provide for two-way communication between the system master and a remote personal computer, via a dial-up modem and a direct connect to the system master. The system software shall be fully compatible with all equipment supplied in the system and shall be compatible with the latest Windows operating system. The software shall be new and in the original packaging provided by the manufacturer. The system manufacturer shall provide software updates at no cost to the Commission for a period of at least two years from the date of final acceptance of the project. All licensing issues shall be addressed by the contractor.

1092.4.5.2.1.2 Closed Loop System Components. The principal components of the closed loop system shall consist of the system master, local intersection controller(s) and a modem.

1092.4.5.2.1.2.1 System Master. The system master controller shall consist of a NEMA or Type 170 microcomputer signal controller as specified in the plans, prom module and all necessary connectors and cables. The system master controller shall be installed in the local controller cabinet designated on the plans. A separate cabinet will not be required.

1092.4.5.2.1.2.2 Local Intersection Controller. The local controller assembly shall consist of a NEMA or Type 170 complete actuated traffic controller assembly, as specified in the plans and in accordance with these specifications.

1092.4.5.2.1.3 Cabinet Accessories.

1092.4.5.2.1.3.1 Telephone Interface Panel. The panel shall provide for interfacing of a leased, unconditioned telephone drop to a Hayes compatible modem that connects to the on-street system master. The panel shall be fabricated from 0.125-inch sheet aluminum with deburred edges and rounded corners. The panel shall be mounted on the inside of the cabinet as directed by the engineer. A telephone network interface, such as a Siecor CAL3000 or other approved interface acceptable to the local telephone company, shall be attached to the aluminum panel. The telephone interface shall include the installation of all necessary equipment to connect the interface to the telephone drop. The contractor shall be responsible

for the installation of the telephone line. The system acceptance test shall not begin until the telephone line is in operation.

1092.4.5.2.1.3.2 Extra Service Outlet. One extra duplex service outlet shall be provided in the controller cabinet housing of the system master. The extra duplex service outlet shall not be located on the door of the cabinet. The receptacle shall be connected to the 120 volts alternating current auxiliary circuit in the cabinet.

1092.4.5.2.1.3.3 Interconnect Panel. The interconnect panel shall provide for system communication between the system master and local intersection controller units. An interconnect panel shall be provided in each controller cabinet. The panel may include terminations for system detector inputs and other auxiliary input/output functions. All controller assemblies shall be configured with inputs for system detectors. The panel shall be fabricated from 0.125-inch sheet aluminum with deburred edges and rounded corners. The panel shall be mounted on the inside of the cabinet on the left side. Over-voltage protectors shall be provided and shall be an encapsulated, three-element gas tube type equipped to mate with a ten-circuit Buchannan Connector PnPcB1B. As a minimum, the over-voltage protection ratings shall be:

(a) Primary surge current – 10 kiloamps (80 x 20 us, waveshape).

(b) Secondary protector: Solid state clamps 1.5 kilowatts.

(c) Response time < 5 nanoseconds.

(d) Clamp voltage – 8 volts.

1092.4.5.2.1.3.4 Door Alarm. A limiting switch shall be installed and wired to activate an alarm when the cabinet door is opened.

1092.4.5.2.1.3.5 Dial-Up Modem. The modem shall be in accordance with Sec 1092.4.6 and shall be installed in the controller cabinet housing of the on-site system master.

1092.4.5.3 Twisted Pair Interconnect. If 3-pair cable is specified, the interconnect cable for system communication between the on-street master and local controllers shall be 16 AWG, stranded copper conductor, twisted pairs individually shielded. The cable shall be PVC insulated, aluminum shielded, in accordance with specifications of Belden No. 1037A. Each interconnect cable shall have three pairs. Each pair shall be wired to a terminal strip on the interconnect panel. Each shield shall be grounded on at least one end.

1092.4.5.4 Wireless Interconnect.

1092.4.5.4.1 Wireless Closed Loop System Components. The wireless system shall consist of a fully operational wireless interconnect system between the system master and all local controllers. Components shall include telemetry radios, interface cables between the radios and signal controllers, radio power supply and handheld diagnostic/programming keypads.

1092.4.5.4.1.1 Telemetry Radios. The telemetry radio shall be an unlicensed frequency hopping spread spectrum and shall be a Microwave Data Systems, Model 9810 or equivalent, in accordance with the following:

Item	Requirement
Frequency Band	902-928 Megahertz FCC Part 15 Spread Spectrum Band or1.2 Gigahertz FCC Part 15 Spread Spectrum Band
Frequency Hopping Range	8 Selectable Zones @ 128 frequencies – 1019 total frequencies
Frequency Stability	± 1.5 ppm @ -20 to 140 F
Data Interface	RS232 (or as required by the system)
Data Interface Rate	Std. Baud Rates up to 19200 bytes/second, minimum
Latency	<10 milliseconds typical (buffer off mode)
Transmitting Power Output	1 watt minimum, adjustable
Transmitting Duty Cycle	Continuous
Transmitting Max Voltage Standing Wave Ratio (VWSR) (No Damage)	Infinite, all phase angles
Receiving Bit Error Rate	Less than 10^{-6} at -110 decibels
Receiving Intermodulation	75 decibels, minimum
Receiving Desensitization	65 decibels, minimum
Receiving Spurious	70 decibels, minimum
Operating Humidity	95% Relative Humidity at 104 F
Operating Temperature	-20 to 140 F with full performance

1092.4.5.4.1.1.1 Telemetry radios shall provide transparent communications between signal controllers. All radio equipment shall be installed in the signal controller cabinets. Radio power supplies shall meet all requirements of the radio manufacturer, including power, temperature and humidity. All required interface cables and connectors shall be provided with the radios.

1092.4.5.4.1.1.2 The radio shall have the capability to monitor receiver signal strength and be programmed through a diagnostic/programming keypad. Two handheld diagnostic/ programming keypads for the radios shall be provided with the system.

1092.4.5.4.1.2 Antenna System. The antenna system shall consist of the omnidirectional antenna or yagi directional antenna, as specified, antenna mounts, coaxial cable and surge and lightning protection. Antennas shall be products manufactured by Decibel Products, Celwave, Scala or Antenna Specialists, and shall meet the following requirements.

1092.4.5.4.1.2.1 Omnidirectional Antenna. All omnidirectional antennas shall be in accordance with the following:

Item	Requirement
General Frequency Range	896-960 Megahertz
Bandwidth at Rated VSWR	70 Megahertz, min.
VSWR	1.5:1, min.
Polarization	Vertical
Maximum Power Input	250 watts, min.
Connector	N Female
Antenna Housing	Fiberglass Radome
Radiating Elements	Brass or Copper
Support Pipe	6061-T6 Aluminum
Lightning Protection	Direct Ground
Rated Wind Velocity	100 mph, min.

1092.4.5.4.1.2.2 Yagi Directional Antenna. All yagi directional antennas shall be in accordance with the following:

Item	Requirement
General Frequency Range	896-960 Megahertz
Gain	10 decibels, min.
Bandwidth at Rated VSWR	60 Megahertz, min.
VSWR	1.5:1, min.
Horizontal Beamwidth	45 degrees, min.
Vertical Beamwidth	30 degrees, min.
Polarization	Vertical or Horizontal
Maximum Power Input	100 watts Min.
Connector	N Female
Radiating Elements	Gold Anodized Welded Aluminum Alloy
Lightning Protection	Direct Ground
Rated Wind Velocity	100 mph Min.

1092.4.5.4.1.2.2.1 Directional antennas shall be in accordance with the level of gain shown on the plans and with the following:

Antenna	Gain	Vertical Beam Width
3 decibel	3 decibels, min.	30 degrees, min.
6 decibel	6 decibels, min.	16 degrees, min.
9 decibel	9 decibels, min.	7 degrees, min.

1092.4.5.4.1.2.3 Antenna Mounts. Mounts shall provide a rigid mounting of the specified antenna that will withstand winds of up to 100 mph minimum. Mounts and associated hardware shall be constructed of galvanized steel, aluminum or stainless steel.

1092.4.5.4.1.2.4 RG-8/U Coaxial Cable. All antenna cable shall be a low loss, RG-8/U, Belden 9913 or equivalent, coaxial cable in accordance with the requirements listed below. Connectors for antenna cable shall be Type N male connectors constructed of silver-plated brass with a gold plated pin and soldered center connection.

Item	Requirement
Impedence	50 ohms, nominal
Attenuation at 900 Megahertz	5.7 decibels/100 ft., max.
Overall Diameter	0.405 in., nominal
Outer Conductor	Tinned Copper Braid with 95% min. coverage
Inner Conductor	0.108 in. Copper
Dielectric	Foam-Polyethylene
Outer Jacket	Black Polyvinyl Chloride

1092.4.5.4.1.2.5 Antenna Surge and Lightning Protection. A lightning and surge arrestor shall be provided for the coaxial cable in the controller cabinet. The arrestor shall be bulkhead-mounted or flange-mounted and shall be securely fastened to a grounded metal surface inside the cabinet. The arrestor shall be manufactured by Polyphaser and shall be in accordance with the following:

Item	Requirement
Throughput Energy	220 µj
Maximum Surge Current	50 kiloamps
Turn On Voltage	600 volts
Turn On Response	2.5 nanoseconds
Connectors (both ends)	N Female
Housing	Aluminum
Hardware	Stainless Steel

1092.4.5.5 Fiber Optic Interconnect. The fiber optic system shall consist of a fully operational fiber optic interconnect system between the system master and all local controllers. Components shall include fiber optic cable, splice cabinet, closed loop system components, modem and a fiber distribution unit.

1092.4.5.5.1 Splice Cabinet. The Type 336 cabinet and EIA 19-inch rack cage shall be in accordance with the *Traffic Signal Control Specifications* published by the California Business, Transportation & Housing Agency, Department of Transportation (Caltrans), dated January 1989, including all current addenda and revisions. Housing shall include, but will not be limited to, the enclosure, doors, latches/locks, hinges and door catches, ventilation, gaskets, cage supports and mounting, the rack cage, and anchor bolts.

1092.4.5.5.1.1 Each splice cabinet shall include a fiber distribution unit to provide a termination and service access point for the fiber optic cables. The fiber distribution unit shall be mounted on the 19-inch rack cage and shall be a modular design to support both fusion and mechanical splices of multimode and single mode fiber. The single cabinet construction shall have a minimum termination/connection capacity of 48 fibers and four splice trays. The connector panel, to be located at the top of the unit, shall be designed to accommodate stick and turn (ST) and other standard connectors. Six ST couplings with ceramic inserts, designed to accommodate both single mode and multi-mode fiber, shall be provided and installed for future use. One single mode splice tray and one multi-mode splice tray, each with a closure for 12 fusion splices, as a minimum, shall be provided in each cabinet. Additional trays shall be provided as necessary to splice or terminate fibers in accordance with the system design and this specification.

1092.4.5.5.1.2 The design of the unit shall allow stacking of splice trays in a manner that permits access to individual trays without disturbing other trays and splicing to be conducted at a distance from the unit. The lower portion of the unit shall provide for the neat storage of

continuous tubes. Excess cable may be stored either in the fiber distribution unit or within the splice cabinet. The unit shall provide both front and rear access with hinged door access and cable strain relief accommodations. The unit and splice tray shall be constructed of durable aluminum designed for outdoor applications. Plastic doors may be considered for approval by the engineer.

1092.4.5.5.2 Fiber Optic Data Link for Closed Loop System. The data link between the fiber optic cable and the master or local intersection NEMA or Type 170 controller arranged in a closed loop system shall be accomplished using a data link, referred to as a modem on the plans, compatible with daisy chain operation to transmit RS-232 data using fiber optics. This data link shall be compatible with and installed in the NEMA or Type 170 controller unit in accordance with the manufacturer's recommendations.

1092.4.5.5.2.1 The fiber optic data link shall be capable of operating in a full duplex mode of operation, employing asynchronous RS-232 data link protocols. RS-232 signals shall be converted to light and transmitted from data link to data link until the light is reconverted to RS-232 electrical signals sent to a particular controller. The fiber optic data link shall operate in a daisy chain communication mode.

1092.4.5.5.2.2 On the data link assembly, there shall be two pairs of clearly labeled optical emitters and optical detectors, designed to attach to standard ST connectors. There shall be two clearly labeled LED's, one for transmit and one for receive. These LED's shall illuminate when the fiber optic data link is either receiving or transmitting at the local controller. There shall be a slide switch labeled "M" for master operation and "L" for local operation.

1092.4.5.5.2.3 In the master mode of operation, the electrical data entering the fiber optic data link from the controller unit shall be transmitted as optical signals in a parallel mode from each of the two emitters. The optical signals received by the two detectors shall be converted to electrical signals and sent in parallel to the controller.

1092.4.5.5.2.4 In the local mode of operation, optical signals received by Detector 1 shall be converted to electrical signals and sent the to the controller unit. These same signals shall be regenerated and transmitted by Emitter 2 to the next adjacent fiber optic data link downstream in the daisy chain. Optical signals received by Detector 2 shall be regenerated and transmitted by Emitter 1 to the next adjacent fiber link upstream. Electrical signals received by Emitter 1 from the controller shall be transmitted to the next adjacent fiber link upstream. Regeneration shall maintain pulse fidelity within ± 0.1 percent for each data link.

1092.4.5.5.2.5 The fiber optic data link shall have an emergency backup power source that allows continued daisy chain operation when the NEMA or Type 170 controller unit is removed or if the power to the controller has been turned off. The backup power source shall provide uninterrupted operation of the daisy chain interconnect system, both upstream and downstream from the affected data link, for a period of 12 hours. An RJ11/4 jack shall be available on the assembly to interface an external data link, allowing fiber optic communications in four directions.

1092.4.5.5.2.6 The fiber optic data link shall operate with all fiber ranging from 50/125 glass to 1 mm plastic fiber and shall meet the following electrical requirements:

Item	Requirements
Voltage	12-volt direct current
Current	26 milliamps continuous
Wavelength	850 nanometers
Data Link Sensitivity	Maximum 0 decibels, Minimum –40 decibels
Data Rate	100 to 19.2 k baud

Operating Range	1.9 miles from data link to data link
Temperature Range	-30 to 165 F

1092.4.5.5.2.7 Fiber Distribution Unit. Each controller cabinet shall be equipped with a fiber distribution unit to provide a termination, storage and service access point for fiber optic cables. The fibers in the interconnect cable(s) shall be terminated on one side and duplex jumpers shall extend on the other side to the data links. The fiber distribution unit shall be a modular design to support a minimum termination/connection capacity of 12 fibers, one splice tray and strain relief for up to four cables. No splice tray will be required. The connector panel shall be designed to accommodate ST connectors for both multi-mode and single mode fibers, as appropriate. ST couplings with ceramic inserts shall be provided to accommodate all fibers brought into the controller cabinet from the splice cabinet. The unit shall provide both front and rear access with hinged door access. The unit shall be constructed of durable aluminum constructed for outdoor applications. Plastic doors may be considered for approval. The unit shall be sized to fit in the controller cabinet and shall be positioned to allow fiber cables to be routed with bending radii exceeding manufacturers recommendation. The unit shall not conflict with other cabinet components or panels. Fiber cables shall not conflict with other cabinet wiring.

1092.4.5.5.3 Training for Fiber Optic Installation. When specified in the contract documents, training on system software and system operation shall be provided. Training shall be conducted by qualified instructors and shall be provided to personnel designated by the engineer on all facets of the system. Personnel shall be trained to operate the system, analyze system performance and revise critical operating parameters based on the analysis. The training shall be in a classroom atmosphere and shall be for a minimum of 16 hours over two days. The first eight-hour training session shall be conducted prior to the system acceptance test. The second eight-hour session shall be conducted at the conclusion of the system acceptance test. Maintenance personnel shall be trained on maintenance and repair of all serviceable equipment. Training shall include field level troubleshooting and bench repair. The training shall be for a minimum of eight hours in one day.

1092.4.6 Dial Up Modems. The dial-up modem shall be an auto-dial, auto-answer modem and shall be installed in the controller cabinet as specified on the plans. If specified, an identical modem shall be installed at the central office computer facility in the MoDOT district office. The modem shall be Hayes compatible capable of responding to the standard "Hayes command set" and shall be self-contained. The unit shall be powered by a nominal 120-volt alternating current from the duplex service outlet provided in the cabinet. The modem shall be capable of operating at all standard baud rates from 300 to 56k baud over a standard dial-up, unconditioned telephone line and shall be capable of reliable operation from -35 to 165 F. Installation shall include the appropriate interface cable to connect to an RJ-11 telephone jack on the telephone interface panel, the RS-232 cable from the modem to the system master and all other cabling, connectors and incidental items necessary for operation.

1092.4.7 Detectors.

1092.4.7.1 Induction Detector Probes. The encapsulated induction detector probe shall detect the passage or presence of all vehicles with a standard induction loop detector amplifier. The induction detector probe shall operate in a temperature range from -35 to 165 F with 0 to 100 percent humidity. The operating field intensity range shall be 0.2 to 1.0 oersted with a nominal inductance of 20 microhenries plus 20 microhenries per 100 feet of cable. The nominal direct current resistance shall be 0.5 ohm plus 3.2 ohms per 100 feet of probe cable. Induction detector probes shall be as specified on the plans and shall meet the following:

(a) The sensing probes shall be cylindrical having maximum dimensions of 7/8-inch diameter by 4 inches long. The sensing probes shall be suitable for installation in a one-inch

diameter bored hole. The interconnecting four-conductor cable and lead-in cable shall be suitable for installation in a 1/4-inch wide pavement sawed slot.

(b) The jacket on the interconnecting cable and the casing on the sensing probe shall be an abrasion resistant polyurethane elastomer. The device shall be impervious to moisture and chemically resistant to all normal motor vehicle petroleum products. Lead-in cables shall be shielded, chemical resistant and completely waterproof.

(c) The combined probe sets, manufacturer specified lead-in cable and detector probe shall detect all vehicles up to a lead-in cable length of 750 feet with up to six probes per set.

(d) The conductor cable from the probes to the detector panel in the controller assembly shall be as specified by the detector manufacturer, shall be continuous and unspliced and shall be a minimum of 50 feet in length. Probes shall be assembled in a set to form a vehicle detector as shown on the plans. No more than six probes shall be assembled as a set. The cables between probes shall be long enough to provide the spacing shown on the plans plus 5 feet. If spacing is not shown on the plans, 15 feet of cable shall be provided between probes. Each set of probes shall have one lead-in cable.

1092.4.7.2 Pedestrian Push Button. Pedestrian push-button detectors shall be of the pressure-activated type with essentially no moving parts. The housing shall be black, round in shape and shaped to fit the curvature of the post to which it is attached and shall provide a rigid installation. Contacts shall be normally open, entirely insulated from the housing and actuator, and have connecting terminals. The housing shall have one outlet tapped for ½ inch pipe. The actuator shall be a minimum of 2 inches in diameter, raised, contrast visually with the housing and be made of brass or corrosion-resistant metal alloy or non-metallic material. A maximum force of 5 pounds shall be required to activate the switch. Switch shall be of the solid-state electronic, piezo type, The operating voltage shall not exceed 24 volts. The entire assembly shall be weatherproof, secure against electrical shock to the user and vandal resistant. Entire assembly shall be rated to operate between –30 degrees F to 165 degrees F and shall not allow ice to form such to impede the operation of the button.

1092.4.7.3 Induction Loop Detectors. Induction loop vehicle detectors shall detect a vehicle stopped within the field of the loop or passing over the loop at speeds up to 80 mph. Induction loop detectors shall be card rack mounted. For double controller cabinets, card rack assemblies and detectors shall be installed in the same compartment as each respective associated controller.

1092.4.7.4 NEMA Card Rack Assemblies. The supporting and connecting rack shall contain space for a minimum of two power supplies and shall have a minimum of eight card positions for two-channel detector units. Upper and lower slide guides shall be provided for the power supply and each detector card. Where detectors are specified, the rack and power supplies shall be included with the detectors, and no direct payment will be made.

(a) The card mounting rack shall be attached to the controller cabinet by a hinge or pivot assembly, which allows the rack to rotate horizontally so as to expose the rack wiring to facilitate maintenance operations. The rack shall be positioned to rotate out freely 90 degrees without conflicting with other wiring, equipment or the controller cabinet. Sufficient wire lengths shall be provided for rotation. The rack shall not block the back panel or other termination panels.

(b) The power supply shall be capable of supplying a minimum of 200 milliamps to each detection channel position. The power supply shall be capable of operating a full rack of time delay detectors regardless of the amount and type of detectors required. Each power

supply channel shall power no more than one detector card. Each channel shall be individually fused.

(c) Each card rack detector shall have a regulator for the power input. The regulator shall have the appropriate power and voltage rating for operation of the detector.

(d) Card racks shall mate with a 44-terminal, double row, 0.156-inch contact spacing, Cinch Jones card edge connection 50-44A-30M or equivalent. Input/output connector pin terminations shall be in accordance with NEMA Specification TS. All useable functions shall be fully wired for use.

(e) All circuitry shall be of solid state, temperature compensating components.

(f) Unless shown otherwise on the plans, each detector in the card rack shall be associated with the appropriate phase as follows:

Channel	**Card Position**							
	1	2	3	4	5	6	7	8
1	ø 1	ø 1 or 6	ø 6	ø 6	ø 3	ø 3 or 8	ø 8	ø 8
2	ø 5	ø 5 or 2	ø 2	ø 2	ø 7	ø 7 or 4	ø 4	ø 4

(g) Each detector channel shall be clearly labeled with phase and direction.

1092.4.7.4.1 Card Rack Detectors. Card rack detectors shall meet the following requirements:

(a) Card rack-mounted detectors shall incorporate two detection channels.

(b) Each detector channel shall have at least a two-frequency selection capability, at least two levels of operational sensitivity and shall be capable of tuning to a minimum inductance range of 70 to 1000 microhenries.

(c) All controls and indications shall be mounted on the front panel of the sensing unit, with the exception of extension and delay timing controls on card rack mounted detectors.

(d) A manual control shall be provided for each channel to select pulse or full presence operation.

(e) Each detector channel, after installation and initial adjustment, shall automatically tune to various loop configurations ranging in size from 6 x 6 feet minimum to 6 x 100 feet maximum. The maximum lead-in length shall be 750 feet.

(f) Each detector channel shall time out and retune automatically if a continuous vehicle occupation of the loop field for a nominal time of 10 to 30 minutes is sensed.

(g) In the event of power loss to the detector or channel, a continuous call shall be made to the controller.

(h) All circuitry shall be of solid state, digital design and incorporate temperature-compensating components, with the exception of the output relay.

(i) If specified, each channel shall have extension and delay timing features, as follows:

(1) Delay timing range from 0 to 30 seconds in 1.0-second increments.

(2) Extension timing range from 0 to 7.5 seconds in a maximum of 0.5-second increments.

(j) The sensing unit shall have a light that will illuminate when a vehicle is within the loop field. Other visual indications of relay closure may be used if approved by the engineer.

(k) Each detector and channel shall be in accordance with NEMA Standard Publication TS.

1092.4.7.4.2 Dual Output Card Rack Detectors. Dual output card rack detectors shall be in accordance with NEMA and shall provide two relay outputs per induction loop detector. One output shall be capable of pulse detection for the purpose of traffic counting, speed and occupancy measurements. The other output shall be capable of presence detection. Each detector output shall be assigned to a separate detector input into the controller.

1092.4.7.5 Calling Detector Relay. A calling detector relay shall operate with any detector and allow the detector to place only one actuation when the red indication is being displayed to the associated phase. The relay shall be self-contained.

1092.4.7.6 Microwave Vehicle Detectors. The unit shall detect all vehicles moving within the field of detection at speeds from 2 to 80 mph. The unit shall have a minimum detection range from 3 to 200 feet for all vehicles. The pattern spread of the detection field shall be no more than 16 degrees. The unit shall be self-tuning and capable of continuous operation over a temperature range of -35 to 165 F. The unit shall be microprocessor based using Doppler microwave at an operating frequency of 10.525 GHz. The unit shall have FCC certification and shall be tested to the applicable FCC specifications. The unit shall be capable of side-fire mount or overhead mount. The enclosure shall be constructed of aluminum or stainless steel and shall be water resistant. The unit shall be capable of detecting directional traffic and the direction shall be user selectable. All user operated controls and adjustments shall be clearly marked and easily accessible. The unit shall have a relay detection output to the controller with a minimum 5-amp rating and shall be designed to place a constant call to the controller in the event of any failure. The unit shall have an easily accessible indicator showing activation of detection relay. Required wiring shall be as specified by the manufacturer. Mounting hardware for the type of mounting shown on the plans and power supply equipment shall be as specified by the manufacturer and shall be provided with the unit.

1092.4.7.7 Video Detection System.

1092.4.7.7.1 System Requirements. The video detection system shall provide flexible detection zone placement at any location and at any orientation within the combined field of view of the image processors. Preferred presence detector zone configurations shall be a box or lines placed across lanes of traffic or lines placed parallel with lanes of traffic. Detection zones shall be capable of overlapping.

1092.4.7.7.1.1 The detection zones shall be created by using a track ball to draw the detection zones on the video image. A graphical user interface shall be built into the automatic control unit (ACU) and displayed on a video monitor or computer. Editing of previously defined detector configurations to fine-tune detection zone placement shall be possible.

1092.4.7.7.1.2 When a vehicle is detected by crossing a detection zone, there shall be a visual change on the video display, such as a flashing symbol or a change in color or intensity to verify proper operation of the detection system.

1092.4.7.7.1.3 Overall performance of the video detection system shall be comparable to inductive loops. Using camera optics and in the absence of occlusion, the system shall be able to detect vehicle presence with 95 percent accuracy under normal day and night conditions with only slight deterioration in performance under adverse weather conditions, including fog, snow and rain. When visibility exceeds the capabilities of the camera, the system shall default to placing a call on all detectors.

1092.4.7.7.1.4 The video detection system shall be programmable via one dial up modem connection at a minimum of 19,200 bytes per second to the camera(s). Still image and real time detection displays to a remote computer using supplied system software through the modem shall be provided.

1092.4.7.7.2 System Components. The video detection system will be defined as the complete assembly of all required equipment and components for detection of vehicles. Each system shall consist of the video camera(s), lightning arrester for video cabling, an ACU, a track ball, software and license, if applicable, for system control via a computer, one dial-up modem, 56.6 kilobytes per second maximum connection and V.90 compliant and a monitor. All camera views shall be obtainable without requiring the disconnection and reconnection of cables within the system.

1092.4.7.7.2.1 System Software. The system shall include software that detects vehicles in multiple lanes using only the video image. Detection zones shall be defined using a video monitor and a pointing device to place the zones on a video image, which may include a laptop computer. A minimum of 12 detection zones per camera shall be available.

1092.4.7.7.2.2 Automatic Control Unit. The bus connections used to interconnect modules of the ACU shall be gold-plated DIN connectors. Serial communications to a computer shall be through an RS-232/RS-422 serial port. The port shall have the capability to access detection system data as well as the real-time imagery needed to show detector actuations. A subminiature "D" connector on the front of the ACU shall be used for serial communications with a computer running supplied system software.

1092.4.7.7.2.2.1 The equipment shall be provided with either a NEMA TS1 or NEMA TS2 interface as shown on the plans.

1092.4.7.7.2.2.1.1 For TS1 systems, the ACU process unit shall be equipped with a TS1 detector interface for a minimum of 16 detector outputs or 32 detector outputs, if required by specifications. NEMA red/green inputs for each phase shall be available to provide delay/extend functions, either through the detector or the controller. Logic output levels shall be compatible with the TS1. A subminiature "D" connector on the front of the ACU shall be used for interfacing to these outputs.

1092.4.7.7.2.2.1.2 For TS2 systems, the ACU processor unit shall be equipped with a TS2 Type 1 detector interface, where detector information is transmitted serially via an RS-485 data path. NEMA red/green inputs for each phase shall be available to provide delay/extend functions, either through the detector or the controller. A 15-pin subminiature "D" connector, meeting the requirements of the TS2 standard, shall be used for the serial detector output. A minimum of 32 detector outputs will be required.

1092.4.7.7.2.2.2 The video detection system shall be provided for either single camera or multiple camera installations as shown on the plans.

1092.4.7.7.2.2.2.1 For single camera installations, the ACU shall have an RS-170 (NTSC) video input to process the camera or any other synchronous video source in real-time. The ACU shall have an RS-170 (NTSC) video output.

1092.4.7.7.2.2.2.2 For multiple camera installations, the ACU shall have a minimum of four RS-170 (NTSC) composite video inputs to process the synchronous video cameras or any other synchronous video source in real-time. A fifth video input shall be provided to allow connection of a local surveillance camera or other non-detection video source. The video from the auxiliary input shall not be processed for video detection. The ACU shall have an RS-170 (NTSC) composite video output, which may correspond to any of the video inputs, as selected remotely via RS-232 or locally by front panel switch. Multiple video inputs requiring external cable connections will not be permitted.

1092.4.7.7.2.2.3 The ACU or computer shall store a minimum of two separate detection zone configurations. The ACU shall be capable of switching to any of the different detector patterns at the request of the user and shall be a menu selection with a track ball.

1092.4.7.7.2.3 Monitor. The monitor shall have a 9-inch screen, an NTSC-M system and BNC video in-out connections.

1092.4.7.7.2.4 Video Camera and Housing. The ACU supplier shall furnish the video camera for traffic detection. The camera shall produce a video image of vehicles under normal roadway lighting conditions regardless of time of day. The video shall produce a clear image for scenes with a luminance from 0.009 to 929 footcandles.

1092.4.7.7.2.4.1 The camera shall provide a minimum resolution of 500 lines horizontal and 350 lines vertical.

1092.4.7.7.2.4.2 The camera shall include an electronic shutter or auto iris control based on average scene luminance and shall be equipped with an auto iris lens.

1092.4.7.7.2.4.3 The camera shall have a variable focal length. The maximum aperture of the lens shall not be smaller than f1.8 and the minimum aperture shall not be larger than f300. The camera shall have a horizontal field of view ranging from a minimum angle of view between 5 degrees and 10 degrees wide to a maximum angle of view 45 degrees or more. The adjustments for focus and focal length shall be made without opening up the camera housing.

1092.4.7.7.2.4.4 The camera shall be contained in an enclosure that is waterproof and dust-tight to NEMA-4 specifications. A heater shall be incorporated in the camera to prevent the formation of condensation and to assure proper operation of the lens' iris mechanism. The heater shall not interfere with the operation of the image sensor electronics and shall not cause interference with the video signal. The enclosure shall allow the camera to be rotated in the field during installation.

1092.4.7.7.2.4.5 The housing shall be equipped with a sun shield that prevents sunlight from directly entering the lens. The sun shield shall include a provision for water diversion to prevent water from flowing in the camera field of view.

1092.4.7.7.2.4.6 The total weight of the enclosure, camera, lens, housing, sun shield and mounting bracket shall be less than 10 pounds.

1092.4.7.7.2.5 Cable. Coaxial cable shall be a 75 ohm, precision video cable with 20 AWG solid or stranded bare copper conductor, maximum of 10.1 ohms/m Nom. direct current resistance, solid polyethylene insulating dielectric, 96 percent minimum tinned copper double-braided shield with a black polyethylene outer covering. The signal attenuation shall not exceed 0.8 decibels per 100 feet at 10 megahertz. Nominal outside diameter shall be 0.305 inches. The cable shall be in accordance with Belden Type 8281, West Penn P806 or approved equal.

1092.4.7.7.2.5.1 Seventy-five ohm BNC plug connectors shall be used with coaxial cable. The supplier of the video detection system shall approve the coaxial cable, BNC connectors and crimping tool. The manufacturer's instructions shall be followed.

1092.4.7.7.2.5.2 Multi-conductor cable shall be per the manufacturer's recommendations and in accordance with Sec 1061.

1092.4.7.7.2.6 Maintenance and Support. The supplier shall maintain an ongoing program of technical support and software updates for the video detection system following expiration of the warranty period. The supplier shall maintain an adequate inventory of parts to support maintenance and repair of the video detection system.

1092.4.7.7.2.7 Warranty of Video Detection System. The video detection system shall be warranted to be free of defects in material and workmanship for a minimum of two years. During the warranty period, technical support from factory certified personnel or factory certified installers shall be available from the supplier. Ongoing software support by the supplier shall include updates for the ACU and computer software and shall be provided at no cost to the Commission during the warranty period. The update of the ACU software to be National Transportation Communications for ITS Protocol (NTCIP) compliant shall be included.

1092.4.7.7.2.8 Training of Video Detection System. A minimum of one day of training shall be provided in the operation, setup and maintenance of the video detection system.

1092.5 Detector Loop Sealant. Loop sealant shall have the following minimum characteristics:

(a) The loop sealant used to fill the saw cuts and other gaps shall be of a type intended for and designed to be used as traffic loop embedding. The sealant shall be designed for installation when the surface temperature of the roadway is between 40 and 120 F and exhibit minimal shrinkage and stringing during and after installation. The curing time of the sealant shall be a maximum of 72 hours. Cured sealant shall retain permanent flexibility to 0 F, be temperature stable and ensure the integrity of the loop detector installation from -40 to 200 F. The loop sealant shall adhere to the roadway pavement and resist the effects of weather, including freeze-thaw cycles, de-icing chemicals, salts, gasoline and motor oils, such that the operation of the detector is not affected.

(b) The three types of allowable loop sealant will be two-part polyester resin, one-part moisture curing polyurethane and hot-melt bituminous.

(c) The loop sealant shall provide a minimum shelf life of nine months. Prior to the installation of any detector loop sealant, the MSDS or an OSHA Form 20 along with the manufacturer's technical data sheet, shall be submitted to the engineer. Any sealant used on loop detectors shall meet the approval of the engineer.

1092.6 Warranty. All traffic controller assemblies, excluding video detection systems, shall be warranted by the manufacturer to be free from defects in workmanship and material for at least one year from the date of project acceptance. Any components found to be defective during the warranty period shall be replaced free of charge. All warranties provided shall be transferred to the Commission upon project acceptance. Video detection systems shall be warranted in accordance with Sec 1092.4.7.7.