

SECTION 815
TRAFFIC CONTROL SIGNALS
DESCRIPTION

815.20 General.

This work shall consist of furnishing and installing or modifying at each location, traffic control signals ready for operation.

Included in the work is the furnishing and installing or modifying existing traffic signal control equipment, signal heads, electric lamps, pedestrian push buttons, control equipment, vehicle detectors, posts and bases, poles, pedestals, mast arms, strain pole and span wire assemblies and all incidental materials (included in Section 801 and 813) necessary for operating the traffic control signals.

This work shall also include furnishing and erecting any pertinent signs and all painting required to complete the installation. The removal, salvage, stockpiling, reinstallation or transporting of existing traffic installations will be covered under this section and appropriate pay items where applicable.

The locations of signal heads, controllers, standards and appurtenances shown on the plans are approximate and exact locations will be established by the Engineer in the field.

The responsibility for the exact and satisfactory installation of traffic signals shall rest with the Contractor and work performed, if not acceptable to the Engineer, shall be executed to the satisfaction of the Engineer by the Contractor at the Contractor's expense.

All electrical equipment shall be designed, manufactured and tested in accordance with the applicable standards of the ANSI, EIA, FSS, IMSA, ITE, NEMA, UL and these Specifications.

Unless otherwise designated on the plans, on the Standard Drawings for Traffic Signals as set forth in the Special Provisions, and as specified herein, all work and materials shall conform to the requirements of the Massachusetts Electrical Code herein referred to as the electrical code.

Wherever reference is made to codes or standards mentioned above, the reference shall be construed to mean the code or standard that is in effect on the date of advertising of the project.

All electrical connections, splicing, grounding, resistance tests, service connections and circuit identification shall be done by a licensed electrician holding "Certificate B" issued by the State Examiners of Electricians.

Standard symbols and construction details for traffic signal installations are shown on the current Traffic Signal and Highway Lighting Standard Drawings.

Within 30 days following execution of the Contract, the Contractor shall submit to the Engineer for approval, a list of equipment he/she proposes to install. The submission shall include all equipment identified on the plans or in the specifications by the name of the manufacturer, model or identifying number of each item. The list shall be supplemented by catalog cuts and such other data as may be required, including wiring diagrams of any special equipment and any proposed minor deviation from the plans. All the above data shall be submitted in triplicate for checking. Following checking, correction and review, not less than five (5) complete approved sets shall be resubmitted to the Engineer for distribution. The Department shall not be liable for any material purchased, labor performed, or delay to the work prior to such review and approval.

The Contractor shall provide the Department, within 10 days of receipt of approval, written proof that he/she has ordered the Traffic Control Signal Devices required by this Section.

Shop drawings are required for all structural support materials and fabricated items that are not specifically detailed on the plans. Shop Drawings are not required for items that are on the Department's "Approved Equipment List."

The warranties that the Contractor receives from each manufacturer of equipment and materials pertinent to the complete and satisfactory operation of traffic signal installation shall be turned over to the Department at the time of acceptance of the project, at no cost to the Department. Each warranty so furnished shall indicate its expiration date, and be in effect for a minimum period of one year from the date traffic signals were placed in continuous operation.

If within one year from the date the traffic signal system is placed in continuous operation the equipment and materials do not meet the warrants specified above and the Engineer notifies the manufacturer or his/her authorized representative promptly, the manufacturer or his/her authorized representative thereupon shall correct any defect either by repairing or replacing any defective part or parts, at no cost to the Department.

The Contractor shall, at his/her own expense, replace any part of the traffic signal control equipment found to be defective in workmanship, material or manner of functioning within six months from the date of final acceptance of all the installations.

It is the intent of the Plans, Specifications and Special Provisions to provide a complete traffic control signal system throughout the project.

It is not intended that every fitting, minor detail or feature be shown and described, as the assumption is made that either the Contractor or his/her Subcontractor is an expert in the particular area of responsibility and is capable of interpreting the plans, specifications and special provisions so that the bid shall include all items required and that they shall be provided and installed in a neat and workmanlike manner.

Any installation of wiring by the Contractor will be performed by licensed electricians.

815.21 Equipment.

All new equipment including controllers with cabinets, vehicle detectors and detector amplifiers shall be furnished, except as noted, and installed by the Contractor. When equipment and materials are to be furnished the Contractor by the Department, the equipment and materials will be made available to him/her at the project site.

No equipment or accessories specified in Section 815 will be accepted unless type tested and approved by the Department prior to the date of the proposal.

The Department will list annually all equipment and accessories that have been type tested approved and/or approval withdrawn.

Such approval by the Department of equipment or accessories, however, shall not relieve the Contractor of any responsibility required under Section 5.00. All approvals will be conditional and the Department reserves the right to withdraw its approval of equipment or accessories at any time for any of the following reasons:

- a. Delivery of equipment or accessories which do not meet requirements of Section 815.
- b. Equipment or accessories with abnormal maintenance and performance records.

MATERIALS

815.40 General.

The materials required are those specifically covered in the plans and in accordance with Division III of the Standard Specifications.

Any and all signs required shall conform to Section 828 of the Standard Specifications and the Manual on Uniform Traffic Control Devices.

Unless otherwise indicated on the plans or specified in the Special Provisions, all materials shall be new and of the latest design.

Any equipment that has been type tested and approved by the Department (Subsection 815.21) will be considered as meeting these specifications.

Where existing systems are to be modified, the existing equipment and material shall be incorporated in the revised system, salvaged or abandoned as directed by the Engineer in writing.

815.41 Controllers.

A. General.

1. Operate on a power input of 120 volts, single phase, 60 hertz, alternating current.
2. Capable of operating in a coordinated system with preemption equipment, supervised in a master system, without major internal wiring modifications.
3. Be housed in a weatherproof cabinet of adequate size as specified hereinafter. The cabinet shall be furnished as a housing for the controller, auxiliary equipment and terminal facilities and conform to the following electrical and mechanical requirements.
 - a. Doors – The cabinet shall have a main door equipped with a keyed tumbler lock of the type in current use by the Department and an auxiliary door equipped with a conventional police lock and key. Two keys shall be furnished with each lock. Door hinge pins shall be made from stainless steel.
 - b. Switches – Panel behind the auxiliary door shall be provided with the following switches:
 1. Main power switch.

2. A switch to change from automatic to flashing operation or vice versa, with the controller power "off" in flashing operation.
3. A switch to energize the controller while the signal lights are "off" or on "flashing operation" (accessible only when main door is open). This switch shall be interlocked with the above switch so that the controller must go through the start-up sequence when going from flashing operation to automatic operation (unless prohibited by the conflict monitor). All switches shall be labeled as to function.
 - c. Vents – Cabinets shall be equipped with screened rain-tight "T" vents 40 millimeters or larger for pre-timed controllers. Cabinets containing vehicle actuated controllers shall be equipped with a thermostatically controlled fan and filtered vents.
 - d. Shelves – Cabinets shall be fitted with two (2) substantial shelves or brackets to support the controller and auxiliary equipment.
 - e. Radio Interference – Controllers, flashers or current interrupting devices shall be equipped with suitable radio interference suppressors. The Contractor shall, if notified by the Department of such interference, provide and install the additional equipment necessary to eliminate the interference.
 - f. Flasher – Each cabinet shall be provided with a solid state electronic device capable of providing flashing operations at the rate of 50/60 flashes per minute. Flasher device shall be furnished mounted on a plug-in-base with plug-in mounting. The device shall be capable of normally producing "flashing yellow" indications for all signals facing the main street and "flashing red" indications for signals facing the cross streets, or in a combination specified. The output load rating with incandescent lamp load shall not be less than 15 amperes. The "automatic" to "flash" switch specified in b-2 above shall be wired in such a manner that no pedestrian indications will show during flashing operation.
 - g. Circuit Breaker – A two-pole, solid neutral circuit breaker panel for power service shall be mounted in the cabinet.
 - h. Wiring – All cabinet wiring shall be neat and firm and the following installed in the cabinet:
 1. Unfused terminals for neutral side of power supply.
 2. Terminals for signal light cables, one for each signal circuit and one for more terminals for the common conductor.
 3. Terminals for detectors, pedestrian push-buttons, controllers, auxiliary equipment, field conductors, overlap outputs, plus an additional ten (10) terminals for spares.
 4. Terminals for interconnecting cables (when required).
 5. All terminals shall be suitably identified.
 6. A flexible cable shall be furnished for connecting the controller to the cabinet terminals.
 7. Signal light load switches (number as required by type of controller).
 8. Convenience outlet, Standard 3-wire grounding duplex receptacle, 20 amperes capacity, with integral ground fault interrupter.
 9. Overload protection for all wiring and auxiliary equipment.
 10. Surge protector for protecting equipment against over-voltage transients, caused by manmade or natural sources.
 11. Three power service unfused terminal connections (AC-, AC+ and ground) having the ability to connect No. 6 AWG conductor.
 - i. Meter Socket – Each cabinet shall be provided with a standard residential meter socket with no knock-out on top. The rating shall be 125 Amps, 100 Amps continuous, 600 VAC, CU/AL rated. The meter socket shall be attached and electrically grounded to the cabinet.

B. Actuated Controllers.

Traffic actuated controllers shall consist of a complete assembly of the following elements:

1. Controller Unit (Dispatcher or Timer)
2. Interface Requirements
3. Terminals and Facilities
4. Solid-State Load Switches
5. Solid-State Flashers
6. Voltage/Conflict Monitors
7. Auxiliary Equipment
8. Cabinets
9. Cabinet Foundations and/or Anchor Bolts

10. Technical Manuals and "Box Prints"

The first eight (8) elements of the controller assembly shall be wired to perform all the controller signal operations for the specific type of controller specified.

1. Controller Unit (Dispatcher or Timer).

a. The controller unit shall meet all applicable requirements of the National Electrical Manufacturers Association (NEMA) Standards contained in NEMA Publication No. TS-1 current edition and the following:

b. Be in compliance with Section 815.21, Equipment.

c. All controllers units shall provide solid-state timing circuits utilizing power line frequency as a base.

d. All timing and control parameters, *except time clock operation*, shall be retained in memory when power is "off", battery-backup to retain memory will not be accepted.

e. The controller units shall be modular or integral keyboard entry type.

f. Modular Controller Units

Operator programmable data entry adjustments for the modular units shall be accomplished through thumb-wheel, pin or keyboard devices located on the front panel of the unit. All plug-in modules of like function shall be interchangeable between 2 to 4 phase frames and 2 to 8 phase frames.

All modules of unlike function shall be keyed and electrically interlocked to prevent insertion or operation in a slot not designed for its use and to prevent malfunctions.

g. Integral Keyboard Entry Controller Units

Operator programmable data entry adjustments for integral keyboard entry units shall be accomplished through a front panel keyboard and a liquid crystal display. The unit shall utilize a menu driven format which shall list, in English, the major categories of programming data. Once the user selects the appropriate category the program shall provide prompting for additional keystrokes until full programming is accomplished. The integral keyboard entry unit shall have the capacity of operating in either a single ring or dual ring mode with two through eight phase control. The unit shall be capable of either sequential or concurrent phase control. Overlap phases shall be programmable through the keyboard. The unit shall be capable of operating as a volume density controller and shall also have internal time base coordination (TBC). The coordination control shall conform to Subsection 815.41.F.3. The keyboard entry controller unit shall have a security code function and internal pre-emption control capabilities. The phase or phases selected for "call to nonactuated" (CNA) modes shall be determined as needed by keyboard entries. The keyboard entry controller unit shall have a standard RS-232 serial port for data transfer to another controller or printer. A data transfer/printer cable shall be included with the controller.

2. Interface Requirements.

a. The controller frame types listed in Table 2 shall meet all the applicable interface requirements of NEMA Standard TS-1, Section 13.

3. Terminals and Facilities.

a. Each electrical terminal within the facility shall be identified with nomenclature that corresponds to the nomenclature on the controller assembly wiring diagram. Terminal nomenclature shall be adjacent to terminals. All load switches, relays, flashers, circuit breakers, fuses and switches within the facilities shall be identified with nomenclature on the controller assembly wiring diagram.

b. All functional points on the connectors of the controller units shall be terminated in the facilities.

c. All conflict monitor input channel leads that can be used to monitor the maximum number of signals available in a given configuration shall be terminated on terminal strips in the cabinet.

d. The facilities shall be so wired that the intersection will revert to flashing operation if the conflict monitor is disconnected.

e. Unless otherwise specified, loop detector leads and harnesses will be required and shall be terminated (4-harnesses for 2-to-4-phase frames and 8-harnesses for 2-to-8-phase frames).

f. Fully-programmable wired load switch sockets with load switches, flash transfer relay sockets with relays, and dual circuit flasher socket with flasher shall be provided in quantities shown in Table 2.

g. When specified, programming automatic transfer from normal operation to flashing operation (Uniform Code Flash), shall comply with the requirements of the MUTCD Section 4B-18, Flashing Operation of Traffic Control Signals.

h. It shall be possible to easily change the flash indications (Flashing Yellow to Flashing Red or vice-versa) and load switch positions (Overlap to Pedestrian or vice-versa) from the front side of the terminal facilities using only simple tools without the need to unsolder or resolder connections.

i. A support shall be provided so that, as a minimum, it is supporting the flasher and load switches at some

point between 75 millimeters and 200 millimeters from the panel surface. At least 90% of the area beneath the load switch and flasher shall be open to allow for the free flow of air across the load switches and flasher (see NEMA TS-1, Section 10 for other requirements).

4. Solid-State Load Switches.

- a. The solid-state load switches shall be a modular assembly containing three (3) solid-state switch packs.
- b. The front panel shall be provided with three indicators to indicate the state of the input circuit of the load switch.
- c. Each switch pack shall be readily serviceable by the use of a screwdriver or small hand tools without soldering or unsoldering connections.
- d. Load switches shall meet requirements of NEMA Standard TS-1, Section 5.

5. Solid-State Flasher.

- a. Solid-state flashers shall meet the requirements of NEMA Standard TS-1, Section 8 for Type 3, 15 ampere, dual-circuit. Load switch packs shall be serviceable as in 4. above.

6. Voltage/Conflict Monitors.

- a. Voltage/Conflict monitors shall meet the requirements of NEMA Standard TS-1, Section 6, as follows:
 1. Type 6 – for 2-to-4 phase frames.
 2. Type 12 – for 2-to-8-phase frames.

7. Auxiliary Equipment.

- a. Space shall be provided for all shelf mounted auxiliary equipment including harnesses, cables and space for equipment with maximum dimensions of 175 millimeters high by 275 millimeters deep by 310 millimeters wide.

8. Cabinet (Aluminum).

- a. Cabinets shall be fabricated from 5052-H32 sheet aluminum alloy at least 3 millimeters thick and adequately reinforced. It shall be of all-weather construction.
- b. Meet the applicable requirements listed under A. General.
- c. The convenience outlet required by this section shall have integral ground fault interrupter.
- d. An incandescent light, with switch shall be installed in the cabinet (switch to be installed next to test switch).
- e. Detector test switches shall be provided on the back of the door inside the cabinet (100 millimeter Type CB cabinets and 200 millimeter Type CC and CD cabinets).
- f. The cabinet shall be equipped with a door stop assembly to hold the door open at approximately 90 degrees and 180 degrees.
- g. The cabinet shall be equipped with a thermostatically controlled fan assembly (adjustable between 30 °C and 65 °C) with a minimum capacity of 3.0 cubic meters per minute. The fan shall be mounted in the top of the cabinet in a manner to prevent rain, snow or insects from entering the cabinet.
- h. Each cabinet shall be provided with a filtered louver vent in the front door. A UL listed vent filter shall be supplied which is odorless and fireproof. The filter shall contain a metal grill for protection. Filter resistance shall be rated at 90 meters per minute of air at 1.5 millimeters water column.
- i. All surfaces of the cabinet and doors shall be painted a minimum of two (2) coats of aluminum paint, excluding primer, as follows:
 1. Cabinets that come from the manufacturer with one or more coats of paint (excluding primer) will be accepted, if there are no scars and abraded areas.
 2. If cabinets show any scars or abraded areas the Contractor shall repair these areas and apply one (1) coat of aluminum paint.

9. Cement Concrete Cabinet Foundations and/or Anchor Bolts.

- a. All cabinets shall be complete with 19 millimeter x 400 millimeter anchor bolts, 2 for Type CA or CB cabinets and 4 for Type CC or CD cabinets.
- b. When new cement concrete foundations are required they shall be constructed in accordance with section 801.

10. Technical Manuals and “Box Prints.”

The following documentation shall be provided prior to final acceptance as furnished by the manufacturer.

- a. Controller Unit, Flasher, Load Switches, Conflict Monitor and all external logic units.
 1. Electronic schematic of circuit boards.
 2. Pictorial layout of components on circuit boards.

3. Service manual for troubleshooting.
4. Manual describing the theory of operations.
5. Parts list showing manufacturers part number and location.
- b. Controller cabinet.
 1. Cabinet wiring diagram.
 2. Field wiring diagram.

The following types of controllers shall be furnished, as specified:

Type 2DW to 4DW – A 2 to 4-phase full-vehicular-actuated or semi-vehicular-actuated control device, that in response to vehicular actuation from all streets, transfers the right-of-way from one phase to another as the movement of traffic on all streets demands and with a separately adjustable timing for the pedestrian portion of combined pedestrian-vehicular phase for all phases and with the addition of adjustable timing capable of increasing and decreasing the various time intervals due to variation in volume of moving and waiting traffic (Use Type 4DW Controller).

The minimum timing requirements for adjusting of time intervals are shown in Table 1.

Type 5DW to 8DW – A 2 to 8-phase control device as specified for Type 2DW to 4DW with four additional phases added (Use Type 8DW Controller).

The minimum timing requirements for adjusting of time intervals are shown in Table 1.

All vehicular actuated controllers shall be installed in a weatherproof outdoor cabinet of adequate size to house the controller, load switching assemblies and any other auxiliary equipment required by the plans and specifications.

The nominal minimum size cabinets for controllers shall be as follows:

Type CA – Cast Alum. Base Mounted (350 millimeters x 700 millimeters x 1200 millimeters) Approx.

Type CB – Sheet Alum. Based Mounted (400 millimeters x 700 millimeters x 1150 millimeters) Approx.

Type CC – Sheet Alum. Base Mounted (600 millimeters x 950 millimeters x 1350 millimeters) Approx.

Type CD – Sheet Alum. Base Mounted (600 millimeters x 950 millimeters x 1800 millimeters) Approx.

**TABLE 1
 NOMINAL MINIMUM TIMING REQUIREMENTS FOR CONTROLLERS**

The following functions, with the associated minimum timing ranges and maximum increments, shall be provided as a minimum when required by the application listed under Controller Type number in Table 2.

Function	Range (seconds)	Increment (seconds)
Minimum Green (Initial)	1 - 30	1
Passage Time (Vehicle)	0* - 9	0.25
Maximum 1	1 - 99	1
Maximum 2	1 - 99	1
Yellow Clearance	0* - 7	0.25
Red Clearance	0* - 7	0.25
Walk (W)	1 - 30	1
Ped. Clearance (FDW)	0* - 30	1
Added Initial	0* - 3 per act.	0.125
Time to Reduce	1 - 60	1
Time Before Reduction	1 - 60	1
Minimum Gap	0* - 7.75	0.125

* Note: Zero shall be satisfied by any time between zero and 100 milliseconds.

TABLE 2

Controller Type	4DW	8DW
Frame Type	2-4	2-8
Conflict Monitor Type	6	12
Vehicle Load Switches	4	8
Ped. Load Switches	1	3
Overlap Load Switches	3	1
Flash Transfer Relays	4	6
2-Cir. Flasher (15A)	1	1
Power Cir. Breaker	30A	50A
Cabinet MHD Type	CB	CC

Note 1: Type 5DW to 8DW Controllers may require external logic to produce an exclusive pedestrian phase.

Note 2: CB cabinets are to be wired for 2 - 4 phase frames.

CC cabinets are to be wired for 2 - 8 phase frames.

C. Pre-Timed Controllers.

1. A pre-timed electro-mechanical controller assembly shall consist of a controller, flasher and other equipment as specified in contract documents, that are wired in a controller cabinet to make a complete and operational traffic controller assembly.

2. A pre-timed solid-state controller assembly shall consist of a controller, load switches, a flasher, a conflict/voltage monitor and other equipment as specified in contract documents, that are wired into a controller cabinet to make a complete and operational traffic controller assembly. Pre-timed solid-state controller assemblies shall meet all applicable requirements of the elements listed under B. Actuated Controllers.

The following types of controllers shall be furnished as specified:

Type 11A or 11B – a multi-dial device which shall be of the type capable of being operated as an isolated unit, as a unit in a non-progressive system, or when specified, a unit in an interconnected progressive system equipped to provide an omissible push-button actuated exclusive pedestrian phase without any physical changes to the controller required. Unless otherwise specified, each controller shall be furnished with 3-dial units with 3-offsets per dial for Type 11A and equipped with master supervisory contacts to provide supervision for an interconnected system for Type 11B.

Type 12A, 12B or 12C – Multi-cycle length, multi-cycle split, and multi-cycle offset control device arranged to operate with a master controller and capable of operating in any split, cycle and offset selected from a central source or at the controller itself for Type 12A, equipped with master supervisory contacts capable of operating as a master-local for Type 12B and equipped with master supervisory contacts capable of operating as a master only for Type 12C.

Type 13 – A single dial control device which shall be of the type capable of being used as an isolated unit, when specified, or as a unit in an interconnected progressive system where exclusive pedestrian control is required. This controller shall be of the alternate sequence type providing for a constant total cycle length. Time required for the exclusive push-button actuated pedestrian phase shall be deducted from the latter part of the main street green interval.

Type 14 – A single dial control device which shall be of the type capable of being used as an isolated unit where exclusive pedestrian control is required. This controller shall be of the alternate sequence type with the time required for exclusive push-button actuated pedestrian phase added to the total time cycle. This controller shall not be used in an interconnected system.

Type 15A or 15B – A single dial control device which shall be of the type capable of being used as an isolated unit, or when specified, as a unit in an interconnected progressive system at mid-block locations for Type 15A or at an intersection for Type 15B, where exclusive pedestrian control is required.

Type 16 – A master controller supervising a series of controllers of various types into a traffic adjusted interconnected coordinated system. When this type of controller is required special provisions will be prepared for the particular project.

Unless otherwise specified, all the above controller types shall be installed in weatherproof metal cabinets of

the type regularly supplied by the manufacturer, pre-timed electro-mechanical controllers shall be supplied with a complete set of timing gears (60-70-80-90-100-110-120 seconds) for all timing dials contained therein.

Cabinets shall be fitted with the necessary adapters to permit post top mounting on a standard signal post or in a ground mounted cabinet.

D. Railroad Pre-emptors.

In response to remote instructions, the pre-emptor shall stop controller timing and start pre-emption timing, the pre-emptor shall simultaneously select and time the proper signal indications for the protection interval, as shown on the plans. Pre-emption equipment may be housed in a separate cabinet.

E. Time Switch (Type TS-4).

A Type TS-4 time switch is a four (4) circuit solid-state device that controls multiple daily operations on a weekly schedule and may be instructed to suspend operations when programmed.

The elements of the Type-4 Time Switch are as follows:

1. Precision Time Reference.

The time reference shall be accomplished by digital methods using 60 Hertz power line frequency as a time base when power is present and a crystal controlled oscillator back-up source when power has failed or the time reference may be the digital encoded time signal that is broadcast by the National Bureau of Standards.

In the event of power failure, all programs and relationships shall be held in memory, without modification, or the use of batteries, for at least forty-eight (48) hours. The back-up source shall have an accuracy of 0.005% or greater.

2. Time Clock.

The time clock shall be provided with four (4) independent circuits which are controlled by pre-programmed time of day events. The time of day shall be accurately set to the nearest second. Time of day, day of week, date, year and the operation of the four (4) relay outputs shall be easily set from the integral keyboard. All data required to properly set and program the clock and review the stored program shall be clearly displayed. The time clock shall be capable of remembering a minimum of twenty (20) program steps. A program step is defined as the time of day and the day or days of the week for which the relay outputs shall be turned on or off. The time clock shall be capable of initiating a minimum of ten (10) basic program plans. The time clock shall automatically compensate for daylight saving time (DST) and eastern standard time (EST) changes.

3. Outputs.

The time switch shall have four (4) single pole, double throw relay outputs with a contact rating of at least 10A at 120 VAC resistive load. Skip plan relay control shall be limited to one (1) output relay. Interface to the power line and the controlled device shall be by suitable connectors and cabled wire harness at least 1.2 meters long. Each conductor shall be a minimum of #18 AWG with 600 volt insulation suitable for at least 90 °C.

4. Physical.

The time switch shall be provided with a case. The case shall be provided to protect the circuits from dust, and shall be fastened securely to the unit and be easily removable for servicing. At least two (2) mounting holes shall be provided for mounting to a suitable backplate. Holes shall provide clearance for at least a No. 10 screw. In addition to the above mounting required, a mounting adaptor plate shall be provided to simplify mounting in crowded cabinets.

5. Power Requirements.

The time switch shall perform under the following conditions:

- a. Voltage – 95 to 135 VAC, nominal voltage 120 VAC.
- b. Frequency Range – 60 Hertz plus or minus 3.0 Hertz.

6. Documentation.

A complete set of operating and maintenance instructions shall be provided with each unit.

F. Special Function Units.

1. Master Control Units.

These units (solid-state or electro-mechanical) shall be designed to perform such functions as coordination, detector switching preemptor, double clearance timing and other functions as may be required by complex traffic control signal systems. When these types of units are required plans and special provisions will be prepared for the particular projects.

2. Time Base Coordination Units (TBCU).

The TBCU shall coordinate control equipment to achieve the coordinated operation of an intersection with other intersections without the use of wire or cable between intersections. The elements of the TBCU are as follows:

a. Precision Time Reference.

The time reference shall be accomplished by digital methods using 60 Hertz power line frequency as a

time-base when power is present, and a crystal controlled oscillator back-up source when power has failed or the digital encoded time signal that is broadcast by the National Bureau of Standards. In the event of power failure, time of year, all programs, and synchronization relationships, shall be held in memory, without modification, for at least 100 hours. The back-up source shall have an accuracy of 0.005% or greater.

b. Time Clock.

The time clock shall operate on a fifty-two (52) week cycle that is easily programmed to the nearest second of the week, day, hour, and minute of the year. The fifty-two (52) week cycle shall begin with week zero (0) and return to week zero (0) after week fifty-one (51). Days of the week shall cycle Sunday day zero (0) through Saturday day six (6). Hours of the day shall be on a twenty-four hour basis with double zero (00) being midnight. The clock shall make automatic correction for Daylight Savings Time and return to Standard Time at user programmed times, programmed at the start of week zero (0) of the one (1) year cycle.

c. Programmable Microprocessor.

The TBCU shall provide for programming of all timing and operation parameters as follows:

(1) Cycle and Offset.

The TBCU shall be capable of providing four (4) cycle lengths adjustable from 030 to 255 seconds in one (1) second increments. At least three (3) smoothing routines shall be provided and be user programmable to smooth coordination plan cycle and offset change.

(2) Free/Flash.

Time selection of the "free" function shall cause the intersection controller to operate in the free mode. Time selection of "flash" function shall cause the intersection controller to operate in the "flash" mode, subject to the requirements of Section 4B-18 of MUTCD.

3. Coordination Control.

The TBCU shall be capable of providing coordination control methods of cycle select, offset select, yield/hold with force-off, phase omit, phase skip, permissive period, and similar control functions.

4. Program.

At least eight (8) programmable outputs shall be provided capable of being programmed to change its state (on or off) at any second of the year in one (1) second increments or change its state (on or off) on a per cycle basis with the TBCU capable of setting the duration of the cycle and the starting and ending times of the outputs. In addition, two of the eight outputs shall be capable of being programmed for up to eight (8) starting and ending times on a per cycle basis for NEMA Force-off Ring 1; Phases 1, 2, 3, 4 and Force-off Ring 2; Phases 5, 6, 7, 8 and/or Phase Omits. Sufficient user programmable memory shall be provided to allow implementation of the following program structure:

- a. 50 event times (a listing of times at which controlled events start or stop during a 24-hour period).
- b. 15 day programs (a listing of which outputs switch at which event time during a 24-hour period).
- c. 200 day program events (a listing of coordinating plan conditions or the time switching of an output).
- d. 5 week programs (a week program specifies which day program shall be used on each day of the week).
- e. 1 year program (specifies which week program shall be used on each week of the year).
- f. 30 exception days (an exception day causes a day program different from that in the year program to be used on a specific day).
- g. 4 cycle lengths (cycle lengths are the times in seconds of the coordinated background cycles).
- h. 12 offset values (a system reference for the start of an individual intersections coordinated phase green).
- i. 3 smoothing methods (select interrupter, short way, or maximum dwell smoothing of offset and cycle changes).
- j. Free/Flash (the controller may be time-switched to free of coordination control or to flash mode by time-switching).
- k. 2 Daylight Savings/Standard Time changes (a change ahead 1 hour and a change back 1 hour that can be programmed).
- l. 4 synchronization reference times (1 per cycle to start time of an external timing reference pulse).
- m. 4 programmable entries to define on and off times in percent of each cycle for outputs that

pulse 1 or more times each cycle.

5. Programming Methods.

To prevent accidental unauthorized changing of stored coordination plans it shall be required to enter a predetermined number code before memory can be entered, erased, or altered. However, it shall be possible to read all data stored in memory without entering the memory number access code. This memory shall be easily programmed by using any of the following methods:

a. Keyboard Entry

The keyboard entry shall give positive feedback to the programmer that a key was pressed and recognized.

b. Program Transfer

Any TBCU shall be capable of programming any other unit of the same make and model by plugging a simple transfer cable between the programmed unit and the unit to be programmed. If an error occurs during program transfer, this error shall be indicated and the unit shall erase itself.

6. Display.

The TBCU shall be capable of displaying any of its stored information, operation status, battery fail and power on/off.

7. Inputs/Outputs.

Eight NEMA "Phase-On" signal information shall be input to the TBCU to be used as enables for the two (2) eight pulses/cycle outputs to control force-off and/or phase omit outputs. The TBCU shall operate with any type of traffic signal controller using NEMA TS-1 compatible input and output levels and conventions. Each output shall be totally isolated from each other and from the internal logic circuitry. The TBCU shall contain monitoring circuitry to turn all output off whenever failures such as a processor malfunction, power supply out of regulation, invalid data in user memory, battery overly discharged, and program conflicts have occurred. Electrical connections to and from the TBCU shall be made by inserting a keyed mating connector. The TBCU shall be completely replaceable in the controller cabinet without the use of tools or the necessity of disconnecting and re-connecting individual wires leading therefrom.

8. Operating Standards.

The TBCU shall perform under the following conditions:

a. Voltage

95 to 135 Volts AC. The nominal voltage shall be 120 Volts AC.

b. Frequency Range

60 Hertz plus or minus 3.0 Hertz.

c. Power Interruptions

See NEMA TS-1 – 2.1.04.

d. Temperature and Humidity

See NEMA TS-1 – 2.1.05.

e. Power Service Transients

See NEMA TS-1 – 2.1.06 and 2.1.08.

f. Vibration

See NEMA TS-1 – 2.1.14.

g. Shock

See NEMA TS-1 – 2.1.15.

9. Housing.

Housing and hardware shall be manufactured from corrosion resistant materials. Circuit boards and assemblies shall be readily accessible for servicing and materials shall conform to the requirements of NEMA TS-1 – 4.2.02. All controls shall be on the front panel and including a fuse for line voltage input power, replaceable without disassembling the TBCU.

10. Harness.

All connections to external points shall be made through front panel connections and each TBCU shall have included a harness with mating connectors at least 2 meters in length.

815.42 Detectors.

A. Magnetic Detector Amplifiers and Sensors.

Magnetic detector amplifiers shall be entirely solid-state with the exception of the output relay, designed to operate in extremes of temperature and humidity. Front panel adjustments shall be provided to control sensitivity. The amplifier in combination with the sensors listed shall be capable of providing the following:

1. Multi-lane Sensor.

Non-directional, non-compensated, with a zone of influence 3.75 meters each side of sensor.

2. Single-Lane Sensor.

Non-directional, non-compensated, with a zone of influence 500 millimeters each side of sensor.

The magnetic detector amplifier and sensors shall conform to all applicable requirements of Section III of "A Standard for Vehicle Detectors," a revised standard of The Institute of Transportation Engineers.

B. Magnetometer Detector Amplifier and Sensors.

Magnetometer detector amplifiers shall be entirely solid-state with the exception of the output relay, designed to operate in extremes of temperature and humidity. Front panel adjustments shall be provided to control select mode of operation, calibrating the units and adjustment for hold time. The amplifier in combination with the sensors listed shall be capable of operating satisfactorily with the following sensors.

1. One (1) to six (6) sensors, cylindrical in shape no larger than 25 millimeters in diameter and 100 millimeters in length.

The magnetometer detector amplifier and sensors shall conform to all applicable requirements of Section IV of "A Standard for Vehicle Detectors," a revised standard of The Institute of Transportation Engineers.

C. Inductive Loop Detector Amplifier and Sensors.

Inductive loop detector amplifiers shall be entirely solid-state with the exception of the output relay, designed to operate satisfactorily with sensors embedded in a roadway. Inductive loop amplifiers shall conform to all applicable requirements of the National Electrical Manufacturers Association (NEMA) Standards Publication TS-1 (latest revision) for the following types:

1. Type 1 – Shelf-mounted, 1-channel detector unit, as specified, with delay and extension timing, relay output and powered from a 120 volt AC source. Units shall conform with the applicable requirements of NEMA TS-1, Sections 7, 11 and 15.

2. Type 2 – Shelf-mounted, 2-channel detector unit, as specified, with delay and extension timing, relay output and powered from a 120 volt AC source. Units shall conform with the applicable requirements of NEMA TS-1, Sections 7, 11 and 15 and the following:

Inductance Range – Any configuration of wire-loop sensor(s) and shielded lead-in, including series/parallel combinations having a total inductance up to 2000 microhenries with a maximum shielded lead-in length of 300 meters.

Tuning Adjustments – No tuning adjustments, units shall automatically self-tune within ten (10) seconds upon the application of power or following power interruption.

Sensitivity – Each channel of the unit shall be capable of detecting any valid vehicle over any test loop configuration described in NEMA TS-1, Sections 7, 11 and 15. A minimum of eight (8) sensitivity adjustments shall be provided for each channel.

Each channel MS connector output of the Type 1 and Type 2 detector units shall mate with cable connector MS 3106A-18-1S to be supplied with each unit (1-cable for 1-channel units, 2-cables for 2-channel units). Each connector cable supplied for each channel of each unit shall be ten (10) wire color coded and labeled A through J pin terminations as follows:

A. AC - Common	F. Output N.O.
B. Relay Common	G. Output N.C.
C. AC + Line	H. Chassis Ground
D. Loop Input	I. Delay/Extension Logic Ground
E. Loop Input	J. Delay/Extension Logic Input

Each cable shall be a minimum of 1.5 meters in length.

D. Ultra-Sonic Vehicle Detectors.

Ultra-sonic transceivers shall be entirely solid-state with the exception of the output relay, designed to operate in extremes of temperature and humidity. Front panel adjustments shall be provided to control range and gain. The transceiver in combination with a transducer shall be capable of providing the following:

1. Multi-Lane detection (Overhead mount)
2. Single-Lane detection (Overhead mount)
3. Multi-Lane detection (Side-fire mount)
4. Single-Lane detection (Side-fire mount)

Ultra-Sonic vehicle detectors shall conform to all applicable requirements of Section VI of "A Standard for Vehicle Detectors," a revised standard of The Institute of Transportation Engineers.

E. Pedestrian Push Buttons.

Pedestrian push buttons shall be of the tamper-proof type. They shall consist of direct push type buttons and momentary contact switch in a cast metal housing.

The assembly shall be waterproof and so constructed that it will be impossible to receive any electrical shock under any condition. The housing shall be shaped to fit the curvature of the pole to which it is attached, to provide a rigid installation. Saddles shall be provided to make a neat fit when required.

Immediately above each pedestrian push button a 125 millimeter x 200 millimeter (*nominal*) metal sign shall be installed on the crosswalk side of the post or pole.

815.43 Mast Arms – Strain Poles and Span Wire Assemblies.

A. General.

1. Mast Arms shall consist of a shaft complete with bracket arm, shaft cap, cable support (“J” hook), with or without transformer base as specified, signal head hanging device, and safety chain anchor lug. Unless otherwise specified mast arms shall be made of aluminum or steel.

The design includes two types of mast arms:

Type I – Arms with one signal at the end.

Type II – Arms with signals mounted at intermediate points and at the end.

The arms shall upsweep in design without tie-rods or overbracing. Arms shall be self-supporting (single member arm) or supported by an underbrace (truss). Arm upsweeps shall be limited to between 0 and 2 meters of rise from the lowest point of attachment to the pole to the tangent terminal point of attachment of the signal head hanging device. Unless otherwise specified, single member arms shall not be made of aluminum.

All mast arms shall provide for wiring entrances directly into the pole of shaft from inside the mast arm; there shall be no exposed wiring.

Nominal wall thickness of aluminum structural members shall be not less than 5 millimeters and for aluminum structural pole or shaft members not less than 6.4 millimeters. Steel structural members shall not be less than 5 millimeters.

All arms shall be provided with a lug for anchoring signal head safety chain.

2. Strain Pole and Span Wire Assemblies shall consist of galvanized steel strain poles, span wires, compression fittings, tether wires when specified, clamps, pole caps, wire entrances, disconnect hangers, signal head hanging devices, signal cable hanging devices, sign hanging devices when specified and all necessary miscellaneous materials to form a complete span wire assembly.

The design includes two types of span wire assemblies.

Type I – Span Wire Assembly with free swinging signals.

Type II – Span Wire Assemblies with Tether Wire.

Span Wire Assemblies shall conform to the requirements as shown on the Standard Drawings.

B. Support for Mast Arm Mounted and Span Wire Mounted Signal Heads.

Mast Arm Type I – The structure shall be designed to support free-swinging signal heads, of 0.5 square meters projected area having a mass of 75 kilograms at the extreme end of the 6.0, 7.5, 9.0, 10.5, or 12 meter arms as shown on the plans. For signal heads over 0.5 square meters projected area, see Type II below.

Mast Arm Type II – When free-swinging signal heads over 0.5 square meter projected area, or fixed signal heads at the extreme end of the arm, or at intermediate points on the arm are specified, requirements will be as shown on the plans and/or Special Provisions. Acceptance of the Type II Mast Arm will be contingent upon the review and approval of shop drawings submitted by the Contractor.

Span Wire Assemblies Type I and Type II – Requirements will be shown on the plan and/or Special Provisions.

Acceptance of Type I or Type II Span Wire Assemblies will be contingent upon the review and approval of shop drawings submitted by the Contractor.

All structures shall be designed and constructed in accordance with the requirements of AASHTO “Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals” (Current Edition) for a wind speed of 150 kilometers per hour.

All structures shall be constructed in accordance with the applicable requirements of the Department’s Standard Drawings.

C. Anchor Bolts.

Anchorage shall consist of four or more high strength steel bolts positioned and designed to withstand the forces corresponding to the moment which will cause failure to the shaft.

Bolts shall be of the proper size, length and design to develop proper bond in transferring loads to the cement

concrete foundation.

Anchor bolts shall be furnished with a template.

Each anchor bolt shall have two (2) hex nuts, two (2) flat washers and one (1) lockwasher to facilitate leveling of the shaft. Anchor bolts shall be galvanized.

D. Finish.

The bracket arms shall be furnished with a finish compatible to that of the shaft to insure uniformity of appearance. The exterior of the shaft and bracket arm shall be free of protuberances, dents, cracks, discoloration and other imperfections marring their appearance.

For shipping purposes, the shaft and bracket arm shall be protected to preserve the finish.

815.44 Post and Bases.

Standard Signal Post shall consist of a 100 millimeter shaft complete with an octagonal base (2.5 meters or 3.0 meters long including base).

Pedestal Signal Post shall consist of a 100 millimeter shaft complete with a pedestal base (2.5 meters or 3.0 meters long including base).

All posts and their bases shall be of the same material, either steel or aluminum. Aluminum sign posts shall utilize a tapered shaft.

815.45 Vehicle Signal Heads.

Signal heads shall be weathertight assemblies, conforming to the requirements of "Adjustable Face Vehicle Traffic Control Signal Head Standard," ITE Technical Report #1, ANSI (D10.1).

Optically Programmed Adjustable Face Traffic Control Signal Heads that have been type tested and approved by the Department (Subsection 815.21) will be considered as meeting the requirements of this specification.

815.46 Pedestrian Signal Heads.

Pedestrian signal heads shall be of the incandescent type or the fiberoptic type.

A. Incandescent Type.

The incandescent pedestrian signal heads shall be of the two section type conforming to the ITE Standard for Adjustable Face Pedestrian Signal Heads (ITE Technical Report Number 5).

All new pedestrian signal indications shall be rectangular in shape and shall consist of symbolized messages. These symbolized messages consist of a walking person illuminated in Lunar White to symbolize WALK, and an upraised hand illuminated in Portland Orange to symbolize DON'T WALK. The symbols are the 'international symbols' as set forth in the "Standard Highway Signs" booklet published by the United States Department of Transportation, latest edition. Each indication shall be independently illuminated and emit a single color.

The DON'T WALK signal section shall be mounted directly above the WALK signal section.

The Minimum height of each symbol shall be 150 millimeters.

When not illuminated, the WALK and DON'T WALK symbols shall not be readily visible by pedestrians at the far end of the crosswalk they control.

B. Fiberoptic Type.

1. General.

The unit shall consist of a matrix of fiberoptic bundles forming two displayed messages within a single section on a rectangular background facing the same direction. A single section head displaying two messages via international symbols (Hand)/(Person Walking) in Portland Orange and Lunar White, respectively, shall be used. The symbol size shall be 230 millimeters wide x 280 millimeters high.

The messages shall be clearly legible and shall attract the attention of pedestrians under all ambient lighting conditions varying from total darkness to bright sunlight at all distances from 3 meters to the width of the area to be crossed. A visor or hood shall not be required for legibility.

The message shall be visible at full intensity anywhere within a 90° cone centered about the optical axis and perpendicular to the surface of the matrix display. When not energized, the signal shall be blanked out (unreadable) with no phantom image, regardless of solar intensity or direction.

The messages shall be bright in color against a flat black background. The displays shall be made from a single row of fiberoptic bundles with a nominal 13 millimeter spacing between centers.

The light source shall be designed and constructed so that in case of an electrical or mechanical failure the WALK symbol and the DON'T WALK symbol will remain dark. Each message shall be displayed separately and never concurrently.

2. Materials.

One 42 watt 10.8 volt Type ENL lamp with a rated life expectancy of 10,000 hours shall be used as the light source for each display. The lamp shall be a multi mirror reflector quartz halogen bulb operating at an approximate color temperature of 2900 °K.

3. Optical System.

The signal shall consist of:

- a. Weatherproof housing, door, gasket and visor
- b. Fiberoptic module within individual output bundles
- c. Color filters for desired message colors
- d. Light sources
- e. Transformers
- f. Protective back cover for the module
- g. Electrical system including wiring

4. Optical Requirements.

The optics shall be glass-on-glass fiber with an 83% core to 17% cladding ratio. It shall have an average numerical aperture of 0.56 with a maximum transmission attenuation of 800 DB per kilometer. Each fiber shall have a 0.05 ± 0.005 millimeter diameter with an included acceptance angle of 68 degrees. Output bundles located at the face of the sign shall have a minimum diameter of 1.2 millimeters for the international symbols. The input fiber bundle located at each light source shall have a maximum diameter of 19 millimeters.

The output bundles shall be protected by a vandal resistant UV stable prismatic polycarbonate lens 3.2 millimeters thick. Individual fiberoptic bundles shall not be jacketed or encased.

Color filters shall be optical quality glass. The filters shall be color fast and in accordance with the I.T.E. Signal Color Specification for Chromaticity.

The prismatic polycarbonate lens shall be gasketed and mounted at a pre-focused distance in the door, away from the fiberoptic panel.

All optical fiber utilized in the production of the fiberoptic unit shall be tested for:

- a. Core to clad fusion
- b. Size
- c. Roundness of fiber
- d. Optical transmission
- e. Brittleness

Results of these tests shall be available upon request.

5. Construction.

The front panel shall be flat black aluminum alloy, minimum 3 millimeters thick, and shall have a maintenance-free black anodized, acid test finish.

All fiberoptics, transformer and lamps shall be mounted on the door of the unit. All screws, washers, nuts and bolts shall be stainless steel. All components shall be readily accessible when the door is opened. The only tool required for maintenance or replacement of components shall be a standard screwdriver.

No moving parts are permitted in the optical system.

6. Electrical.

Electrical connection shall be provided by a barrier type terminal strip for connecting field wires.

Transformers shall be used to reduce the incoming 120 volts AC to 10.8 volts AC.

Transformers shall have Class A insulation impregnated with a double coating of epoxy resin so as to preclude intrusion of moisture and shall be rated at 48.5 volt-amps.

A separate transformer and bulb shall be used for each color to allow connection with existing controller wiring and conflict monitors.

815.47 Louvered Hood and Optically Programmed Adapters.

1. Where specified, louvered hoods shall be either of the following stipulated types:

Type A – 200 millimeters or 300 millimeters 3-vane with 7 degree cut-off.

Type B – 200 millimeters or 300 millimeters 6-vane with 3 degree cut-off.

Type C – 200 millimeters or 300 millimeters Multi-vane with adjustable 2-1/2 to 30 degree cut-off.

2. Optically programmed signal adapters shall be comprised of an optical extension adaptable to standard 200 millimeter signal sections for controlling the visibility of the indication. The projected indication may be selectively visible or veiled anywhere within 20 degrees of the optical axis.

815.48 Traffic Signal Lamps.

Lamps shall be of the type designed to withstand excessive vibration and intended for use in traffic signal heads. All traffic signal lamps for use in 200 millimeter signal heads shall have a light center length of 61.9 millimeters. All traffic signal lamps for 300 millimeter signal heads shall have a light center length of 76.2 millimeters. All lamps shall have a voltage rating of 125 volts and a rated life of 8000 hours minimum.

Other requirements shall be as follows:

- 1. **For 200 Millimeter Signal Heads**
 - a. 60 watt series, 675 Approximate Initial Lumens.
- 2. **For 300 Millimeter Signal Heads**
 - a. 150 watt series, 1950 Approximate Initial Lumens.
- 3. **Optically Programmed Heads**
 - a. 75 watt PAR for pedestrian heads
 - b. 150 watt PAR for signal heads
- 4. **Flashing Warning Beacons**
 - a. 25 watt series (200 millimeter heads)
 - b. 40 watt series (300 millimeter heads)

CONSTRUCTION METHODS

815.60 General.

Details of construction shall conform to all applicable requirements of the Standard Specifications and drawings, plans, details, Special Provisions, manufacturer’s instructions and directions of the Engineer.

815.61 Painting.

All painting required shall be done in conformance with applicable portions of Subsection 960.63.

Aluminum posts, pedestals, poles, standards or mast arms shall not be painted. All galvanized surfaces shall not be painted unless abraded or damaged at any time after the applications of the zinc coating. The surfaces shall then be repaired by thoroughly wire brushing the damaged areas and removing all loose and cracked coatings after which the cleaned areas shall be painted with two coats of paint, conforming to the requirements of Subsection M7.04.11.

All traffic signal, highway lighting and related electrical equipment (except new traffic signal controller cabinets) that comes from the manufacturer with one or more coats of paint (excluding primer) will be accepted, as one coat if scars or abraded places are properly cleaned and spot coated.

Two additional coats of paint shall then be applied. If such equipment is painted at the factory with just a primer coat, the Contractor shall apply three coats of paint.

Paint shall be applied to all interior surfaces before equipment and appurtenances are installed and to all exposed parts of the equipment and appurtenances after they have been completely installed, using the following colors:

Controller Cabinets (Exterior)	Aluminum
Controller Cabinets (Interior)	Aluminum or White
Signal Posts (Exterior Steel)	Yellow
Signal Posts (Interior Steel)	Aluminum or Yellow
Mast Arm and Mast Arm Pole (Exterior).....	Aluminum
Mast Arm and Mast Arm Pole (Interior).....	Aluminum
Housings (Back)	Yellow
Housings (Front)	Black
Visors (Outside).....	Yellow or Black
Visors (Inside)	Dull Black
Backboards	Dull Black
Louvers	Dull Black

Meter Sockets Aluminum

Painting may be omitted if equipment and materials are received from the manufacturer with equivalent paint specified above. All scars and abrasions shall be spot coated with two coats of the specified paint.

Steel poles (inner and outer surfaces) shall be painted in accordance with the applicable provisions of the Specifications.

All surfaces of aluminum bases in contact with concrete shall be coated, in the field, with a protective coating recommended by the manufacturer of the base.

815.62 Signals.

A. General.

Signal posts, bases, mast arms, mast arm shafts and strain poles shall be handled in loading, unloading and erecting in such a manner that they will not be damaged. Any parts that are damaged due to the Contractor's operations shall be repaired or replaced at the Contractor's expense.

Unless otherwise directed by the Engineer, posts, bases, mast arms and strain poles shall not be erected on concrete foundations until the concrete has set for at least three days.

Mast arms and strain poles shall be raked sufficiently to be plumb after all loads have been placed; poles shall be raked by adjusting double nuts. Shims or similar devices for plumbing or raking will not be permitted.

The bottom of the housing assembly of a signal head not mounted over a roadway shall not be less than 2.5 meters nor more than 4.5 meters above the sidewalk, or, if none, above the pavement grade at the center of the roadway.

The bottom of the housing assembly of a signal head suspended over a roadway shall not be less than 5.0 meters nor more than 5.8 meters above the pavement grade at the center of the roadway.

Each signal face shall consist of one or more sections, rigidly and securely fastened together, capable of being positioned to face one direction of traffic.

Each section shall be a self-contained assembly consisting of a housing with door, visor and optical unit (lens and reflector) with traffic signal lamp.

B. Signal Head Section.

Each section shall be constructed to the requirements of ANSI specified in Subsection 815.46 including the following:

1. Optical units for 200 millimeter sections shall be equipped with traffic signal lamps as specified in Subsection 815.48.
2. Optical units for 300 millimeter sections shall be equipped with traffic signal lamps as specified in Subsection 815.48.
3. Optical units for 300 millimeter optically programmed sections shall be equipped with traffic signal lamps as specified in Subsection 815.48, equipped with dimming device to reduce lumen output of each signal lamp for night time operations.

Signal faces containing sections with both 200 millimeter and 300 millimeter lenses may be required. All signal heads including multiple assemblies shall be completely shop assembled and delivered ready for erection. Multiple units shall be assembled using 38 millimeter pipe for the supporting framework and include 38 millimeter center supporting pipe for post top mountings. Span wire and mast arm units shall have approved tie braces for the lower framework without a center support. Welding shall not be used in frame assembly.

Each socket shall be wired with two #18 AWG stranded leads not less than 5 meters long conforming to the requirements of Subsection 813.40 for Type 5 traffic signal head wire, Type TFF or TEW.

The color of the leads from the socket behind the:

- Red lens – 1 red and 1 white wire
- Yellow lens – 1 yellow and 1 white wire
- Green lens – 1 green and 1 white wire
- Green arrow – 1 blue and 1 white wire

At the option of the manufacturer, approved connecting blocks may be installed inside the housing for these connecting wires, provided a 5 meter colored lead for each socket and 1 white common lead is furnished as an integral part of each housing.

C. Hangers and Adapters.

Hangers and adapters shall be of bronze or malleable iron, or other approved material, strongly constructed, and of hollow design to permit the suspension of signal heads from mast arms or span wires or mounted on brackets, posts or

pedestals.

Signal heads intended for post or pedestal mounting shall have suitable slipfitters for post top mounting and be secured to posts by means of set screws.

Mast arm mounted signal heads shall have an approved universal joint and safety chain.

Bracket mounted signal heads shall have suitable brackets to attach them to timber or metal poles to permit either internal or external wiring. Brackets shall be of proper size to be properly attached to pole as shown on the Standard Drawings.

Span-wire mounted signal heads shall have a span-wire hanger similar in design to that shown on the Standard Drawings. Hanger shall be specifically designed for supporting a hanging object from steel stranded messenger cable and have "U" bolts to prevent lateral movement only. Each hanger shall be complete with a wire entrance device.

Where specified, integral terminal compartments shall be provided for any of the above types of mounting. Terminal compartments shall be fabricated of non-frangible metal and be of adequate size to accommodate a terminal block containing not less than twelve poles, each with two pressure type connectors. Each connector shall be capable of holding four #12 AWG conductors.

D. Backplates.

Where stipulated, backplates shall be furnished and installed. Backplates shall be constructed of anodized half hard aluminum sheet, 1.5 millimeter nominal thickness, or polycarbonates, and of the dimensions to fit the signal head housing used.

E. Pole Clamps.

When required for mounting signal heads or equipment, pole clamps shall conform to the general design shown on the Standard Drawings.

815.63 Controllers.

All controller cabinets, control equipment and accessories shall be factory wired ready for operation. Field work will be limited to placing cabinets and equipment and the connecting of field wiring to terminal strips. Cabinets shall be mounted on the foundation and a clear silicone sealer shall be used at the base of the cabinet to form a water-tight seal with the foundation.

In addition, the Contractor shall provide to the Engineer two (2) copies of the Operating and Maintenance Instruction Manuals complete with wiring diagrams of the internal, external and field connections for each type of controller furnished on the project and listed in Section 815.41, C. Pre-Timed Controllers, and two copies of the Technical Manuals and "Box Prints" for each type of controller furnished on the project and listed in Section 815.41, B. Actuated Controllers; the required Technical Manuals are listed in Paragraph 10 of the above Section 815.41, B. Actuated Controllers.

815.64 Detectors.

The Contractor shall install the detectors at the locations as shown on the signal layout plan in accordance with the applicable requirements of the Department's Standard Drawings.

All detector lead-in cable shall be continuous without splices from the pull box nearest the detector to the controller cabinet terminals provided without passing through any signal bases.

Splices, when necessary in the pull box nearest the detector shall be soldered and made completely watertight using an approved rigid body re-enterable closure.

Detector leads shall not be run in the same cable sheath (jacket) with wires carrying signal currents.

Magnetic Detector Multi-Lane shall be installed inside a 80 millimeter Type NM conduit, 450 millimeters below the surface of the road in a cement concrete envelope not less than 100 millimeters thick at any point as shown on the Standard Drawings.

Magnetic Detector Single Lane Detectors shall be installed in accordance with manufacturer's recommendations.

Ultra-Sonic Detectors shall be installed overhead on mast arms or on posts (side-fired) in close conformity with the required lines and grades.

Wire-Loop and Micro-Loop Detectors shall be installed in the slots saw-cut in the pavement and oriented to the traffic lane.

The size and type of conductor and method of installation shall conform to the Department's Standard Drawings.

The saw-slots shall be filled with an approved roadway loop embedding sealer to protect the wire.

815.65 Disposal of Existing Equipment.

When removal of existing traffic signal equipment and appurtenances is called for, the order of work shall be as directed by the Engineer. Removal of existing traffic signal equipment and their accessories shall be done in a manner that will not damage reusable material.

All signal posts and bases shall be separated from one another without damage to either unit (100 millimeter shaft unscrewed from base).

When stipulated, existing material shall be utilized in the construction of the new installation. Material to be installed shall be thoroughly cleaned before reinstallation. All reinstalled material, after cleaning and spot coating, shall receive two brush coats of paint to all parts as specified for new installations. Paint shall be applied after material is in place.

The Contractor shall furnish and install all necessary materials and equipment, including new foundations, etc., required to complete the reinstallation.

All traffic signals, flashing beacons and pedestrian signals to be reinstalled shall be relamped with new lamps of the size and type required for new installations.

Existing material removed and not utilized in the new installation shall be salvaged and transported by the Contractor to the Department Storeroom, unless directed otherwise.

Underground conduit, conductors, foundations and detector frames not reused shall be removed from the project, except if not interfering with other construction, they may with written approval of the Engineer be abandoned in place.

815.66 Tests Required Before Acceptance.

The Contractor shall record and make a written report of the following tests to be made on all traffic control signal installations in the presence of the Engineer:

1. Resistance Test required by Section 813.62.
2. An insulation resistance 500 Volt megger test shall be made for each inductive loop sensor and lead-in at the controller cabinet where the combination is to be terminated.

The following test procedure shall be performed in the presence of the Engineer before and after the loop sensor is sealed in the pavement as detailed below.

The cost of equipment, labor, and materials to perform such testing and similar re-testing following repairs, replacement, or adjustment of any detector assembly within the project area shall be included in the price bid for the Traffic Control Signal installation for that location, or under Item 819.831 if applicable.

After installation of wire loop sensors in the roadway and installation of shielded lead-in connecting the loop sensors to the terminals in the controller cabinet, each loop sensor and lead-in combination shall be tested (at the controller cabinet before termination) for proper installation.

The resistance from lead to lead of the same loop sensor shall not exceed 3 ohms per 300 meters as measured by a high quality meter suitable for measurements of low resistance.

A megohm-meter test at 500 Volts DC shall be made between the two leads of a loop/lead-in combination temporarily spliced together, but otherwise disconnected from all terminals, and the shield drain wire and then the earth ground connection. These resistances shall be recorded and shall be equal to or greater than one hundred (100) megohms. The lowest acceptable value shall be 80 megohms under certain worst case conditions as determined by the Engineer.

A megohm-meter test at 500 Volts DC shall be made between lead-in shield and earth ground connection. This resistance should be at least one hundred (100) megohms. The lowest acceptable value shall be greater than fifty (50) megohms under worst case conditions as determined by the Engineer.

If any loop sensor lead-in combination fails to pass any one of the above four tests, it shall be repaired and then re-tested on two occasions at least two weeks apart, and then shall pass on each re-test occasion.

If the loop sensor lead-in combination does not pass all these re-tests, a new loop sensor and/or lead-in shall be installed, and then shall pass all tests, at no additional cost.

After the above tests have been satisfactorily completed, all loop sensor/shielded lead-in inductances shall be measured and a written report of the results shall be filed with the Engineer and a copy stored with the "Box Prints" at the intersection along with a copy of the ground electrode resistance tests required by Section 813.62B and the above.

Operation Tests – After satisfactory completion of the required tests, the system(s) shall be placed in operation.

Final acceptance will not be made until the system(s) has operated satisfactorily, as designed and the timing has been fine tuned, for a period of not less than 30 days from a date designated by the Engineer.

This test period shall be included within the specified contract time. Operation of the system(s) shall not in any

way be construed as an acceptance of the system(s), or any part of it, or as a waiver of any of the provisions of the contract.

The Contractor shall be responsible for the system(s) during this period of operation and he/she shall make any adjustments or repairs that may be required and remedy defects or damages which may occur, at his/her own expense.

815.67 As Built Drawings.

1. Upon completion of the work, the Contractor shall mark and submit five (5) complete copies of “as built” or corrected copies of the contract plans (copies for marking furnished by the Department), showing in detail all construction changes, especially locations and depths of conduit and locations of posts, standards, handholes, manholes and pull boxes. All “as built” drawings shall be dated.

2. Manufacturer’s instructions for the maintenance, servicing and operation of all equipment, wiring diagrams of all equipment (except traffic signal controllers specified in Section 815.41B, Paragraph 10), and a parts list sufficient for the ordering of any parts, and any other data thereof as required by the Engineer.

Copies to be distributed as follows:

1. District Traffic Maintenance (1 complete set)
2. Electrical Systems Boston (1 set as described in 1 above)
3. Control Cabinet (one set as described in 2 above) with Technical Manuals and “Box Prints” required by Section 815.41B, Paragraph 10.

COMPENSATION

815.80 Method of Measurement.

Traffic Control Signals, Traffic Control Signals removed and reset or stacked or transported, Traffic Signal Controllers and accessories shall each be measured for payment as a unit.

Signal post, signal post bases, mast arms (with the specified bracket arm lengths with or without transformer bases) and span wire assemblies shall be paid for at the contract unit price each complete in place.

Signal heads, mounting assembly, louvers, backplates and pole clamps will be paid for at the contract unit price each and when specified, as complete assemblies, which price shall be full compensation for work necessary or incidental to the construction of signal heads, modifying existing heads, or both, including conduit, wiring, and salvaging existing materials.

All additional materials and labor required to complete all of the above items as specified shall be considered as incidental to the construction and be included in the contract unit price each.

815.81 Basis of Payment.

The accepted quantities of traffic signal controllers and accessories, signal posts, signal post bases, transformer bases, mast arms with specified bracket arm lengths, span wire assemblies and traffic signal vehicle detectors shall be each measured for payment as a unit which price shall include full compensation for anchor bolts.

When specified in the Contract, Traffic Control Signals and Traffic Signals removed and reset, stacked or transported shall be paid for as a contract lump sum price which price shall be full compensation for all work necessary to perform the stated work, including, but not limited to, modification of existing signals, excavation, backfilling, compaction, concrete foundations, conduit, wiring, restoring facilities destroyed or damaged during construction and salvaging existing materials.

All additional materials and labor necessary to complete the work shall be considered as incidental to the construction and be included in the lump sum price.

815.82 Payment Items.

815.4 to 815.8	Traffic Control Signal Type ___ * (*4DW to 8DW)	Lump Sum
815.911 to 815.916	Traffic Control Signal Type ___ * (*11 to 16)	Lump Sum
816	Traffic Signal Removed and Reset	Lump Sum
816.0_*	Traffic Signal Reconstruction *Location No.	Lump Sum
816.40	Traffic Control Signal Removed and Reset	Lump Sum
816.80	Traffic Control Signal Removed and Stacked	Lump Sum
816.90	Traffic Control Signal Removed and Transported	Lump Sum

817.10	Signal Post and Base Standard - 2.5 meters	Each
817.11	Signal Post and Base Standard - 3.0 meters	Each
817.20	Signal Post and Base Pedestal - 2.5 meters	Each
817.21	Signal Post and Base Pedestal - 3.0 meters	Each
817.40	Signal Base Standard - 350 millimeters Octagonal	Each
817.41	Signal Base Pedestal - 375 millimeters Square	Each
817.50 to 817.53	Signal Mast Arm * ___ meters - Aluminum	Each
817.60 to 817.63	Signal Mast Arm * ___ meters - Steel	Each
817.70 to 817.73	Signal and Lighting Mast Arm ___ meter x ___ meter	Each
818.01 to 818.05	Signal Head 1 Way ___ * ___ Section 200 millimeter Lens	Each
818.11 to 818.15	Signal Head 1 Way ___ * ___ Section 300 millimeter Lens (*1-5)	Each
818.23 to 818.25	Signal Head 1 Way ___ * ___ Section 50 - 300 millimeter Lens	Each
818.33 to 818.35	Signal Head 1 Way ___ * ___ Section 300 millimeter Red Lens (*3-5)	Each
818.40	Signal Head 1 Way ___ 1 Section 225 millimeter Square Lens	Each
818.41	225 millimeter Incandescent Pedestrian Signal Head	
	- International Symbols	Each
818.42	300 millimeter Incandescent Pedestrian Signal Head	
	- International Symbols	Each
818.43	300 millimeter Fiberoptic Pedestrian Signal Head	
	- International Symbols	Each
818.51 to 818.54	* ___ Way Post Top Mounting Assembly	Each
818.55 to 818.58	Mast Arm Mounting Assembly ___ * ___ Way	Each
818.59 to 818.62	Post Side Mounting Assembly ___ * ___ Way	Each
818.63 to 818.66	Span Wire Mounting Assembly ___ * ___ Way (*1-4)	Each
818.70 to 818.71	Louvered Hood for * ___ meter Signal Section	Each
818.80 to 818.81	Back-Plates for * ___ millimeter Signal Head (*200 millimeters - 300 millimeters)	Each
818.82	Back-Plates for Combined 200 millimeter + 300 millimeter Signal Head	Each
818.90 to 818.94	Ornamental Pole Clamp * ___ millimeter Diameter (*115 millimeters- 200 millimeters)	Each
818.95	Pole Clamp with Wire Entrance	Each
819.04 to 819.08	Traffic Signal Controller Type ___ (*4DW to 8DW)	Lump Sum
819.39	8-Phase, Menu-Driven Traffic Controller Unit	Each
819.50	Railroad Pre-Emptor	Each
819.51	Fire Station Pre-Emptor	Each
819.52	Special Internal Unit	Each
819.53	Special Function Unit	Each
819.60 to 819.64	Coordinating Unit - Type * - (*Type FF to Type S4)	Each
819.70	Signal Light Switching Assembly - Type DC	Each
819.71	Signal Light Switching Assembly - Type SS	Each
819.72	Detector Unit Conflicting Green	Each
819.111 to 819.116	Traffic Signal Controller Type ___ * (*11 to 16)	Lump Sum
819.800	Magnetic Detector Amplifier	Each
819.801	Vehicle Detector (Directional) Compensated Magnetic	Each
819.802	Vehicle Detector (Multi-Lane) non-Compensated Magnetic	Each
819.803	Vehicle Detector (Single-Lane) non-Compensated Magnetic	Each
819.810	Detector Amplifier - Magnetic (Special)	Each
819.811	Detector Sensing Head - Magnetic (Special)	Each
819.820	Vehicle Presence Detector - Ultrasonic	Each
819.821	Vehicle Motion Detector - Ultrasonic	Each
819.830	Inductive Loop Detector Amplifier	Each
819.831	Wire Loop Installed in Roadway	Meter

819.832	Microloop Installed in Roadway	Meter
819.850	Pedestrian Push Button	Each
819.851	Push Button for Green Light (Sign)	Each
819.852	Push Button for Walk Signal (Sign)	Each

SECTION 820

HIGHWAY LIGHTING

DESCRIPTION

820.20 General.

This work shall consist of furnishing and installing or modifying highway lighting.

Included in the work is the furnishing and installing or modifying of electrical conduit, electric manholes, handholes, pull or junction boxes, concrete foundations, wire and cable, equipment grounding, ground rods, service connection, lighting poles or towers, luminaries, control equipment, load center assemblies, photoelectric control switches, contactors, time clocks, and all incidental materials necessary for operating and controlling highway lighting systems as indicated on the plans. All systems and/or components shall be complete in every respect, fully wired, thoroughly tested, and ready for use.

The locations of highway lighting equipment shown on the plan are approximate and the exact locations will be established by the Engineer in the field with the exception of Lighting Poles or Towers. The locations of Lighting Poles or Towers may not be altered more than 3 meters (\pm) without the written permission of the Engineer if obstructions are encountered during installation.

TRAFFIC CONTROL DEVICES

All electrical equipment shall be designed, manufactured and tested in accordance with the applicable standards of the ANSI, EIA, FSS, IMSA, ITE, NEMA and UL and these specifications.

Unless otherwise designated on the plans, on the Standard Drawings for Highway Lighting, as set forth in the Special Provisions, and as specified herein, all work and materials shall conform to the requirements of the NEC as amended by the MEC, herein referred to as the electrical code.

Wherever reference is made to codes or standards mentioned above, the reference shall be construed to mean the code or standard that is in effect on the date of advertising of the project.

All electrical connections, splicing, grounding, resistance tests, service connections and circuit identification shall be done by a licensed electrician holding "Certificate B" issued by the State Examiners of Electricians.

Standard symbols and construction details for highway lighting installations are shown on the current Traffic Signal and Highway Lighting Standard Drawings.

Within 30 days following execution of the Contract, the Contractor shall submit to the Engineer for approval, a list of equipment which he/she proposes to install. The submission shall include all equipment identified on the plans or in the specifications by the name of the manufacturer, model or identifying number of each item. The list shall be supplemented by catalog cuts and such other data as may be required, including wiring diagrams of any special equipment and of any proposed minor deviation from the plans. All of the above data shall be submitted in triplicate for checking. Following checking, correction and review, not less than five (5) complete approved sets shall be resubmitted to the Engineer for distribution. The Department shall not be liable for any material purchased, labor performed, or delay to the work prior to such review and approval.

The warranties that the Contractor receives from each manufacturer of equipment and materials pertinent to the complete and satisfactory operation of highway lighting installation shall be turned over to the Department at the time of acceptance of the project, at no cost to the Department. Each warranty so furnished shall indicate its expiration date, and be in effect for a minimum period of one year from the date the highway lighting was placed in continuous operation.

The contractor shall replace at his/her own expense any part of the lighting equipment found to be defective in workmanship, material or manner of functioning within six months from the date of final acceptance of all the installations.

If within one year from the date the highway lighting system is placed on continuous operation the equipment and materials do not meet the warrants specified above and the Engineer notifies the manufacturer or his/her authorized representative promptly, the manufacturer or his/her authorized representative thereupon shall correct any defect either by