Section 647—Traffic Signal Installation

647.1 General Description

This work consists of furnishing materials and erecting a traffic signal installation including all traffic signal equipment, poles, bases, wires and miscellaneous materials required for completion of the installation.

It also includes all test periods, warranties and guarantees as designated in subsequent sections, and response to maintenance and operational issues as described in subsequent sections.

Apply for, obtain and pay for all utility services, communications services to, and pole attachment permits that are necessary for the signal installation and operation required in the Plans. Maintain these utility services until final acceptance of the signal.

Upon final acceptance, make an orderly and uninterrupted transfer of these services and permits to the local government or other jurisdiction that will be responsible for subsequent maintenance and operation.

647.1.01 Definitions

General Provisions 101 through 150.

647.1.02 Related References

A. Standard Specifications

Section 106—Control of Materials
Section 500—Concrete Structures
Section 501—Steel Structures
Section 631—Changeable Message Signs
Section 636 – Highway Signs
Section 639—Strain Poles for Overhead Sign and Signal Assemblies
Section 645—Repair of Galvanized Coatings
Section 680—Highway Lighting
Section 681—Lighting Standards and Luminaires
Section 682—Electrical Wire, Cable, and Conduit
Section 700—Grassing
Section 800—Coarse Aggregate
Section 801—Fine Aggregate
Section 832—Curing Agents
Section 833—Joint Fillers and Sealers
Section 850 Aluminum Alloy Materials
Section 853—Reinforcement and Tensioning Steel
Section 854—Castings and Forgings
Section 861—Piling and Round Timber
Section 870—Paint
Section 886—Epoxy Resin Adhesives
Section 910—Sign Fabrication
Section 911—Steel Sign Posts
Section 912—Sign Blanks and Panels
Section 913—Reflectorizing Materials
Section 915—Mast Arm Assemblies
Section 923—Electrical Conduit
Section 925—Traffic Signal Equipment
Section 935—Fiber Optic System
Section 936—CCTV System

Section 937—Video Detection System

Section 938—Radar Detection System

Section 939—Communications & Electronic Equipment

Section 940—Navigator Integration

B. Referenced Documents

National Electrical Manufacturers Association (NEMA) Traffic Control Systems Standards No. TS 1

NEMA Traffic Control Systems Standards No. TS 2

AASHTO Roadside Design Guide

The Manual on Uniform Traffic Control Devices (MUTCD), current edition

National Electrical Code (NEC)

GDT 7

GDT 24a

GDT 24b

GDT 67

647.1.03 Submittals

Submit to the Engineer, signal material specifications information on all materials proposed for use on the project. The Engineer will forward the materials submissions to the District Traffic Operations offices, which will forward the information onto the Traffic Operations offices at the TMC building.

Written approval is required from the State Traffic Signal Design Engineer prior to beginning any work on the project.

A. Review

For all submittals, the State Traffic Signal Design Engineer's review of the material should be completed within thirty (30) days from the date of receipt of the submission unless otherwise specified. The State traffic Signal Design Engineer will advise in writing, as to the acceptability of the material submitted.

All material submittals for fiber optic communications equipment and materials used on the project will be reviewed by the Department's Traffic Signal Electrical Facility (TSEF). The material review should be completed within thirty (30) days from the date of receipt of the material submission unless otherwise specified. The State Traffic Signal Engineer will advise in writing as to acceptability of materials to be used on the project.

The State Traffic Signal Design Engineer may determine that the item is approved, in which case no further action is required; or the item may be partially or totally rejected in which case, modify the submittal as required and resubmit within fifteen (15) days. At this time, the review and approval cycle described above begins again.

B. Submittal Costs

Include the costs of submittals within the price paid for individual bid items. No additional compensation will be made.

C. Steel Strain Pole, Concrete Strain Pole or Steel Pole Certification

Instruct the supplier or manufacturer of the strain poles or steel poles with traffic signal mast arms to submit a certification, including mill certificates to:

Department of Transportation

Office of Materials and Research

15 Kennedy Drive

Forest Park, Georgia 30297

Include the following in the certification:

- A statement that the items were manufactured according to the Specifications, including the Specification subsection number
- Project number and P.I. number

Instruct the supplier or manufacturer to send copies of the transmittal letter to the Engineer. Refer to Subsection 647.3.03.C.

Prepare Shop Drawings and related signal strain pole design calculations. Provide "bending moment at yield" to determine the foundation size according to the signal strain pole foundation drawings. Submit all Shop Drawings and related signal strain pole design calculations to the Engineer to be forwarded to the State Bridge and Structural Design Engineer for review and approval. Obtain written approval prior to pole fabrication and installation.

Show all dimensions and material designations of the designs on the drawings. See Section 501 for the certification procedure for poles and anchor bolts.

D. Signal Item Certification

Submit six (6) copies of material catalog product numbers and descriptions to the Engineer. Reference the project number, P.I. number and Specification subsection number for the following traffic signal items:

- Signal heads
- Mounting hardware
- Controllers
- Cabinet assemblies
- Detectors
- Monitors
- Cable
- Load switches
- Blank-out signs
- Lane use signals
- Preformed cabinet bases
- Other related signal equipment
- Modems
- Fiber Optic Modems

E. Test Results Submittal

Submit the results of the testing of the following items to the Engineer:

- Loop Detector Testing
- Signal Cable Testing
- Interconnect Cable Testing
- Pre-emption Testing
- Controller and Cabinet Testing
- Any other operational testing required by the Engineer

F. Mast Arm Pole Chart

For locations with mast arm pole installations, submit a "Mast Arm Pole Chart" for review and approval by the Engineer. The "Mast Arm Pole Chart" shall also include a sketch on an 8 ½ inch x 11 in (216 mm x 297 mm) sheet of paper showing the following:

- Curb lines
- Location of mast arm pole based on utility information. (Final location of mast arm pole must meet the criteria for setback from the road as specified in the Roadside Design Guide by AASHTO and in the Standard Detail Drawings)
- Distance from both adjacent curbs to mast arm pole

- Distance along mast arm from pole to curb and from curb to each proposed signal head
- Directional arrow
- Street names
- Position of Luminaries

Label the sketched distances. Once this pole chart is approved, the contractor shall use the distances measured to the proposed signal head locations when ordering the mast arm to ensure that the mast arm is fabricated with holes for signal head wiring in the correct locations

647.2 Materials

647.2.01 Delivery, Storage, and Handling

A. State-supplied Equipment

For projects where traffic signal equipment is to be supplied by the Georgia Department of Transportation, obtain State-supplied traffic signal equipment from the Traffic Signal Electrical Facility (TSEF):

1. Contact the Engineer by phone or correspondence within one week after receiving the Notice to Proceed and arrange for a location to pick up the signal equipment.
2. Sign GDOT's Warehouse Issue Request Form 592 to accept delivery of the State-supplied equipment from GDOT's Traffic Signal Equipment Warehouse. Initial Form 592 if equipment is received from a GDOT District Field Office.
3. Inspect the equipment to ensure that it is operating properly and perform any operational tests within ten (10) calendar days after receiving the equipment.
4. Before installation, and within ten (10) calendar days, certify to the Engineer in writing that the State-supplied equipment was received in good condition.
5. Notify the Engineer in writing if the State-supplied equipment is defective. The State Signal Engineer will replace the defective State-supplied equipment.
6. If no written dissent is received after ten (10) calendar days or if equipment is installed in the field, the Engineer will consider this equipment to be satisfactory and accepted.
7. The Contractor shall supply new equipment to replace State-supplied equipment that is damaged by the Contractor.

B. Signal Equipment

See Section 925 for signal equipment specifications.

The signal equipment, components, supplies, or materials used in traffic signal installation may be sampled and tested if not previously approved by the Department.

Test according to the Specifications and the Sampling, Testing, and Inspection Manual using one or more of the following methods:

- Have the Department use their own facilities.
- Have the supplier or manufacturer use their facilities with an authorized Department representative to witness the testing.
- Provide independent labratory test results indicating compliance with Department Specifications referenced in Subsection 647.1.02, "Related References", of this document.
- When testing by the Department is required, supply the item to the Department. Acceptance of materials tested does not waive warranties and guarantees required by the Specifications.

C. Cable

Use cable that conforms to Section 680, Section 925, and the appropriate IMSA, NEMA, or UL Specifications for the wire or cable.

Obtain pole attachment permits required by local utility companies or pole owners to allow joint use for signal cable, hardware, or other auxiliary devices.

D. Interconnect Communications Cable

The interconnect cable (communication cable) links the master controller, the field controllers, and sensors. Follow these guidelines:

1. Use fiber optic interconnect cable for all new interconnected signal systems. See Section 935 for fiber optic cable information, specifications and installation and testing techniques.
2. Use copper cable only as directed by the Project Engineer or where specifically shown in the Plans. Refer to Section 647.3.05, "Construction", of this document for installation.

E. Messenger Cable

Use cable that conforms to ASTM A 475 Siemens-Martin grade or better with Class A coating. The messenger is used to support cable indicated in the Plans as overhead cable. Use devices such as wire ties or lashings to attach the cable.

- Before erecting the messenger strand, determine the suspension strand length to span the distance between the poles.
- Run the messenger strand from structure to structure without splicing.
- The maximum allowable sag is five percent (5%) of one-half of the longest diagonal distance between the signal poles.
- Calculate attachment points for the messenger strand at the signal pole according to the Plan detail sheet.

F. Fiber Optic Cable

Use fiber optic cable that complies with Section 935. Use Department approved materials, and utilize Department and fiber optic cable manufacturer recommended installation methods practices and techniques for installation, storage and termination of fiber optic cable.

- Use minimum 24 fiber, single mode fiber optic cable, for communications unless otherwise specified in the plans.
- Submit fiber optic cable manufacturer supplied product information on materials to be used for review for Specification Section 935 for compliance.
- Before erecting the messenger strand, determine the suspension strand length to span the distance between the poles.
- Run the messenger strand from structure to structure without splicing.
- The maximum allowable sag is five percent (5%) of one-half of the longest diagonal distance between the signal poles.
- Calculate attachment points for the messenger strand at the signal pole according to the Plan detail sheet.
- For underground installation, utilize materials and techniques approved by the Engineer and in conformance with Subsection 647.3.05.M and detail sheets for conduit and pull box installations. Underground fiber optic cable installation shall include tone tape or cable for utility detection and in compliance with project detail sheets.

G. Conduit on Structures

Use rigid metallic materials for all exposed conduit for cabling. Use metallic conduit on the exterior of signal poles and other structures and to house signal conductors for the entire length from the weatherhead on the pole to the interior of the cabinet (see Subsection 647.3.05X).

647.3 Construction Requirements

Refer to Subsection 107.07 of the Specifications regarding proper conduct of The Work.

647.3.01 Personnel

For the definition of a qualified electrician, see Subsection 755.1.01.

647.3.02 Equipment

Use machinery such as trucks, derricks, bucket vehicles, saws, trenchers, and other equipment necessary for the work and approved by the Engineer prior to installation operations.

647.3.03 Preparation

Utility Permits

A. Application

Apply for, obtain, and pay for utility services and pole attachment permits for signal operation required in the Plans.

B. Maintenance

Maintain these utility services until Final Acceptance of each signal installation. After Final Acceptance, transfer these services and permits to the local government or jurisdiction responsible for maintenance and operation. Ensure that the transfer does not interrupt service.

C. Utility Location

1. Adjustment

   Prior to ordering signal poles, locate utilities and adjust the location of poles, where necessary, to minimize utility conflicts. Obtain approval from the Engineer for any deviation from the Plans.

   Determine the final length of mast arms based on any field adjusted pole locations. Final location shall be approved by the Engineer.

2. Clearance

   When installing aerial cable of any type, ensure that overhead clearance and separation requirements conform to local utility company standards and the NEC. Refer to the Standard Details Drawings for further information on utility clearances.

3. Pre-emption

   When traffic signal pre-emption is used, coordinate with the railroad, fire department or any other agency that uses pre-emption to obtain pre-emption output and route output cable to the signal controller operating the intersection to be pre-empted. Obtain all permits and approval for crossing at grade or grade separated railroad facilities.

647.3.04 Fabrication

General Provisions 101 through 150.

647.3.05 Construction

A. Acquiring and Disposing of Equipment

Do not modify the signal equipment, design, and operation without the District Traffic Operations Engineer's written approval.

All traffic signal equipment removed or replaced shall be returned to District Traffic Signal Shops unless otherwise noted in the Plans or as directed by the Engineer.

B. Traffic Signal Equipment Modification and Removal

Upon modification of any existing traffic signal equipment, responsibilities for maintenance, operations and response to traffic signal malfucntion become the responsibility of the contractor and provisions of Section 647.3.07, "Contractor Warranty and Maintenance", apply.

1. Remove existing signal equipment that is not used in the final installation when the new signal equipment is operational.

   Carefully remove equipment to minimize damage and retain it in its original form. This equipment may include:

   - Steel poles including the foundation down to 2 feet (600 mm) below ground level finished grade
   - Concrete Strain poles
   - Timber poles
   - Traffic signal cabinets including contents, cabinet base and work pads
   - Original signal heads including span wire support
   - Other equipment not retained in the final installation

   Salvage the equipment as directed in the Plans or as directed by the Engineer

2. If the Plans specify delivery of salvaged equipment to a Department facility, provide an inventory list and arrange a mutually agreeable delivery time with the Engineer twenty-four (24) hours in advance.
3. Replace traffic signal equipment that the Engineer determines has been damaged or destroyed during installation or modification of the traffic signal, at no expense to the Department. Replace with new material.
4. If the Engineer finds that the existing material to be relocated is unsatisfactory, replace with new material. The costs will be paid for as Extra Work. Include the removal costs of all equipment, including salvaged equipment, in the cost of the overall bid price submitted.

5. Remove old signal heads by the end of the day that the new signal equipment is placed in operation. Remove all other signal equipment within seven (7) days after operations of the newly operational equipment, or within thirty (30) day burn-in period commencement.

C. Auxiliary Cabinet Equipment

Provide auxiliary cabinet equipment or special purpose equipment with connecting harnesses, if necessary, or as shown in the Plans or Standard Detail Drawings.

1. Install the equipment in its associated cabinet. Extraneous wiring maybe necessary to install the equipment. Additional cabling shall be enclosed in rigid, galvanized conduit and neatly secured.
2. Connect the auxiliary equipment to its cable harness, or insert it in premounted racks or sockets.

D. Signal Controllers

Furnish and install approved microprocessor controllers at the locations shown in the Plans or as directed by the Engineer. All equipment furnished shall comply with Section 925,"Traffic Signal Equipment".

1. Identify the controller and other auxiliary equipment by serial number and model. These numbers shall agree with previously approved catalog submittals.
2. Assemble the controller, cabinet, and auxiliary equipment to provide the operational sequence shown in the Plans and future operations specified.

E. Cabinet Assembly

1. Location

   When placing the cabinet, choose a location that:

   a. Protects maintenance personnel from vehicles when servicing the equipment
   b. Allows the front panel door of the controller to open away from the intersection for view of signal indications while servicing or performing cabinet work.
   c. Does not block a sidewalk or passageway and complies with Federal regulations for Americans with Disabilities Act (ADA) clearance requirements.
   d. Is located away from the roadway or curb line to prevent vehicular damage to the cabinet.
   e. Is not located within drainage areas or installed in areas likely to collect and hold surface water.

   Relocate the cabinet to avoid conflicts from proposed reconstruction projects, commercial driveways, etc. within the right-of-way at the Engineer's discretion.

2. Erection

   Install and level traffic signal controller cabinets at locations shown in the Plans and/or as directed by the Engineer.

   a. Install cabinets to conform to the Standard Detail Drawings. Install pole or base-mounted as indicated in the Plans.
   b. Seal base-mounted cabinets to their base using silicone based sealer. Pliable sealant used shall not melt or run at temperatures as high as 212 ºF (100 ºC).
   c. Use prefabricated bases and work pads
   d. Install technician pad in front and rear of the controller cabinet door. See standard details for pad information.

3. Field Cabinet Wiring

   All wiring shall be neat and secured and comply with NEC, NEMA, and Table 647-1, Table 647-2, Table 647-3 and Table 647-4 of this Specification.

   a. Cut field cabinet wiring to the proper length and organize it in the cabinet.
      - Use at least No. 6 AWG wire on conductors between service terminals and the "AC+" terminals to signal light relays, and buss terminals.
      - Use at least No. 6 AWG wire on terminal connections to light neutral.
   b. Crimp terminal connections to conductors with a ratchet-type crimping tool that will not release until the crimping operation is completed.
   c. Do not use splices inside the controller cabinet, base, or conduit.
   d. Do not use solid wire, except grounding wire.

e. Supply the cabinets with cabinet wiring diagrams, schematic drawings, pin assignment charts, and manuals for circuits and components. Store these documents in the cabinet in a resealable, weatherproof container.

F. Signal Monitors

Furnish signal monitor equipment as follows:

1. Mount signal monitors in a rack with appropriate connectors to attach to the wiring harness.
2. Program the monitor card according to the signal operation indicated in the Signal Plans before placing the installation in flash or stop-and-go operation.
3. Configure and equip the signal monitor to monitor all red signal indications. Ensure that the red output for unused or vacant load bays or output slots is jumpered to 120 V AC+.

G. Power Disconnect

Install a power disconnect box at each intersection as shown in the Standard Detail sheets. Install service cables from disconnect box and terminate as specified on the controller cabinet-wiring diagram.

H. Flashing Beacon

Furnish and install the flashing beacon controller at the locations shown in the Plans and/or as directed by the Engineer. Install it as a complete unit (solid state flasher and cabinet with time clock, if applicable) and ensure that it conforms to this Specification.

I. Loop Detector Systems

Install and test loop detector systems according to NEMA Standards Publication TS 1-1983, Section 15, Inductive Loop Detectors, subsequent revisions (except as shown in the Plans), details, notes, and this Specification.

Ensure that loop detectors are complete and fully operational before placing the signal in stop-and-go operation.

1. General Installation Requirements

   Each loop must consist of at least two turns of conductor, unless otherwise shown in the Plans or this Specification. Do not place a portion of the loop within 3 feet (1 m) of a conductive material in the pavement such as manhole covers, water valves, grates, etc.

   a. Install pull boxes, condulets, and conduits before beginning loop installation.
   b. Ensure that the ambient pavement surface temperature in the shade is at least 40 ºF (5 ºC) before placing sealant into saw cuts.

2. Loop Saw Cuts
   a. Outline the loop on the pavement to conform to the specified configuration.
   b. Install the detector loop in a sawed slot in the roadway surface deep enough to provide at least 2 inches (50 mm) of sealant cover.
   c. Ensure that the slot is at least 0.25 inches (6 mm) wide for stranded No. 14 AWG loop wire, THHN, THWN, XHHN, or XLPE, and at least 0.31 inches (7 mm) wide for polyethylene or PVC encased No. 14 AWG loop wire.
      1) At the intersection of the slots, drill a 1.25 inch (31 mm) diameter hole or make miter saw cuts in the pavement.

         Overlap miter saw cuts at the intersection of saw cuts so that the slots have a full-depth and smooth bottom.
      2) Prevent the wire from bending sharply.
      3) Do not install detector loop wire unless sawed slots are completely dry and free of debris. Use compressed air to thoroughly dry the sawed slot.
      4) Install the loop wire starting at the nearest pull box or condulet, around the loop for the specified number of turns, and back to the pull box or condulet.

      NOTE: Loop wire from the street is to be spliced in condulets or pull boxes only.

   d. Press the wire in the slot without using sharp objects that may damage the jacket.

e. Hold the loop in place every 5 feet (1.5 m) with 1 inch (25 mm) strips of rubber, neoprene, flexible tubing, or foam backer rod as approved by the Engineer.

f. Leave the hold down strips in place when filling the slot with loop sealant.

g. Where encased loop wire is used, apply a waterproof seal to the ends of the polyethylene tubing that encase the wire to prevent moisture from entering the tube.

h. Where the loop wires cross pavement joints and cracks, protect the loop wires using the method specified in "Miscellaneous Details" in the Plans.

3. Loop Sealing

After successfully testing each loop, fill the slots with sealant to fully encase the conductors.

a. Ensure that the sealant is at least 2 inches (50 mm) thick above the top conductor in the saw cut.

b. Apply the sealant so that subsequent expansion does not extend the sealant material above the pavement surface.

c. Before the sealant sets, remove surplus sealant from the adjacent road surfaces without using solvents or epoxy sealants.

d. Obtain approval from the Office of Materials and Research to use polyurethane sealants. They shall conform to Subsection 833.2.09.

e. When the Engineer determines that the loop sealant can accommodate traffic but the surface is tacky, dust the sealer on the pavement surface with cement dust before opening the roadway to traffic.

f. Dispose of the solvents used to clean loop installation equipment according to the manufacturer's specifications and local, State, and Federal regulations.

4. Loop Connections

Connect loop conductors to a shielded lead-in cable that runs from the pull box adjacent the pavement edge or condulet to the detector hook-up panel in the controller cabinet, unless otherwise specified in the Plans.

a. Use continuous (no splices) shielded lead-in cable from the pull box or condulet to the cabinet input file terminal. Do not ground the shield in the loop lead-in cable at the cabinet.

b. Connect each loop to an individual detector channel as specified in the Plans.

c. If the Plans specify that two or more loops will be operated on the same detector channel or detector amplifier unit, wire them in series to their loop lead-in at the pull box or condulet.

d. Use series-parallel connections when series connections do not meet the manufacturer's specified operating range for the detector amplifier unit.

e. Make weather-tight and waterproof splices as detailed on the plan Standard Detail sheets. Make loop splices to loop lead-in cable only after the detector system has been tested and demonstrated under traffic conditions to the Engineer's satisfaction.

5. Loop Maintenance

Locate all existing loops, determine the operational status of all loop assemblies, and notify the Engineer prior to commencing loop construction activities at the intersection.

Maintain all existing, operational loops, unless otherwise notified by the Engineer. Repair of an existing loop that is non-operational prior to beginning work will be considered as extra work.

Locate points of conflict between new loops and existing loops, and install all new loops and saw cuts so as not to cut existing loop lead-ins and loop wires that are to be retained.

If an existing operational loop that is not scheduled for replacement fails during the construction time frame, notify the Engineer and complete the replacement of the damaged loops immediately.

The Engineer may grant a twenty-four (24) hour period to repair the loops if their operation is not critical. All costs associated with the replacement of the loops damaged during construction shall be charged and paid for by the Contractor.

J. Pedestrian Push Button

Install the push button with a pedestrian instruction sign as illustrated on the Department's standard detail sheets and according to the Plans.

1. Place the pedestrian buttons as shown on the signal plan sheet and within easy access of the pedestrian crosswalk.

2. Position the pedestrian button to correspond to the appropriate signal phase. Locate pedestrian buttons perpendicular to the appropriate signal indication and signal phase, and as field conditions require..
3. Place the buttons approximately 3.5 feet (1.05 m) above the sidewalk or ground level.

K. Cable

Install and connect electrical cable to the proper equipment to produce an operating traffic signal system. Use stranded copper cable conforming to Section 925.

Install wiring in accordance with ISMA, NEMA, UL, and the Department's Traffic Signal Wiring Standards, shown in Tables 647-1, 647-2, 647-3, and 647-4 of this Specification.

In addition to the information provided below, see Section 682, Section 922, and Section 925 for cable equipment and installation specifications.

Table 647-1
Vehicular Signals
Georgia DOT Wiring Standards

Signal Indications	3-Section Signal Heads Seven Conductor Cable		5-Section Signal Heads Seven Conductor Cable
	Phases 2, 4, 6, and 8	Phases 1, 3, 5, and 7	Phases 1/6, 2/5, 3/8 & 4/7
Red	Red Wire		Red Wire
Yellow	Orange Wire		Orange Wire
Green	Green Wire		Green Wire
Red Arrow		White Wire with Black Tracker	
Yellow Arrow		Black Wire	Black Wire
Green Arrow		Blue Wire	Blue Wire
Neutral	White Wire	White Wire	White Wire

Table 647-2
Vehicular Loop Detectors
Georgia DOT Wiring Standards

Detectors	Phases 3, 4, 7, and 8 Presence Loops		Phases 2 and 6 Setback Pulse Loops and Phases 1 and 5 Presence Loops	
	Loop Wires	Shielded Loop Lead-in Cable, 3 Pair	Loop Wires	Shielded Loop Lead-in Cable, 3 Pair
Right Curb Lane	Red Wire	Red/Black Pair (1)	Red Wire	Red/Black Pair (1)
Second Lane	Green Wire	Green Black Pair (1)	Green Wire	Green Black Pair (1)
Third Lane	White Wire	White/Black Pair (1)	White Wire	White/Black Pair (1)
Fourth Lane	Red Wire	Red/Black Pair (3)	Red Wire	Red/Black Pair (3)
Fifth Lane	Green Wire	Green/Black Pair (3)	Green Wire	Green/Black Pair (3)
Sixth Lane	White Wire	White/Black Pair (3)		
First Left-Turn Lane			Red Wire	Red/Black Pair (4)
Second Left-Turn Lane			Green Wire	Green/Black Pair (4)

Table 647-3 Pedestrian Signals Georgia DOT Wiring Standards		
Signal Indications	**2-Section Signal Heads Seven Conductor Cable**	
	Phases 2 and 6	**Phases 4 and 8**
Don't Walk	Red Wire	White Wire with Black Tracker
Walk	Green Wire	Blue Wire
Neutral	White Wire	White Wire

Table 647-4 Pedestrian Detectors Georgia DOT Wiring Standards		
Push Buttons	**3 Pair Shielded Cable**	
	Phase 2 and 6	**Phase 4 and 8**
Call	Green and Black Pair	Red and Black Pair

NOTE: Do not use aluminum cable.

L. Signal Cable for Vehicular Signal Heads and Pedestrian Heads

Install cable for signal heads and pedestrian heads as follows:

1. For vehicle signal heads, install one 7-conductor signal cable for each intersection approach from the controller cabinet to the leftmost through-signal head on each approach. From this leftmost signal head, install a 4-conductor signal cable to each of the other signal heads on the same approach in sequence.
2. For pedestrian signal heads, install one 7-conductor signal cable from the controller cabinet to each pedestrian head installation location to operate either one or two pedestrian heads.
3. Make a minimum 2 foot (600 mm) diameter weather drip loop as shown in the Standard Detail Drawings in the Plans at the entrance to each signal head, pole, overhead conduit, and weatherhead.
4. Neatly tie signal cables leaving a structure or weatherhead to enter a signal fixture. Tie the cables to the messenger cable as illustrated in the Standard Detail Drawings.

M. Interconnect Communications Cable

Use fiber optic interconnect cable for all new interconnected signal systems. See Section 935 for fiber optic cable information, specifications and installation and testing techniques. Install and test interconnect communications cable as follows:

1. Installation
   a. Provide support for the interconnect cable on new or existing utility poles or signal poles; install underground in conduit.
   b. Pull cables with a cable grip that firmly holds the exterior covering of the cable.
   c. Pull the cables without dragging them on the ground, pavement or over or around obstructions. The Engineer will inspect and approve the cable prior to installation. Use powdered soapstone, talc, or other approved inert lubricants to pull the cable through the conduit.
   d. When using a separate messenger cable, spirally wrap the communications cable with a lashing machine according to the IMSA-20-2 Specifications.
   e. Do not splice outside the signal cabinet except at the end of full reels of 5,000 feet (1500 m).
   f. Ensure that splice points are near support poles and accessible without closing traffic lanes.
   g. Unless drop cable assemblies for communications are used, loop the cable in and out of the control cabinets. Coil and tie 10 feet (3 m) of cable in the controller cabinet foundation. Tape the cable ends to keep moisture out until the terminals are attached.

h. Prevent damage to the cable during storage and installation.

> **NOTE: Do not allow workers to step on or run over any cable with vehicles or equipment.**

2. Field Test

Conduct a test for continuity and isolation with the Engineer according to Section 935.

a. Perform the attenuation test for each fiber. Test for all events above 0.10 dB and total attenuation of the cable. Submit both printed and electronic (diskette) OTDR testing results as referenced in Subsection 935.1.03.

b. Perform the isolation test for testing insulation resistance for each conductor and cable shield in the system.

1) Fiber optic cable testing is to be conducted according to the requirements of Section 935.3.06.B, of the Specifications.

2) Record the fiber cable test results for each on the Interconnect Cable Data Sheet and include it as project documentation.

c. If the conductors fail the continuity or isolation test, remove the installed cable, install new cable, and repeat the tests.

Table 647-5
Interconnect Cable Data Sheet

Conditions			
Project Number:			
Date:			
Weather:			
Temperature:			
Contractor:			
Location			
Controller Cabinet:			
City or County:			
Intersection Name(s)			
Route Number(s)			
Termini of Cable:			
Materials			
Type:			
Manufacturer:			
Number of Conductors:			
Splice Point:			
Total Length of Cable:			
Tests			
Conductor Tube Color Description		**Continuity**	**Attenaution**
1.			
2.			
3.			
4.			

5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
Shield		
Comments		
Inspector's Name and Title:		

N. Loop Detector Lead-in Cable

Use 3-pair shielded lead-in cable in compliance with Section 925 for Detector loop lead-in installed for loop detectors. Use a shielded lead-in cable connecting the loop to the detector hook-up panel in the controller cabinet, unless otherwise specified in the Plans.

- Splice the loop detector wire to a shielded loop detector lead-in cable in a pull box adjacent to the loop detector installation.
- Use continuous (no splices) shielded lead-in cable from the pull box or condulet to the cabinet input file terminal. Do not ground the shield in the loop lead-in cable at the cabinet.
- Connect each loop to an individual detector channel as specified in the Plans.
- Make weathertight and waterproof splices between lead-in and loop wire. Loop installation may be approved only after the detector system has been tested and demonstrated under traffic conditions to the Engineer's satisfaction, during the Operational Test Period.

O. Pedestrian Push Button Lead-in

Use 3-pair shielded lead-in cable compliant with Section 925 for pedestrian push buttons. Install one 3-pair shielded lead-in cable to each corner of the intersection, to operate either one or two push buttons. Do not ground the shield for the push button lead-in cable at the controller cabinet.

P. Messenger Cable, Stranded-Steel

Set messenger strands so that the height of the installed traffic signal heads conforms to the clearances on the Standard Detail Drawings. Lash cables to messenger cable or use cable ties spaced at 6 inch (150 mm) increments.

1. Drill wood poles to receive the eye bolts so that the span wire and eyebolt at each connection form a straight angle. Never pull or strain the messenger on the eye bolt to an angle of variance greater than ten degrees (10º).
2. Attach down guy wires to guy hooks. Never attach them directly to the eyebolt.
3. Ensure that messenger strand clearances conform with local utility company standards.
4. Make stranded messenger cable attachment points with the appropriate size strand vises or 3 bolt clamps. Stranded steel messenger cable is not paid for separately under this Specification.

NOTE: Never splice messenger cable between structures.

Q. Underground Cable for Signal Circuits

Underground cable for signal circuits includes cable, with conduit, as shown in the Plans. Install cable under existing pavement or surfaced shoulder, according to Subsection 680.3.05.

1. Cable in Conduit

Pull cable into conduits as follows:

a. Pull cables into conduits without electrical or mechanical damage. Pull cables by hand only. The use of trucks or other equipment is not permitted, unless approved by the Engineer. If mechanical pulling is approved, do not exceed the manufacturer's tension rating for the cable.

b. Pull cables with a cable grip that firmly holds the exterior covering of the cable.

c. Use powdered soapstone, talc, or other inert lubricants to place conductors in conduit according to manufacturer's recommendations.

d. Handle and install the conductors to prevent kinks, bends, or other distortion that may damage the conductor or outer covering.

e. Pull all cables in a single conduit at the same time. When pulling cables through hand holes, pole shafts, etc., use a pad of firm rubber or other material between the cable and the opening edges to prevent cable damage.

f. When installing cable in conduit with existing signal cable circuits, remove all existing cables and pull them back into the conduit with the new cables.

g. The distance between pull boxes in a run of conduit shall not be greater than 250 feet (75 m), unless otherwise shown in the Plans or approved by the Engineer, with the exception of fiber optic cable. The distance between pull boxes in a run of conduit for fiber optic cable shall not exceed 750 feet (225 m). Identification tape and or tone detection wire shall be used for fiber optic cable in conduit. All unused conduit shall have a continuous pull cable installed between pull boxes. All buried conduit shall be marked using sentinel marker posts identifying buried conduit, approved by the project engineer. See Section 682 for additional requirements.

2. Splices

Required signal conductor splicing shall be performed according to the National Electric Code; use materials compatible with the sheath and insulation of the cable.

Make splices at the first opportunity for items such as electrical communication boxes, pull boxes, controller cabinets, or pole bases unless otherwise shown in the Plans.

NOTE: Do not splice signal conductor cables for vehicle signal heads or pedestrian heads between the controller cabinet and the first signal or pedestrian signal head attachment.

Do not splice the pedestrian push button lead-in cable between the controller cabinet and the first pedestrian push button on each corner.

Do not splice fiber optic cable or copper cable between intersections unless otherwise approved by the Engineer. If approved, splice only in above ground enclosures or aerial splice boxes. Do not splice fiber optic or copper cable in pull boxes.

Make signal conductor line splices with copper-clad pressed sleeves or an approved equivalent. See "Pull Box Splices" in the miscellaneous construction details in the Plans.

a. Insulate required splices with plastic, pressure sensitive, all-weather 1.5 mil (0.038 mm)electrical tape

b. Apply the tape half-lap to a thickness 1.5 times thicker than the factory-applied insulation and sheath. Taper it off over the sheath neatly to approximately 3 inches (75 mm) from the conductor splice.

c. For cable splicing in junction boxes, use a heat-shrinkable, self-sealing splice instead of the above.

d. Pad the sharp points and edges of the connector an fill voids with extra wraps of plastic tape. Do not stretch the tape excessively or cause creeping.

e. Make the spliced joints watertight.

Note: Splice detector wires to shielded loop detector lead-in at pull boxes located immediately after the loop wire leaves the roadway. No splices will be permitted in shielded loop detector lead-in cable from this point to the controller cabinet.

R. Aerial Cable for Signal Circuits

Aerial cable for signal circuits consist of one or all of the following cables:

- Loop lead-in (sensor and detector)
- Signal wiring (controller)
- Interconnect cable (communications)

Support these cables on existing or newly installed signal or utility poles as detailed in Subsection 647.2.01.F.

S. Conduit and Fittings

Install conduit by type (rigid, HDPE, PVC) as shown in the Plans and the Standard Detail Drawings. Refer to the NEC, for conduit full percentages.

Separate signal conductors from vehicle detector and communications interconnect cables, except inside of poles. Separate the power cable to the controller cabinet from all other cables in its own 1in (25 mm) rigid conduit except inside poles. Ensure that conduit conforms to Section 682, Section 923 and Section 925 with the following addition:

- Use flexible conduit only where shown in the Details or as directed to do so in writing by the District Signal Engineer.

Use the conduit size specified in the Plans, unless otherwise directed by the Engineer. Obtain written approval from the Engineer prior to installing conduit other than the size specified in the Plans.

All 2 inch (50 mm) conduit elbows shall be "sweep" type. The minimum radius for the elbow is 18 inches (450 mm), unless otherwise approved by the Engineer.

NOTE: Do not use multi-cell conduit.

Install conduit and fittings as follows:

1. Ensure that exposed conduit on poles are rigid, galvanized metal conduit.
2. Ream the ends of metallic conduit after cutting the threads. Ream other conduit as necessary.
3. Cut the ends square, and butt them solidly in the joints to form a smooth raceway for cables.
4. Make conduit joints to form a watertight seal.
5. Coat metallic conduit threads with red- or white-lead pipe compound, thermoplastic or Teflon seal. Ensure that they are securely connected.
6. Make plastic conduit joints with materials recommended by the conduit manufacturer.
7. Install bushings in the conduit to protect the conductors. When conduit is installed for future use, properly thread and cap the ends of the metallic conduit runs.
    a. Plug the ends of nonmetallic conduit runs to prevent water or other foreign matter from entering the conduit system.
    b. Seal the exposed conduit ends with a permanently malleable material.
    c. Ensure that empty conduit installed for future wire or cable has a nylon pull string or cord inside that is impervious to moisture and rot and can withstand a load of 50 pounds (23 kg) without breaking. Secure this pull cord at each open end and at each pull box.
8. Ensure that conduit on pole exteriors are mounted with galvanized, two-hole straps or clamps. Place the clamps not more than 3 feet (1 m) from junction boxes, condulets, or weatherheads. Place it at 5 foot (1.5 m) intervals elsewhere.
    a. Fasten the clamps to wood poles with galvanized screws or lag bolts.
    b. Do not install conduit risers on concrete, steel, or mast arm poles unless approved by the Engineer.
9. Install a weatherhead at the end of exterior conduit runs on a pole or other structure to prevent moisture of other matter from entering the conduit.
10. After installation, ensure that the conduit or fitting placement has not warped or distorted any condulet, terminal, or control or junction box.

T. Underground Conduit

Underground conduit includes encased or direct burial conduit.

1. Install the conduit in a trench excavated to the dimensions and lines specified in the Plans.
   a. Provide at least 18 inches (450 mm) finished cover, unless otherwise specified.
   b. Under pavement, excavate at least 36 inches (900 mm) below the bottom of the pavement.
2. Before excavation, determine the location of electrical lines, drainage, or utility facilities in the area to prevent damage.
   a. Place the conduit where it will not conflict with proposed guardrail, sign posts, etc.
   b. Change locations of conduit runs, pull boxes, etc., if obstructions are encountered during excavation. Changes are subject to the Engineer's approval.
   c. Where possible, provide at least 12 inches (300 mm) between the finished lines of the conduit runs and utility facilities such as gas lines, water mains, and other underground facilities not associated with the electrical system.
3. When the conduit run is adjacent to concrete walls, piers, footings, etc., maintain at least 4 inches (100 mm) of undisturbed earth or firmly compacted soil between the conduit and the adjacent concrete or, when the conduit is encased, between the encasement and the adjacent concrete.

   Unless specified in the Plans, do not excavate trenches in existing pavement or surfaced shoulders to install conduit.
4. When placing conduit under an existing pavement, install the conduit by jacking and boring, or other approved means. See Section 615 for jacking and boring pipe specifications. Obtain the Engineer's approval prior to installing conduit by means of boring-method.
5. When the Plans allow trench excavation through an existing pavement or surfaced shoulder, restore the pavement shoulder surface, base, and subgrade according to the Specification.
6. Cut trenches for conduit on a slight grade (0.25 percent minimum) for drainage, unless otherwise specified. When the grade can not be maintained all one way, grade the duct lines from the center, both directions, down to the ends.
7. Avoid moisture pockets or traps. Excavate vertical trench walls.
8. Tamp the bottom of the trench to produce a firm foundation for the conduit.
9. When necessary to prevent damage, sheet and brace the trenches and support pipe and other structures exposed in the trenches.
10. Conduit installed for fiber optic cable installation shall have detectable tone wire installed for detection as specified and detailed in the Project Standard Detail Sheets.

U. Encased Conduit

Place encased conduit in the locations shown in the Plans unless otherwise specified. Construct as follows:

1. Construct the encasement using Class A concrete that meets requirements in Section 500 .
2. Extend the encasement or conduit under roadway pavements or surfaces 6 inches (150 mm) past the outer edge of paved shoulders or sidewalks, or past curbs if no shoulder or sidewalk is present.
3. Extend the conduit at least 3 inches (75 mm) beyond the encasement.
4. Place 3 inches (75 mm) of concrete in the bottom of the trench and place the conduit on top of it.
5. Temporarily plug the ends of the conduit to prevent concrete or foreign materials from entering.
6. Cover the conduit with at least 3 inches (75 mm) of concrete.

   Wait to encase the conduit with concrete until the Engineer inspects and approves the conduit.
7. Cure the concrete encasement according to Subsection 500.3.05.Z, except curing may be reduced to twenty-four (24) hours. Use a precast encasement if approved by the Engineer.

V. Direct Burial Conduit

Install direct burial conduit as shown in the Plans. Use rigid galvanized steel, polyvinyl chloride, or polyethylene conduit. Excavate at least 36 inches (900 mm) below the top of the finished ground or 36 inches (900 mm) below the bottom of the pavement.

When rock is in the bottom of the trench, install the conduit on a bed of compacted, fine-grain soil at least 4 inches (100 mm) thick.

Conduit installed for fiber optic cable installation shall have detectable tone wire installed for detection as specified in Section 935 and detailed in Standard Detail Sheets.

W. Backfilling

Immediately backfill the conduit after the Engineer's inspection and approval, except for encased conduit, which must complete a twenty-four (24) hour cure period.

1. Backfill with approved material free of rocks or other foreign matter.
2. Backfill in layers no greater than 6 inches (150 mm) loose depth, up to the original ground level.
3 Compact each layer to one hundred percent (100%) of the maximum dry density as determined by GDT 7, GDT 24a, or GDT 24b, GDT 67.

X. Conduit on Structures

Install conduits, condulets, hangers, expansion fittings, and accessories on structures according to the Plans and, unless otherwise specified, the following:

1. Run the conduit parallel to beams, trusses, supports, pier caps, etc.
2. Install horizontal runs on a slight grade without forming low spots so they may drain properly.
3. Run conduits with smooth, easy bends. Hold the conduit ends in boxes with locknuts and bushings to protect the conductors.
4. When not specified in the Plans or Special Provisions, submit the type and method for attachment to structures to the Engineer for submission to the District Traffic Operations Engineer for approval.

All exposed conduit shall be galvanized, rigid condit unless otherwise specified.

Y. Testing Conduit

After installing the conduit, test it in the presence of the Engineer.

1. Test conduit using a mandrel 2 inches (50 mm) long and 0.25 inches (6 mm) smaller in diameter than the conduit.
2. Repair conduit to the Engineer's satisfaction if the mandrel can not pass through. If repairs are ineffective, remove and replace the conduit at no additional cost to the Department.
3. Thoroughly clean the conduits. When installing conduit but wiring at a later date:
   a. Perform the mandrel test.
   b. Ream the duct opening to remove burrs or foreign matter.
   c. Thoroughly clean the duct.
   d. Provide and install a weatherproof cap at each open end.
   e. All installed conduit not used or containing cable shall have a continuous nylon pull string installed between junction boxes.

Z. Grounding

Ground the cabinets, controller, poles, pull boxes, and conduit to reduce extraneous voltage to protect personnel or equipment. See Section 639 and Section 924 for grounding requirements.

NOTE: Grounding shall meet the minimum requirements of the NEC.

Provide permanent and continuous grounding circuits with a current-carrying capacity high enough and an impedance low enough to limit the potential above the ground to a safe level.

Perform grounding as follows:

1. Bond the grounding circuits to nonferrous metal driven electrodes. Use electrodes that are at least 0.625 inches (15 mm) in diameter, 8 feet (2.4 m) long, and are driven straight into the ground.
2. Use the shortest possible ground lead that leads directly to a grounding source.
3. Ensure that the maximum resistance between the ground electrode and the cabinet ground buss or other point in the grounding system is no greater than five (5) ohms.

4. Connect the ground electrodes and the ground wire with an exothermic weld.
5. Connect neutral conductors to the cabinet buss-bar and ground them at each terminal point.
6. Ground the cabinet with a No. 6 AWG solid copper wire between the buss-bar to the ground electrode. Bends shall not exceed 4 inch (100 mm) radius bends.
7. Permanently ground the poles by bonding the No. 6 AWG solid copper wire to a separate ground rod.
8. Ground pole-mounted accessories to the pole.
9. Underground metallic conduit or down guys are not acceptable ground electrodes. Do not use Snap-On connections.

AA. Ground Rod

Install ground rods in or adjacent to the traffic signal pole bases, controller cabinet bases, and pull boxes to shield and protect the grounding system.

When ground rods are not protected, bury them at least 2 inches (50 mm) below the finished ground level. See Section 924 for information pertaining to ground rod composition.

1. Use 0.625 inch (15 mm) diameter ground rods at least 8 feet (2.4 m) long. Use copper clad ground rods.
2. Drive single ground rods vertically until the top of the rod is no more than 2 inches (50 mm) above the finished ground.
3. Attach a length of No. 6 AWG solid copper wire to the top of the ground rod using an exothermic weld.
4. When controller cabinets are mounted on timber poles, ground them with No. 6 AWG solid copper wire attached to the ground rod. Run the wire inside a minimum 0.75 inch (19 mm) rigid conduit attached to the timber pole and to the chassis ground in the controller cabinet.
5. When ground penetration is not obtained:
   a. Place a horizontal ground rod system of three (3) or more parallel ground rods at least 6 feet (1.8 m) center-to-center and no more than 2 inches (50 mm) above the finished ground.
   b. Ensure that this grounding system produces a resistance of 5 ohms or less.
   c. Join the ground rods and connect them to the grounding nut of the traffic signal base with No. 6 AWG solid copper wire.
6. Install a ground wire on wood poles.
   a. Use at least No. 6 AWG solid copper wire bonded to the grounding electrode and extending upward to a point perpendicular to the uppermost span.
   b. Place wire staples no greater than 2 feet (0.6 m) apart to secure the ground wire to the pole.
   c. Connect the span wire to the pole ground using split bolt connectors. Use the pole ground for a pole mount cabinet.
7. Ensure that grounding for signal strain poles conforms to the grounding assembly typical erection detail sheet in the Plans.
8. Permanently ground cabinet and cabinet conduits to a multi-terminal main ground buss.
   a. Use a No. 6 AWG solid copper wire bonded between the buss and grounding electrode.
   b. Connect the power company neutral, conduit ground, and grounds of equipment housed in the cabinet to the buss-bar.
   c. Do not ground to a permanent water system instead of the driven ground rod. Ensure that grounding devices conform to the requirements of the NEC and NEMA.

BB. Signal Poles

See Section 501 for signal pole materials certification and Subsection 925.2.27 and Subsection 925.2.28 for traffic signal equipment. Refer to the Plans for pole locations.

Where necessary, adjust pole location to avoid utility conflicts. Provide minimum clearance distances between the signal pole and the roadway as specified in the Plans and on the Standard Detail Drawings.

1. Strain Poles

   Provide signal strain poles that conform to Section 639.

   Provide caissons or foundations that conform to the "Construction Detail for Strain Pole and Mast Arm Pole Foundations" in the Plans.

Determine the required foundation size based on the manufacturer's specified "bending moment at yield" for the each pole.

Provide strain poles with manufacturer-installed holes for pedestrian heads and push buttons. Seal unused holes with water tight plugs and/or rubber gaskets.

Rake the poles during installation to provide a pole that is plumb once the load is applied.

2. Metal Poles

Install metal poles as follows:

a. Ensure that anchor bolts, reinforcing bars, and ground rods conform to Section 639 and Section 852 and are placed in the excavation.

b. Support the anchor bolts with a template to provide the proper bolt circle for the pedestal or pole to be installed.

c. Wire the reinforcing bars together or to the anchor bolts.

d. Wire the conduits in the base to the reinforcing bars for support. Ensure that they are accessible above and beyond the foundation.

e. Before pouring the foundation concrete, determine that the anchor bolt orientation is correct so that the tensile load is divided between at least two anchor bolts. Pour and vibrate the concrete with the Engineer present.

f. Ensure that the pole foundations and pedestals with the anchor-type base conform to Section 500 and Section 639. Do not install or locate poles without the Engineer's approval.

The Engineer may take a concrete test cylinder as it is being poured.

1) Cure the cylinder and submit it for testing to the Office of Materials and Research.

2) If the concrete foundation fails to meet the requirements of the Specifications and is not accepted, replace the foundation upon notification of failure.

g. After installing poles and applying the load of the signal span, inspect them for plumb and for the proper horizontal position of the mast arm, when applicable.

Correct deficiencies by using the leveling nuts on the anchor bolts or be adjusting the mast arm.

h. The Engineer will examine the pedestals and poles for damaged paint or galvanizing. Restore the finish coating where necessary.

i. After the Engineer approves the pole installation, finish the area between the pole base and the top of the foundation with grounding material.

If the finish or galvanized steel materials is scratched, chipped, or damaged, the material will be rejected. The finish may be replaces as specified under Section 645, with the Engineer's approval.

NOTE: Never add holes or openings to the metal pole or mast arm without approval from the Office of Bridge and Structural Design.

j. For poles or arms that need galvanization, thoroughly clean the steel poles and arms and touch up non-galvanized parts with i-d red or original-type primer.

Apply the remaining coats according to the System V (Heavy Exposure) Section 535, unless otherwise indicated in the Plans.

k. Install a service bracket on one pole at each intersection to attach power service wire as specified in the Plan details. Install a disconnect box on one pole at each intersection to attach power service where the power service is provided overhead.

l. Install poles to which controller cabinets are attached with mounting plates, bolts, nipples, and at least two, 2 inch (50 mm) threaded openings at the top and bottom of the pole.

m. Attach the fittings to the poles as specified by the manufacturer in the Plans or as the Engineer directs. The fittings may include:

- Cast aluminum cap
- Weatherhead with chase nipples and couplings
- Galvanized elbow with bushing installed by cutting the pole and welding in place around the entire circumference

- Copper-clad ground rod that is 0.5 inches (12 mm) or 0.625 inches (15 mm) diameter by 8 feet (2.4 m) long attached to the pole by a tap screw or weld fitting of No. 6 AWG semi-hard drawn solid copper wire and a standard copper clad ground clamp

n. Use a strandvise to attach spanwire to a clevis device or another strandvise. The Office of Materials and Research will inspect the anchor bolts. If approved, the Office of Materials and Research will display the inspector's hammer stamp mark on the top of the bolt.

3. Concrete Strain Poles

   a. Ensure that concrete strain poles meet the requirements of Section 639. Use concrete poles that have threaded couplings to accept weatherheads, pedestrian head mounting hardware, or utility service points shown in the construction details.

   b. Install concrete strain poles so that the angle of variance between the eye bolt on the pole and the span wire is less than ten degrees (10º).

   c. Verify pole hole orientations for pedestrian heads, pedestrian push button stations, luminaries arms, etc., with the Engineer prior to proceeding with traffic signal installation.

4. Mast Arms

   Install mast arms that can accommodate traffic signal mounting hardware and that adhere to the manufacturer's recommended procedures and Section 925 and Section 915. Do not add holes.

   a. Seal the openings in the mast arms to prevent pests from entering.

   b. Align the mast arm to allow the signal heads to hang plumb at the correct height without using extensions.

> **NOTE: The contractor shall submit a "Mast Arm Pole Chart" to the Engineer for review and approval as described in Subsection 647.1.03.E of this Specification.**

   Verify pole hole orientations for pedestrian heads, pedestrian push button stations, luminaries arms, etc., with the Engineer prior to proceeding with traffic signal installation.

5. Aluminum Pedestrian Pedestals Poles

   Install aluminum pedestal poles, which adhere to Section 850 on breakaway aluminum bases that meet the requirements for breakaway construction. See Section 925 for breakaway base requirements. See the Standard Detail Drawings for Pole and Foundation Details.

   a. Secure at least four anchor bolts in a concrete foundation as shown in the construction detail.

   b. Contain the wiring inside the pole. Do not allow conduit outside the pole except to wire the pedestrian push button.

   c. Position the pedestal pole plumb and high enough to clear the pedestrian's head as shown in the Plans - usually 10 feet (3 m) from the ground line.

   d. Instruct the supplier to furnish a mill certificate that shows the alloy and physical properties of the steel used in fabricating the anchor bolts. The bolts may be subjected to a tensile and shear strength test.

6. Timber Poles

   Timber poles do not require the use of concrete for filling the cavity around the pole base.

   Use timber poles that meet the requirements of Section 861. Use Class II for all signal support poles. Use Class IV for aerial loop lead-in or communication cable if approved by the Engineer. Poles shall be inspected and include AWW stamp.

   Drill wood poles to receive the eye bolt so that the angle of variance between the eye bolt and span wire at each connection is less than ten degrees (10º). See the Standard Detail Drawings for additional information.

   Guy timber poles use single or double guy wires as shown in the Plans and as directed by the Engineer. Guy helper cables with separate guy wires when helper signal span cables are indicated in the Plans.

> **NOTE: Never attach down guy wires to eye bolts. Attach down guy wires to guy hook brackets only and install insulating rods on all down guy installations as detailed on Standard Detail Sheets .**

CC. Pull Boxes

Ensure that pull boxes conform to Subsection 680.3.05.B and the Standard Detail Drawings or Plan Detail Sheet. Install pull boxes as required by the Specifications and Plans.

1. Include provisions for drains in pull box excavations as specified.
2. Do not place the aggregate for the drain until the Engineer approves the excavation.
3. Set the precast pull boxes in place, level, and install conduits at required (conduit shall penetrate at least 3 inches (75 mm) into the pull boxes). Adjust the location of the pull box if necessary to avoid obstacles.
    - Do not locate pull boxes on the curb side of the signal pole in the intersection radius return
    - Install pull boxes so that the long dimension is parallel to the adjacent roadway
    - Install the pull box at a location that is level with the surrounding ground or pavement. Do not place a pull box in a ditch or depression. Unless otherwise shown in the Plans, when installed either in a sidewalk or in the ground, the top of the pull box shall be level with the sidewalk or ground surface
4. Obtain the Engineer's approval, and begin backfilling and installing the frame and cover. Ground metal lids or covers.

DD. Span Wire and Span Wire Assemblies

Use span wire to support signal heads, cable, and other hardware only. Use messenger cable to support the aerial cable plant. Install span wire and messenger wire where specified in the Plans and in accordance with the Standard Detail Drawings. See Section 925 for information on span wire and messenger cable.

1. Install signal span wire not to exceed the sag specified in the Standard Detail Drawings.
2. Use helper cables where specified in the plans and on the Standard Detail Drawings.
3. See Subsection 639.3.05.F except, when erecting cable on a timber pole, in which case locate the attachment point a minimum of 18 inches (450 mm) from the top of the pole, to determine the required attachment point.
4. For construction of a box or modified box span, use either bullrings or interlocking strandvises. Be consistent throughout the intersection in use of bull rings or strandvises.
5. Install 8 inch (200 mm) diameter drip loop wrapped two times at the cable entrance to signal heads. Arrange cable so that it enters the structure from the bottom of the drip loop. Use a 24 inch (600 mm) diameter drip loop where cables enter a weatherhead and use a 24 inch (600 mm) sag at corners of a span.
6. Lash cables to span wire or use cable ties spaced at 6 inch (150 mm) increments.
7. Ground all span wire and down guy assemblies as shown on Standard Detail Sheets .

EE. Traffic Signal Heads

Place traffic signal heads according to the signal design and Plan detail drawings. Deviation from the Plans must be according to the MUTCD, current edition and at the Engineer's approval.

1. Install traffic signal heads at least 17 feet (5.1 m), but no greater than 19 feet (5.7 m) over the roadway.
2. Use extension mounting hardware to give signal heads on the same approach the same vertical clearance.
    a. If extensions are over 2.5 feet (0.75 m), tether them at the bottom of the signal head using 0.25 inch (6 mm) span wire and a breakaway tether plate or fitting.
    b. Measure the clearance from the pavement to the lowest part of the assembly, including brackets and back plates.
    c. Mount traffic signals on the side of wood or metallic poles with a clearance of at least 12 feet (3.6 m) above the sidewalk or pavement grade of the center of the highway, whichever grade is higher.
3. Connect the signal cable to the wire in each signal head to provide the correct signal indication when the cables are connected to the controller cabinet back panes. Do not splice cables except in hand holes at the bases of poles or overhead in junction boxes.
4. Install optically programmable (OP) signal heads as shown in the Plans and standard detail sheet and as directed by the manufacturer.
5. Mount OP heads securely or tether them to limit movement. Mask the lamp for directing visibility under the Engineer's supervision.
6. Tether signal heads that have tunnel visors longer than 12 inches (300 mm), at the discretion of the Engineer.

7. Attach signal heads to mast arms using rigid mounting brackets. See Section 925 for equipment information. Adjust signal heads on mast arms so that all red indications on the same mast arm are at the same elevation.
8. Install lane control heads for reversible lane systems and ramp metering heads as shown in the Plans and the Standard Detail Drawings. Center each signal over the lane or lanes under signal control.

   Leave a vertical clearance for blank-out signs as shown on the Standard Detail Drawings. Use a spirit level to ensure that the bottom edge of each sign is horizontal.

FF. Pedestrian Signal Heads

Install pedestrian signal heads on wood, concrete, steel strain poles, wood or steel auxiliary poles, or metal pedestal poles. Do not mix pole mount methods at the same intersection installation.

Install the pedestrian signal heads as shown on the Standard Detail Drawings and the intersection plan sheets and drawings.

Leave a vertical clearance from the bottom of the head to the ground level of least 10 feet (3 m) unless specified by the Engineer.

1. Pedestal Mounts

   Make pedestal mounts with a lower supporting assembly consisting of:

   - A 4 inch (100 mm) slip-fitter bracket
   - Hollow aluminum arms with a minimum inside cross-sectional area equal to a 1.5 inch (38 mm) pipe

   Use serrated locking devices that firmly hold the signal heads in the required alignment.
2. Pole Mounts (Side of Pole)

   For Metal poles, use side hinge "clamshell" mounting hardware or hardware as described in Wood Pole or Metal Pole alternate.

   a. Side Hinge "Clamshell"

      See the Standard Detail Drawings.

   b. Wood Pole or Metal Pole alternate:

      Make pole mounts with the upper and lower assembly consisting of:

      - A post arm with a minimum cross-sectional area equal to a 1.5 inch (38 mm) pipe
      - A post hub plate that matches the outside pole contour
      - Secure the hubs to metal or concrete poles using 0.75 inch (19 mm) wide stainless steel bands. Secure the hubs to wood poles using lag bolts

Space the junctions so that each pedestrian signal head can be directed toward approaching traffic as needed.

Use serrated locking devices that hold the pedestrian signal heads in alignment.

GG. Blank-out Signs

Install blank-out signs as follows:

1. Securely fasten the sings to a stationary structure or to a messenger strand support system.
2. Center each sign over the lane or lanes under sign control, where applicable.
3. Leave a vertical clearance for blank-out signs as shown in the Plans or in Subsection 647.3.05.EE, "Traffic Signal Heads." Use a spirit level to ensure that the bottom edge of each sign is horizontal.
4. Use terminal strips to connect each sign electrically to the external control box or cabinet.

647.3.06 Quality Acceptance

A. Testing Loop Detector Installation

Test each loop after installing the conductors in the slots cut in the pavement and before sealing.

- Perform a test where the loop wire is spliced to the shielded lead-in wire and where the shielded lead-in wire enters the controller cabinet
- If there are no splice points, such as in direct entry to the controller cabinet, only perform the tests at the controller

- Record the test results on the Loop Installation Data Sheet in Table 647-8, as shown in this section. Make copies of the data sheet as needed
- Include the data sheets in the records, and place a copy in the controller cabinet

Conduct the following five (5) tests to evaluate each loop installation for acceptance before sealing the loop in the pavement:

1. Induced AC Voltage Test

   Read 0.05 V AC or less on a digital voltmeter or no deflection on the pointer of an analog meter.

2. Inductance

   Inductance (I) is measured in microhenries (mH), and the total inductance is equal to the inductance of loop plus inductance of the loop lead-in.

   Acceptable inductance is within 10 percent (10%) of the calculated value for a single loop with the design criteria listed in Table 647-6 and Table 647-7:

Table 647-6
Standard (Bi-Pole) Loops

6 ft x 6 ft (3 turns) [1.8 m x 1.8 m (3 turns)]	I = 76 mH per 100 feet of loop lead-in cable I = 76 mH per 30 m of loop lead-in cable
6 ft x 18 ft (2 turns) [1.8 m x 5.4 m (2 turns)]	I = 80 mH per 100 feet of loop lead-in cable I = 80 mH per 30 m of loop lead-in cable
6 ft x 30 ft (2 turns) [1.8 m x 9 m (2 turns)]	I = 126 mH per 100 feet of loop lead-in cable I = 126 mH per 30 m of loop lead-in cable
6 ft x 40 ft (2 turns) [1.8 m x 12 m (2 turns)]	I = 165 mH per 100 feet of loop lead-in cable I = 165 mH per 30 m of loop lead-in cable
6 ft x 50 ft (2 turns) [1.8 m x 15 m (2 turns)]	I = 205 mH per 100 feet of loop lead-in cable I = 205 mH per 30 m of loop lead-in cable
6 ft x 70 ft (2 turns) [1.8 m x 21 m (2 turns)]	I = 285 mH per 100 feet of loop lead-in cable I = 285 mH per 30 m of loop lead-in cable

Table 647-7
Quadrupole (QP) Loops

6 ft x 30 ft (2, 4, 2 turns) [1.8 m x 9 m (2, 4, 2, turns)]	I = 269 mH + 23 mH per 100 feet of loop lead-in cable I = 269 mH + 23 mH per 30 m of loop lead-in cable
6 ft x 40 ft (2, 4, 2 turns) [1.8 m x 12 m (2, 4, 2 turns)]	I = 349 mH + 23 mH per 100 feet of loop lead-in cable I = 349 mH + 23 mH per 30 m of loop lead-in cable
6 ft x 50 ft (2, 4, 4 turns) [1.8 m x 15 m (2, 4, 4, turns)]	I = 429 mH + 23 mH per 100 feet of loop lead-in cable I = 429 mH + 23 mH per 30 m of loop lead-in cable
6 ft x 60 ft (2, 4, 2 turns) [1.8 m x 18 m (2, 4, 2, turns)]	I = 509 mH + 23 mH per 100 feet of loop lead-in cable I = 509 mH + 23 mH per 30 m of loop lead-in cable
6 ft x 70 ft (2, 4, 2 turns) [1.8 m x 21 m (2, 4, 2, turns)]	I = 589 mH + 23 mH per 100 feet of loop lead-in cable I = 589 mH + 23 mH per 30 m of loop lead-in cable

3. Leakage Resistance to Ground

   The resistance to ground shall be 1 Mμ or more.

4. Loop Resistance

   The resistance reading on an ohmmeter is approximately within ten percent (10%) of the calculated value:

   - Acceptable Resistance @ (dc @ 68 ºF [20 ºC]):ohms(μ)

- No. 14 AWG wire: R = 13.32μ/mile (or) R = 2.523 x 10^{-3}μ/ft. Approximately 2.52 ohms per 1,000 feet of No. 14 AWG wire)[R = 8.3μ/km (or) R=8.3 x 10^{-3}μ/m]
- No. 12 AWG wire: R = 5.2μ/mile (or) R = 9.85 x 10^{-4}μ/ft. Approximately 0.98 ohms per 1,000 feet of No. 12 AWG wire [R = 3.24μ/km (or) R = 3.24 x 10^{-3}μ/m]

5. Loop Q

   Q at 50 kHz is greater than 5.

Report to the Engineer an out-of-range reading on any of the above tests. If a test is found unacceptable, remove the loop, install new wire, and repeat the test procedure.

Include in the test results:

- Type and model number of the equipment used (must be ohmmeter having a high resistance scale of R x 10 KW or greater)
- The last calibration date of the equipment and the scale used

Check the loop using an impedance tester to determine the natural operating frequency and impedance.

Ensure that the completed units detect all motor vehicles. If the loop detection system does not meet the above test requirements, payment will not be made for work on the signal installation until corrections are completed.

Table 647-8
Loop Installation Data Sheet

Conditions	
Project Number:	
Date:	
Contractor:	
Weather:	
Temperature:	
Pavement Condition - Wet ( ) or Dry ( )	
Location	
City or County:	Phase:
Intersection Name or Number:	Function:
Route Number(s) or Name (s):	Lane Location:
Installation or Plan Sheet Number:	No. of Turns:
Size and Type of Loop:	Downstream/Upstream: Down ( ) Up ( )
Distance from Stop Bar:	Distance E.O.P/Curb to Lead-in:
Distance Lead-in Cable:	
Material	
Loop Wire Color/Insulation Type/Gauge:	
Loop Lead-In Wire Color/Insulation Type/Gauge:	
Splice Point:	
Conduit Length from Curb/E.O.P. to Splice Point:	
Conduit Length from Splice Point to Cabinet:	
Sealant Type and Part Number:	
Sealant Manufacturer and Lot No.:	

Interconnect Wire Type and Length:	
Loop Tests	
1. Induced Voltage _____ 2. Inductance _____ microhenries 3. Leakage Resistance to Ground _____ megohoms 4. Loop Resistance _____ ohms 5. Loop Q (Quality) _____ Q	
Comments	
Inspector's Name, and Title	

B. Field Tests

In addition to performing tests during installation and before turning on the equipment, perform the following tests on traffic signal circuits in the presence of the Engineer:

- Test each circuit for continuity
- Test each circuit for grounds

If a test fails, repair the circuit immediately. New signals shall operate in the flash mode for three (3) days prior to beginning stop-and-go operation unless otherwise directed by the Engineer.

C. Operational Tests

After the equipment is installed and the system checkout is complete:

1. The Engineer will notify the District Traffic Operations Engineer in writing to request final inspection.
2. The District Signal Technicians will conduct an in-depth inspection and will give the Engineer a written punch list of items that the Contractor needs to correct within three weekdays of the notification.
3. When defects are resolved, the District Traffic Operations Engineer will begin an operational test period to demonstrate that every part of the system functions as specified.
   a. The operational test for the traffic signal system shall be at least thirty (30) days of continuous, satisfactory operation.
   b. If a component or system fails or shows unsatisfactory performance, the condition must be corrected and the test repeated until thirty (30) days of continuous satisfactory operation is obtained.
   c. The District Traffic Operations Engineer will send the Engineer and Construction Office a letter showing the start, termination, suspension, or successful completion of the operational test period.
4. The District Traffic Operations Engineer may recommend payment only after the successful completion of the test period.
5. The Contractor shall obtain written acceptance of the signal installation from the District Traffic Operations Engineer before Final Acceptance.

Costs incurred during operational tests, including power consumption, shall be at the Contractor's expense and included in the price bid for Contract Items.

647.3.07 Contractor Warranty and Maintenance

A. Traffic Signal Equipment Maintenance

Perform an inspection with the Engineer to determine the operational status of existing field equipment and finalize materials and equipment is to be removed due to the project.

Prepare written directions identifying what equipment was operational and non-operational and responsibility for repair.

Functional responsibility for new traffic signal equipment installed will become the responsibility of the contractor until successful completion of a 30 day Acceptance Test Period.

Contractor responsibility for operation and maintenance for newly installed signal material at the intersection begins from the first day of construction activity at the intersection, including modification of existing equipment due to construction activity, until Final Acceptance of the traffic signal.

Measure and document existing vertical signal head clearance during the inspection. Maintain existing vertical clearances until Final Acceptance.

Failure to measure and document vertical clearances as part of the inspection will require that all signals be maintained with a vertical clearance of 17 feet (5.1 m) until Final Acceptance. Maintain newly installed signals continuously as detailed in following sections, until Final Acceptance.

Provide a telephone number where the Worksite Traffic Control Supervisor (WTCS) responsible representative of the contractor can be reached twenty four (24) hours a day seven (7) days a week in the event of an emergency.

If a signal is not functioning properly:

1. Non-Emergency

   Commence work on this signal within one (1) day of the written notice from the Engineer requesting per calendar day charged against monies due or that may become due until the maintenance work is started.

   Liquidated damages are in addition to those specified in Subsection 108.08, "Failure or Delay in Completing Work on Time," for delay or failure in completing the Work within the specified time and to the satisfaction of the Engineer.

   The contractor shall be responsible for all materials and equipment necessary to correct signal malfunction or repair.

2. Emergency

   If the District Traffic Operations Engineer determines that the signal malfunction or failure is an operational hazard, the contractor is to take corrective action within three (3) hours of notification.

   Failure to respond within three (3) hours will result in a non-refundable deduction of money of $1,000.00 with an additional charge of $500.00 per hour after the first three (3) hours until a work crew arrives on site and begins corrective action.

   In addition, the cost of labor and material will be charged if the Department takes corrective action using its own forces or local municipality forces.

   Total charges will not exceed $5,000.00 (per emergency call) in addition to the material cost and labor incurred to make repairs by the Department or local municipality forces.

   The Department will not be held responsible or liable for any alleged damage to the signal or as a result of the signal malfunction due to problems that may occur after Department or local municipality forces make emergency repairs.

   The contractor shall be responsible for all materials and equipment necessary to correct signal malfunction or repair.

   In the event of failure to replace or repair to original condition any equipment or material within seven (7) calendar days from the Engineer's notice, the Engineer may have the work done by others and charge the cost of money due from the contract work.

   Final Acceptance will not be given until payment for such work is received.

B. Warranties

Provide manufacturer's warranties or guarantees on electrical, electronic, or mechanical equipment furnished, except state-supplied equipment.

Ensure that warranties and/or guarantees are consistent with those provided as customary trade and industry standard practices; or as otherwise specified in the Plans, Standard Specifications, or Special Provisions.

Upon Final Acceptance, transfer the manufacturer and Contractor warranties or guarantees to the Engineer. Ensure that warranties are continuous and state that they are subject to transfer.

Acceptance or approval of the Work does not waiver warranties or guarantees where required by the Specifications. Final Acceptance will not be granted until all warranties and guarantees are received.

C. Guaranties

Repair and/or replace all equipment and material supplied under these Contract Documents which has been determined by the Engineer to not meet Specifications.

The Engineer reserves the sole right to determine suitability or unsuitability of the supplied equipment and material. Bear the total cost of delivery and transportation related to the repair and replacement of equipment and material throughout the duration of the Contract unless otherwise approved by the Engineer.

Transfer to the Engineer any warranties and guaranties remaining on all items after Final Acceptance. Perform transfer at 12:01 AM of the day following Final Acceptance.

647.4 Measurement

Traffic signal items complete, in place, and accepted of the kind, size, and type specified are measured as follows:

A. Traffic Signal Installation

Signal installation will be paid for by lump sum, including furnishing labor, materials, tools, equipment, and incidentals required to compete the work unless otherwise specified in this Subsection.

B. Communications Wire, Fiber Optic Cable

The number of feet (meters) of communications cable, wire or fiber optic cable, is the actual number of linear feet (meters) of the size installed and accepted. Communications cable shall be paid for under Section 935.

C. Strain Poles, Traffic Signs

Highway signs are measured and paid for under Section 636. Strain poles are measured and paid for under Section 639.

D. Miscellaneous

Miscellaneous items will be measured as specified in the pay item.

No measurement will be made for individual items unless a pay item is included in the plans for the specific item.

647.4.01Limits

General Provisions 101 through 150.

647.5 Payment

The lump price bid for Traffic Signal Installation covers all Items of work in this Specification including furnishing labor, materials, tools, equipment, and incidentals required to complete the work.

Costs for installation, operation, maintenance, and removal of the traffic signal equipment are included under this Item.

Include payment for removal; disposal of existing pavement, shoulder surface, base and sub-grade; and restoration to original condition in the Contract Price for the items to which they pertain. They will not be paid for separately.

Furnishing, installing, and removing sheeting, bracing, and supports will not be paid for separately, but is included in the Contract Prices for other items.

No additional payment will be made for testing and storing State-supplied or contractor-furnished traffic signal equipment.

No payment will be made for individual items unless a pay item is included in the plans for the specific item.

Payment will be made under:

Item No. 647-Traffic signal installation no-	Per lump sum

Payment for various elements of traffic signals will be as shown on the plans.

A. Partial Payment

The Contractor may initiate a partial payment process for the lump sum traffic signal Items by submitting a written request to the Engineer. If the Engineer approves this request, payment will be made as follows:

Underground (loops, pull boxes, and conduits)	20%
Overhead (span, heads, poles, push buttons)	30%

Cabinet, contents, and base	30%
Successful completion of operational test	20%

B. Additional Items

Payment Items related to Section 647 are described in the following sections:

Strain Poles	Section 639
Highway Lighting	Section 680
Lighting Standards and Luminaries	Section 681
Electrical Wire, Cable, and Conduit*	Section 682
Grassing	Section 700
Timber Poles	Section 639 and Subsection 861.2.02
Sign Blanks	Section 912
Reflectorization Materials	Section 913
Traffic Signal Equipment	Section 925
* Payment for conduit installation shall be as described in Section 682 unless conduit installation is performed as part of a traffic signal installation, in which case measurement and payment is a part of the complete traffic signal installation. Payment is Lump Sum, unless listed as a separate pay item.	

647.5.01Adjustments

General Provisions 101 through 150.