METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY

NDOT

730N

TENNESSEE DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS

Nashville Department of Transportation & Multimodal Infrastructure (NDOT)

Rev. January 2025

Accepted by: _____

Date: _____

TENNESSEE DEPARTMENT OF TRANSPORTATION
STANDARD SPECIFICATIONS FOR
ROAD AND BRIDGE CONSTRUCTION

January 1, 2021 **(Excerpt)**

SECTION 730N—TRAFFIC SIGNALS

These specifications, Section 730N, are intended as a supplement to Section 730 of the Tennessee Department of Transportation (TDOT) Standard Specifications for Road and Bridge Construction (March 1, 2006, or latest edition). This supplement is applicable to all traffic signal installations within Nashville and Davidson County, Tennessee. The purpose of this supplement is to provide adequate and acceptable technical specifications for the construction procedures and quality of materials that would be in the best interest of safety, convenience, and prosperity of the public. Deviation from these specifications shall be at the discretion of the Nashville Department of Transportation & Multimodal Infrastructure (NDOT). All selected equipment must also be on NDOT's approved Qualified Product List (QPL) unless written approval is provided by NDOT project manager.

730.01—Description of Work.
The work to be performed consists of furnishing and installing all required materials and equipment to complete in-place traffic signal systems and/or modifying existing systems, as shown on approved design Plans, Standard Details, or Special Provisions, and as set forth in these specifications. Unless otherwise indicated on the Plans or specified in the Special Provisions, all materials shall be new.

Where existing systems are to be modified, the existing material shall be incorporated into the revised system, salvaged, or abandoned as specified or as directed by the Engineer.

All incidental parts that are not shown on the Plans or specified herein, and that are necessary to complete the traffic signal or other electrical systems or required for modifying existing systems, shall be furnished and installed as though such parts were shown on the Plans or specified herein. Costs of such incidentals shall be included in the bid price for other items. All systems shall be complete and in operation to the satisfaction of the Engineer at the time of completion of the work. Materials used in any installations must be approved by way of a materials list submission from the Contractor to NDOT.

GENERAL REQUIREMENTS

730.02—Regulations and Code.
All equipment provided must conform to the National Electrical Manufacturers Association (NEMA) Standards Publication, Traffic Control Systems, latest revision, or the Radio Manufacturers Association guidance, whichever is applicable. In addition to the requirements of these specifications, the Plans, and the Special Provisions, all material and work shall conform to the requirements of the National Electric Code (NEC), ASTM International (ASTM), American National Standards Institute (ANSI), Institute of Traffic Engineers (ITE), and International Municipal Signal Association (IMSA); the Manual on Uniform Traffic Control Devices (MUTCD); and applicable local ordinances. Wherever reference is made to the NEC, or the standards mentioned above, consider the reference to mean the code or standard that is in effect on the date of advertisement of the bids or of authorization for force account.

730.03—Submittal Data Requirements.
Within 30 calendar days after the issuance of a work order, the Contractor shall submit to NDOT the manufacturer's **specification documentation** and technical data that fully describe the types of signal equipment the Contractor proposes to use. Descriptive literature shall include the manufacturer, models, etc. and be adequate to determine if the equipment or material meets the requirements of the Plans and these specifications. These sets of submittal data shall include a list of the materials proposed along with descriptive information for, but not limited to, the following items:

- Controller.

- Conflict Monitors and Malfunction Management Unit.
- Cabinet and Exhaust Fan.
- Detectors – Inductive, Video, Radar, etc.
- Signal Heads including Lamp and Light-Emitting Diode (LED).
- Lens Information and Mounting Hardware.
- Loop Wire and Loop Sealant.
- Shielded Detector Cable.
- Signal Cable.
- Communication Cable.
- Cable for Span Wire, Guys, Attachment Hardware, etc.
- Pull Boxes.
- Conduit, Related Fittings, Condulets, and Attachment Hardware.
- Communication Equipment.

The submittal sets shall also include detailed-scale drawings of any non-standard or special equipment and of any proposed deviations from the Plans. If requested to do so, the Contractor shall submit for approval sample articles of any materials proposed for use. NDOT will not be liable for any materials purchased, labor performed, or delay to the work prior to such approval.

Six prints of "Design" or "Shop" drawings indicating the proposed dimensions and material specifications for each of the supports and mast arms involved shall be submitted by the Contractor to NDOT for approval purposes within 30 calendar days after the work order is issued. These drawings, stamped and sealed by an engineer registered in the State of Tennessee, will be reviewed by NDOT at the earliest possible date, and two prints will be returned to the Contractor marked as "Approved for Fabrication" or "Returned for Revisions as Noted." For prints returned for revisions, appropriate action shall be taken by the Contractor to ensure that the earliest possible correction of these items can be achieved so as not to delay the installation.

730.04—Mill Test Reports and Certifications.

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

1. A Mill Test Report for **major** structural items only, as noted in Chart 1, which shall include both physical and chemical descriptions of the material as supplied to the fabricator. When physical properties are altered during the fabrication, the Mill Test Report covering chemical composition shall be supplemented by a certified test report indicating the physical properties of this material after fabrication.
2. Certification of Conformance to the Specifications for all remaining materials not covered by a Mill Test Report as noted in Chart 1.
3. Certification that all welding was performed by operators qualified as follows: steel welders qualified by American Welding Society (AWS) and aluminum welders qualified by American Society of Mechanical Engineers (ASME).
4. Certification of Conformance to the Specifications for the design of all components not completely dimensioned and detailed on the "Standard" drawing.

CHART 1

Component Materials	Mill Test Report	Certification
Tubes for arms and poles	X	
Base castings	X	
Anchor bolts	X	
Pole tops, miscellaneous fittings and hardware		X
Fabricated or cast-type arm connections		X
Galvanizing		X

730.05—Working Drawings.
The Contractor shall provide within the controller cabinet and to NDOT an electrical schematic diagram of the cabinet system wiring and one set of As-Built/Red-Line drawings depicting any field modifications. Manufacturer's instructions for installation, maintenance, and operation of all equipment and components shall also be submitted to NDOT and placed within the controller cabinet. All materials placed in the cabinet shall be mounted in the cabinet inside a plastic envelope.

730.06—Warranty.
The traffic signal system(s) installed under these specifications, including all equipment, parts, and appurtenances in connection therewith, shall be warrantied to NDOT by the Contractor against defective workmanship and materials for a period of not less than one year following the date the signal system is made operational, except in no case shall this warranty expire prior to one year after the final acceptance of the project. Upon completion of the project, warranties on equipment and materials that are offered by the manufacturers as normal trade practice and have not expired shall be turned over by the Contractor to NDOT. At this time, the Contractor should request a written Letter of Acceptance from NDOT for the installation.

730.07—Training.
If requested, the Contractor shall provide to NDOT a training session for the controller and associated cabinet equipment to be supplied by the project. The Contractor shall be notified in advance if training will be required. The training session will last for a minimum of two calendar days unless NDOT determines a lesser time is adequate. The training shall be of a level to train the user in the complete operation and programming features of all controllers. The Contractor shall provide this training at a facility agreed upon by NDOT. The Contractor shall provide the training prior to the acceptance of the project. After the required training, the Contractor shall certify to the Engineer that training has been completed.

This training requirement shall not apply if a training program meeting these criteria has been accomplished by the vendor and/or manufacturer of the equipment being bid within 18 months previous to the date of the invitation to bid but shall apply if the bidder is proposing new, upgraded, or modified equipment not covered in such previous training program.

MATERIALS AND INSTALLATION

730.08—Excavating and Backfilling.
The excavations required for the installation of conduit, foundations, and other equipment shall be performed in such a manner as to cause the least possible damage to streets, sidewalks, and other improvements. The trenches shall not be excavated wider than necessary for the proper installation of the electrical equipment and foundations. Excavating activities shall not be performed until immediately before installation of conduit

and other equipment. The material from the excavation shall be placed in a position where the least disruption and obstruction to vehicular and pedestrian traffic and the least interference with the surface drainage will occur. Trenches shall be graded level with suitable backfill prior to laying the conduit in the trench.

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

Excavations, after backfilling, shall be kept well filled and maintained in a smooth and well-drained condition until permanent repairs can be made.

At the end of each day's work, and at all other times when construction operations are suspended, all equipment and other obstructions shall be removed from that portion of the roadway used by public traffic and parked a minimum of 30 feet (ft) from the edge of pavement unless otherwise protected by guardrail, bridge rail, or barriers installed for other purposes. Any sidewalks damaged during construction shall be traversable by pedestrians at the end of each day’s work. Repair to these sidewalks shall be in accordance with NDOT’s specifications.

Excavation in the street or highway shall be performed in such a manner that not more than one traffic lane shall be restricted in either direction at any time. Traffic shall not be obstructed during hours of peak flow unless approved otherwise by the Engineer or NDOT’s Permits Office. Construction signage shall be incorporated in accordance with the provisions of the MUTCD.

730.09—Removing and Replacing Improvements.
Improvements, such as sidewalks, curbs, gutters, Portland cement concrete and asphalt concrete pavement, bituminous surfacing, base material, and any other improvements removed, broken, or damaged by the Contractor, shall be replaced or reconstructed with the same kind of materials. All replacement shall be in accordance with NDOT standards and specifications.

The outline of all areas to be removed in Portland cement concrete sidewalks and in all pavements shall be cut to a minimum depth of 2 inches with an abrasive-type saw prior to removing the sidewalk and pavement material. Cuts for the remainder of the required depth may be by any method satisfactory to the Engineer. Cuts shall be neat and true with no shatter outside the removal area.

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

All work shall be done in accordance with these specifications, or any local ordinance that may apply, whichever is of a higher standard. The cost of this removal and replacement is to be included in the bid price for other contract items.

730.10—Foundations.
Foundations for posts, standards, and cabinets shall be Class A, Portland cement concrete. All foundations shall include a spare conduit, of a size specified on the Plans, stubbed out parallel to the road.

Foundations for posts, standards, and pedestals shall be poured after the post, standard, pedestal, or anchor bolts or reinforcing steel is in proper position. The exposed portions shall be formed to present a neat appearance. The bottom of concrete foundations shall rest on firm, undisturbed ground. Each foundation shall include one extra 2-inch conduit.

Forms shall be true to line and grade. Tops of footings for posts and standards, except special foundations, shall be finished to curb or sidewalk grade or as ordered by the Engineer. Forms shall be rigid and securely braced in place. Conduit ends and anchor bolts shall be placed by means of a template until the concrete sets. Both forms and ground that will be in contact with the concrete shall be thoroughly moistened before placing concrete. Forms shall not be removed until the concrete has cured for at least 12 hours and hardened sufficiently to allow firm removal without causing damage to the concrete.

Ordinary surface finish shall be applied to exposed surfaces of concrete. Wherever the edge of a concrete foundation or sidewalk section is within 18 inches of any existing concrete improvement, the sidewalk section shall be extended to meet said existing improvement. Any sidewalk construction or repair shall be in accordance with NDOT standards.

Where obstructions prevent construction of planned foundations, the Contractor shall construct a foundation satisfactory to the Engineer.

730.11—Anchor Bolts.
Anchor bolts meeting the requirements of ASTM F 1554, grade 55 or other high-strength steel anchor bolts having a minimum yield strength of 55,000 pounds per square inch (psi) and a minimum ultimate strength of 90,000 psi, each fitted with one regular hex nut and one heavy-duty square nut, shall be furnished with anchor-base type poles. All nuts and not less than 10 inches of the threaded ends of anchor bolts shall be hot-dip galvanized in accordance with ASTM F 153. The anchor bolts shall be capable of resisting at yield strength stress the bending moment of the shaft.. No exposed anchor bolts shall be allowed when work is not in progress. Exposed anchor bolts could pose a hazard to pedestrians.

Plumbing of standards, posts, and pedestals shall be accomplished by adjusting the nuts before the foundation is finished to final grade. Shims or similar devices for plumbing or raking will not be permitted. After plumbing or raking has been completed, anchor bolts shall be cut off ¼ inch above the top nut and the exposed surface painted with rust-protective paint.

Anchor bolts and nuts required for relocating existing standards and posts shall be furnished by the Contractor. Anchor bolts for signal poles shall meet NDOT's minimum diameter standards.

730.12—Pull Boxes, Type B Traffic.
Pull boxes shall have a minimum dimension of 32¼ inches x 19¼ inches x 18 inches and be constructed and installed as shown on the Plans and standard drawings or as directed by the Engineer. Additional pull boxes may be required where conduit runs are more than 150 ft long. Pull boxes shall be installed wherever practicable out of the line of traffic. Covers shall be level with the pavement, the curb or sidewalk grade, or the surrounding ground as required. Each pull box shall include one extra 2-inch conduit.

Electrical conductors shall be placed within pull boxes in such a manner as to be clear of the frame and cover.

The bottom of the pull box shall rest firmly on a bed of crushed stone with a minimum depth of 12 inches below the bottom, and extending 6 inches beyond the outside edge of the pull box, unless otherwise specified by the Engineer.

The frame shall have a minimum weight of 42 pounds (lbs). The cover shall be of the "Extra Heavy" type with a minimum weight of 54 lbs.

1. All pull boxes shall meet Tier 22 requirements.

A. If other than concrete, pull boxes shall be composed of reinforced plastic or epoxy mortar.
B. Shall be designed and tested to a temperature of -50 degrees Fahrenheit (°F).
C. Shall meet the requirements of ASTM D 543, ASTM D 570, ASTM D 790, and ASTM D 635.
D. Shall be based on a vertical design/test load of - 22,500 lbs/33,750 lbs.
E. Loadings shall comply with ANSI 77 2002 and shall meet Tier 22 test provisions for both the cover and sidewall.
F. The word "TRAFFIC" or the words "TRAFFIC SIGNALS" shall be inscribed on top of the covers.

730.13—Fiber Optic Pull Boxes.

Fiber optic pull boxes must be properly grounded according to NEC, Electronic Industries Alliance (EIA)/Telecommunications Industry Association (TIA), and Bellcor (Telcordia) standards. All splice points shall contain sufficient slack (50-ft minimum) to allow for future addition of communication devices, cable and splice repairs, or additional runs of "drop" cable. Sizes for fiber optic pull boxes shall be determined based on the number of cables in the system. Pull boxes shall be required on each side of a street or railroad crossing.

Type A Pull Box with Cover. The pull box shall meet the following requirements:

1. Minimum dimensions: 36-inch x 26-inch x 32-inch exterior pull box and cover shall be precast composite polymer concrete product. Pull boxes with a polymer cover but other material for the box will **not** be accepted.
2. Pull boxes and covers shall be single-stack, open-bottom assemblies configured as shown on the Plans.
3. Vertical design/test load: -22,500 lbs/33,750 lbs. Loadings shall comply with ANSI 77 2002 and shall meet Tier 22 test provisions for both the cover and sidewall.
4. Pull boxes shall meet current NEC requirements for handhole enclosures.
5. Pull box covers shall be labeled (NDOT ITS COMMUNICATIONS) with 3-inch letters.
6. Installation shall be as per guidelines of the TDOT Standard Specifications for Road and Bridge Construction, latest version. Pull boxes and covers shall be installed per the design details.
7. Pull boxes will be measured in units of each and paid for at the contract price per each after the complete installation. The price bid shall include furnishing and installing the pull box and cover including excavation, gravel, restoration, and miscellaneous materials necessary for a complete and accepted installation. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

Type B Pull Box with Cover. The pull box shall meet the following requirements:

1. Minimum dimensions: 49-inch-wide x 32-inch-long x 36-inch-diameter exterior.
2. Pull boxes and covers shall be precast composite polymer concrete product. Pull boxes with a polymer cover but other material for the box will **not** be accepted. Note this is a different pull box than shown in TDOT standard drawings.
3. Pull boxes and covers shall be single-stack, open-bottom assemblies configured as shown on the pans.
4. Vertical design/test load: -22,500 lbs/33,750 lbs. Loadings shall comply with ANSI 77 2002 and shall meet Tier 22 test provisions for both the cover and sidewall.
5. Pull boxes shall meet current NEC requirements for handhole enclosures.
6. Pull box covers shall be labeled (NDOT ITS COMMUNICATIONS) with 3-inch letters.
7. Each pull box shall come equipped with four cable racks and 12 rack hooks. The cable racks shall be a minimum of 24 inches and the rack hooks shall be a minimum of 7 inches in length. The cable racks and rack hooks shall be hot-dipped galvanized steel.

8. Installation shall be per guidelines of the TDOT Standard Specifications for Road and Bridge Construction, latest version. Pull boxes and covers shall be installed per the design details.
9. Cable racks and rack hooks shall be installed in accordance with the manufacturer's recommendations.
10. Ducts shall enter the side of the pull box using a terminator and shall extend into the box no more than 4 inches and no less than 2 inches.
11. Pull boxes shall be measured in units of each and paid for at the contract price per each after the complete installation. The price bid shall include furnishing and installing the pull box and cover including excavation, gravel, restoration, cable rack rails and hooks, terminator rings, and miscellaneous materials necessary for a complete and accepted installation. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

Terminator Ring. The terminator ring shall meet the following requirements:

1. Shall accommodate the number of ducts penetrating into the side of the pull box.
2. Shall mount securely to the side of the box. The terminator shall be a minimum of 1 inch thick and allow adequate spacing of the ducts.
3. Shall be manufactured from a composite material that will not deteriorate in any type of weather conditions.
4. Shall be installed in accordance with the manufacturer's recommendations.
5. Shall be included in the measurement and payment of the Type A pull boxes, Type B pull boxes, and manhole and will not be measured separately for payment.

Payment. The contract unit price shall be full compensation for all work specified in this section. Payment shall be made under:

Item No.	Description	Unit
730.03.23	Install Pull Box (Fiber Optic – Type A)	Each
730.03.24	Install Pull Box (Fiber Optic – Type B)	Each

Pull boxes shall be paid per each as follows:

Stored materials shall be paid per TDOT Standard Specifications.
Final payment shall be made after complete installation and testing.

730.14—Transformer Base.

The transformer base shall be fabricated from steel plate and sheet and designed to harmonize with the shaft. Each transformer base shall be provided with, at a minimum, a 7½- x 9-inch handhole with cover secured with stainless-steel fastening screws; four galvanized steel-bearing plates to fasten the base to the anchor bolts; four galvanized steel bolts, nuts, and washers to fasten base and standard; and a 0.5-inch, 13 UNC grounding nut welded to the inside of the base opposite the handhole opening. The strength of the transformer base shall be comparable with that of the shaft. When a transformer base is required, no handhole shall be required in the shaft.

730.15—Conduit.

Furnishing and installing plastic and steel conduit shall be in accordance with these specifications and in close conformity with the lines shown on the plans or as established by the Engineer.

Threads shall be clean cut, straight, and true, and of sufficient length to permit proper coupling; long-running threads will not be permitted on any part of the work. Threads shall be protected in transit and during installation, and conduit shall be provided with proper supports and protection during construction to prevent injuries. All ends of pipe installed for future connections shall be properly threaded, reamed, and capped to

prevent water and foreign matter from entering the conduit system. Sections shall be made up with red lead, so that ends of conduit will butt together. Threaded ends shall be provided with approved conduit bushings. Conduits for fiber optic cable shall be clear of obstructions. Water-based lubricants shall be used to reduce the potential for outer sheath corrosion.

Signal conduit shall be 2 inches in diameter, and detector conduit 1 inch in diameter, unless otherwise indicated. Conduit for service connections shall be 1 inch in diameter. Conduit shall be 2 inches in diameter for street lights and for communication cable. Conduits smaller than 1 inch in diameter shall not be used unless otherwise specified, except grounding conductors at service points shall be enclosed in ½-inch-diameter conduit. The Contractor may, at its own expense, use large size conduit, in which case it shall be for the entire length of the run with no reducing couplings permitted. There shall be one extra 2-inch conduit provided in each foundation and pull box.

Materials. Types of conduits and fittings used shall be as follows:

1. Steel Conduit.
    A. Rigid conduit and fittings shall be heavy-wall, hot-dipped galvanized steel conforming to Federal Specification WW-C-581-d(3) and ANSI-C 80.1. The conduit shall be galvanized inside and out and shall meet the requirements of ASTM A 53. Each length shall bear the label of Underwriters Laboratories, Inc. (UL).
    B. Flexible conduit shall be galvanized, flexible steel meeting Federal Specification WW-C-581-d(3), ANSI C-80.1, and UL Standard No. 6 with a minimum of 40-mil-thick polyvinyl chloride (PVC) coating conforming to ASTM D 746.
    C. Fiber optic conduits shall be in accordance with ASTM F 2160.
2. Plastic Conduit. Plastic conduit shall be high-impact PVC, Schedule 80.

Installation. All bends shall be in strict compliance with the NEC.

Conduits shall be laid to a depth of 6 inches below subgrade but not less than 24 inches below pavement grade except when approved by the Engineer; conduit may be laid at a depth of not less than 24 inches below the top of the curb when placed in the back of the curb. Conduit runs for detectors shall be parallel to existing or proposed curbs and not more than 18 inches behind the curb face unless other specified. Steel conduit or Schedule 80 PVC conduit shall be placed under existing pavements by approved jacking or drilling methods. Pavements shall not be disturbed without the approval of the Engineer. Where trenching is allowed in a traffic-bearing area, PVC conduit (Schedule 80) encased in concrete shall be used.

All conduits shall have a Teflon™ pull line installed for future use and a No. 14 solid American Wire Gauge (AWG) locating wire installed and terminated in the controller cabinet on one eight position isolated ground bar labeled Locating Buss. Locating wire shall be capped off and identified in all handholes and pull boxes.

After installation of the conduit is completed, all conduits installed under this contract shall be tested with a mandrel having a diameter ¼ inch smaller than the conduit and a length of 2 inches. All conduits that will not allow passage of the mandrel shall be repaired to the satisfaction of the Engineer; if repairs cannot be made, the conduit shall be removed and replaced at no additional cost to NDOT. After the mandrel test, all conduits shall be scoured with a stiff wire brush slightly larger in diameter than the conduit. The Contractor shall clear all conduits in the presence of the Engineer or the Engineer's representative.

Conduits terminating in anchor base standards and pedestals shall extend approximately 2 inches above the foundation and shall be sloped toward the handhole opening. Conduits shall enter pull boxes from the bottom

and shall terminate not less than 4 inches nor more than 6 inches above the bottom of the box and near the box walls to leave the major portion of the box clear.

Existing underground conduit to be incorporated into a new system shall be cleaned by blowing with compressed air, or by other means approved by the Engineer.

730.16—Fiber Optic Conduit.

General Requirements

All continuous flexible conduit products and structure-mounted multi-cell conduit shall meet the requirements specified herein. All continuous flexible conduit and structure-mounted multi-cell conduit shall have been manufactured and labeled no earlier than in the sixth calendar month preceding NDOT's award date of the contract.

Continuous Flexible Conduit (Conduit Duct Bank)

1. Continuous flexible conduit shall be manufactured from virgin high-density polyethylene (HDPE) resin compound with a minimum cell classification of PE 345434C for PE 3408 materials in accordance with ASTM D 3350.
   A. Physical and Mechanical Properties and Test Methods
      (1) Tensile strength at yield – minimum of 3,000 psi in accordance with ASTM D 638.
      (2) Density – minimum of 0.941 grams per cubic centimeter in accordance with ASTM D 4883/1505.
2. Conduit shall be extruded from colored material for uniform full-thickness coloring.
3. All continuous flexible conduit shall be labeled with durable identification providing the name of the manufacturer, conduit size (inner diameter trade size and wall thickness/rating), manufacturer/date codes, the NDOT legend, and sequential foot marking. Labeling shall occur a maximum of every 2 feet.
4. Conduit to be used in bends and sweeps shall have a minimum burn through time of 30 minutes when tested in accordance with Generic Requirement GR-356-CORE, Issue 1, October 1995.
5. The conduit manufacturer shall have a documented Quality Control/Assurance System.
6. All conduit used on this project shall conform to the color scheme and use described below:
   A. Conduit Bank Type 3
      (1) Orange (Trunk Fiber).
      (2) Blue (Drop Fiber).
      (3) White (Spare).
   B. 2-inch Electrical Conduit
      (1) Gray (Electrical Wire).
7. 1¼-inch conduit shall conform to ASTM D 3035 and meet the following requirements:
   A. Smoothwall Standard Dimension Ratio (SDR) 11.
   B. Nominal outer diameter: 1.660 inches.
   C. Minimum inner diameter: 1.313 inches.
   D. Minimum wall thickness: 0.151 inch.

   Whenever 1¼-inch conduit is used, three 1¼-inch conduits shall be bored.

8. 2-inch conduit shall conform to ASTM D 3035 and meet the following requirements:
   A. Smoothwall SDR 11.
   B. Nominal outer diameter: 2.375 inches.
   C. Minimum inner diameter: 1.885 inches.
   D. Minimum wall thickness: 0.216 inch.

9. Coupling
    A. Every effort should be made to minimize coupling. Couplings are permitted only with the Engineer's prior approval.
    B. Couplings shall be airtight and watertight. All couplings shall be installed in accordance with the conduit and the coupling manufacturer recommendations. Only couplings of the type specified below and approved by the conduit manufacturer are permitted.
    C. Couplings shall be accomplished only by hydraulic press-on or electro-fusion coupling methods:
        (1) Use hydraulic press-on couplings of seamless, tool-grade, tubular aluminum with sealing ring barbs and center stop.
        (2) Use hydraulic compression duct coupling tools and follow all manufacturer installation procedures, fully inserting both conduit sections to the coupling center stop.
        (3) Use pre-fabricated electro-fusion couplings that are field-installed using the coupling manufacturer's recommended automatic self-monitoring fusing machine and installation procedures.
        (4) Do not use any other coupling methods.

Conduit Detection Wire. Conduit detection wire shall be No. 10 AWG stranded copper orange-insulated THHN-THWN conductor.

Pull Tape. The pull tape for cable installation shall meet the following requirements:
1. 1,250-lb tensile strength.
2. Flat, not round, construction.
3. Printed sequential foot markings.
4. Pre-lubricated for reduced pulling tension at start of cable pull.
5. Low susceptibility to absorption of moisture; moisture resistant.

Duct Plugs. Duct plugs shall meet the following requirements:
1. Duct plugs intended for underground telecommunications infrastructure shall be installed on conduits.
2. Duct plugs shall be sized to fit the conduits and cables with which they are used.
3. Duct plugs shall provide watertight and airtight gasketed seals by use of mechanical expansion of the duct plug body and gasket. No sealants or caulks shall be used.
4. All metallic components of duct plugs shall be stainless steel.
5. Blank duct plugs shall be used to seal spare conduits and shall have inner rings to which pull tape can be tied.
6. Cable duct plugs shall be used to seal conduits that contain a cable. The plug shall be sized to fit the conduit and cable with which it is used and shall be a split plug with a bushing assembly for sealing around the cable by mechanical compression.

Installation Requirements. All material installed shall follow the guidelines below and in the following sections:
1. Blank duct plugs shall be used to seal the ends of all conduit immediately upon conduit placement. This includes, but is not limited to, intermediate/incomplete sections of conduit prior to conduit splicing or termination in pull boxes and empty conduits in pull boxes prior to cable installation.
2. Conduit shall be installed in a straight-line, horizontal path between pull boxes except where shown otherwise in the Plans.

Continuous Flexible Conduit (Conduit Duct Bank)

1. Conduit duct banks shall be installed by configuring individual continuous flexible conduits into a continuous duct bank from termination point to termination point as shown in the Standard Details and other Contract Documents.
2. Continuous flexible conduit installation in earth shall be trenched, horizontal directional bored or drilled, or plowed at the Contractor's discretion, unless otherwise noted on the Plans, at a minimum depth of 30 inches from the top of the conduit.
3. All continuous flexible conduit located under the paved roadway as shown on the plan sheets shall meet the following requirements: the conduit shall be placed at a minimum depth of 30 inches; backfill shall meet NDOT standards for a paved roadway; and all areas shall be completely restored daily according to the time frames set in the approved Traffic Control Plan.
4. All conduit underneath railroad tracks shall be horizontal directional bored or drilled at a minimum of 10 ft below the railroad bed. It is the Contractor's responsibility to determine any additional requirements of the railroad owner and to meet those requirements in addition to those included in the Plans and these specifications. Any required steel casings or other materials needed to meet the railroad authority requirements shall be included in the cost of the conduit.
5. All conduit to be installed under streams shall be horizontal directional bored or drilled. No open trenching through an area deemed to be a current or wet weather stream shall be allowed. All conduit bored under streams shall be a minimum depth of 5 ft below the stream bed.
6. Bore logs shall be required for each bore location.
7. The Contractor shall submit a proposed bore log format to the Engineer for review and approval.
8. If a drainage or utility conflict arises, the Contractor shall submit a plan for resolving the conflict to the Engineer for review and approval.
9. Every effort should be made to minimize the use of couplings. Couplings are permitted only with the Engineer's prior approval.
10. Conduit shall be placed in the straightest orientation possible, reducing bends, twists, rises, and waves. Conduits shall be held in place during backfilling when necessary to keep straight and at the proper depth. Where field conditions require the trench to change direction and bends are necessary, the bends shall be formed in the trench, should be smooth and even, and shall not have less than a 4-ft radius (as measured to the inside surface of the conduit).
11. Every conduit should be tested after it is installed and before cable or pull tape is installed. Testing shall be performed on all conduit types in these specifications, including but not limited to each cell of multi-cell conduits and each conduit in duct banks. All testing shall be performed using the procedures and mandrel size recommended by the conduit manufacturer. Testing shall be performed in the presence of the Engineer. Payment for all testing shall be included in the cost of the conduit.

Rigid Galvanized Steel Conduit

1. Exposed conduit runs shall be 2-inch rigid galvanized steel unless otherwise required by the Plans.
2. All conduit runs on structures and poles shall be properly terminated into the respective device, or a duct seal shall be installed so as to seal the conduit from moisture, insects, rodents, and other foreign material. The costs of the galvanized steel conduit and all associated fittings shall be included in the cost of other items.
3. Bushings shall be installed in conduit at all exposed conduit terminations for protection of the conductors.

Conduit Detection Wire

1. One conduit detection wire shall be installed within all conduits. Conduit detection wire is required with all conduits installed by any installation method, including trenching, directional boring, or plowing.

2. Only one conduit detection wire is required per installed conduit segment regardless of the number of conduits installed in that segment.
3. Conduit detection wire shall be installed inside the conduit.
4. Conduit detection wire is not required for structure-mounted conduit, except where underground segments of structure-mounted conduit are greater than 20 ft in length.
5. Conduit detection wire is not required for conduit segments between pull boxes and pole/sign structure foundations, except where conduit segments are greater than 20 ft in length.
6. The conduit detection wire shall be continuous and unspliced between pull boxes and shall enter the pull boxes at the same location as the conduit with which it is installed, entering under the lower edge of the pull box.
7. In each pull box or vault, 4 ft of conduit detection wire shall be coiled and secured.
8. Testing
    A. A continuity or tone test shall be performed after installation to confirm that a continuous run of conduit detection wire was installed between pull boxes or vaults.
    B. A test plan shall be prepared for supplying equipment, conducting the test, and documenting the results. The test plan shall be submitted to NDOT at least 15 working calendar days prior to the desired testing date. Testing shall not begin until the Engineer has approved the test plan, and all tests shall be conducted in the presence of the Engineer.

Pull Tape

1. Install pull tape into each empty conduit and empty cell within a multi-cell conduit.
2. Install the pull tape after conduit testing has been completed.
3. Install and secure 5 ft of slacked pull tape in each empty conduit or cell at each pull box.
4. Secure the pull tape by tying it to the blank duct plug for the conduit in which it is installed.

Duct Plugs

1. Install blank duct plugs in each empty conduit that enters a pull box, ground-mounted cabinet, pole foundation, hub, or building entrance.
2. Install cable duct plugs in each conduit containing fiber optic, cat5 or 6 cable, or Radar Detection System (RDS) communications cable that enters a pull box, ground-mounted cabinet, hub, or building entrance.
3. Do not install cable duct plugs on conduits containing power service conductors.

Spare Conduits in Foundations

1. A minimum of one 2-inch spare conduit shall be installed in all pole foundations, and a minimum of two 2-inch conduits shall be installed in the base of all ground-mounted cabinets.
2. Spare conduits shall be sealed with blank duct plugs.

Measurement. All conduit material shall be measured based on the guidelines in the following sections. All conduit types shall be measured in linear feet per type to the nearest foot. All conduit types shall be measured along the conduit as follows:

1. Measurements will be made from center of pull box to center of pull box.
2. No additional measurement will be made for vertical conduit inside the pull box or structure.
3. No additional measurement will be made for conduit between a pull box and the nearby pole or structure.

Continuous Flexible Conduit (Conduit Duct Bank)

1. Unless otherwise specified in the Plans, all costs for trenching, installation, backfilling of trench, plowing, directional boring, restoration, materials including pull tape, duct plugs, fittings, conduit

detection wire, testing, bore logs, and other accessories and hardware necessary for installation of the conduit system shall be included in the overall cost of the conduit or conduit duct bank.

2. Continuous flexible conduit installation in the earth or the shoulder shall be trenched, horizontal directional bored or drilled, or plowed at the Contractor's discretion, unless otherwise noted on the Plans.
3. All conduit to be installed under streams shall be horizontal directional bored or drilled. No open trenching through an area deemed to be a current or wet weather stream shall be allowed.
4. Continuous flexible conduit (conduit duct bank) shall be measured by linear foot for each type of conduit bank after installation and shall include the type and number of conduit indicated below:
   A. Conduit Bank: Three 1¼-inch continuous flexible conduits.
   B. 2-inch Conduit: One 2-inch continuous flexible conduit or PVC Schedule 40 conduit.
   C. 2-inch Conduit with Bank: One 2-inch continuous flexible conduit installed in the same trench as the related conduit bank type as specified on the plan sheet.
   D. Conduit Bank Bored: Three 1¼-inch continuous flexible conduits.
   E. 2-inch Conduit Bored: One 2-inch continuous flexible conduit.

(Note: Separate encasement for borings is not required unless necessary for proper installation due to poor soil conditions. If encasement is needed in those situations, the cost of the encasement shall be included in the cost of the conduit.)

Rigid Galvanized Steel Conduit. Rigid galvanized steel conduit and related materials, including but not limited to couplings, mounting straps, bonding to ground, etc., that are installed on sign structures, on poles, or between the pull boxes and equipment cabinets are included in the cost of other items and will not be measured separately.

Conduit Detection Wire. Conduit detection wire is included in the cost of the conduit and will not be measured separately.

Pull Tape. Pull tape is included in the cost of the conduit and will not be measured separately.

Duct Plugs. Duct plugs are included in the cost of the conduit and will not be measured separately.

Payment. The contract unit price shall be full compensation for all work specified in this section. Payment shall be made according to standard TDOT item numbers.

All conduit shall be paid per linear foot, as applicable, as follows:

1. Stored materials shall be paid per TDOT Standard Specifications.
2. Final payment shall be made after complete installation and testing.

730.17—Fiber Optic Infrastructure.

All fiber optic infrastructure shall be installed per the Plans or where directed by the Engineer.

1. Furnish fiber optic infrastructure materials that meet applicable industry standards including but not limited to:
   A. EIA/TIA.
   B. Rural Utilities Service (RUS).
   C. Institute of Electrical and Electronics Engineers (IEEE).
   D. Insulated Cable Engineers Association (ICEA).
   E. Telcordia.
   F. ASTM.
   G. UL.

H. NEC.
I. National Electrical Safety Code (NESC).

2. Upon request of the Engineer, provide certification from an independent testing laboratory that certifies that the cable conforms to industry standards.
3. Furnish fiber optic infrastructure materials recommended by the manufacturer for outside plant use and the intended application.
4. Furnish all optical fiber, fiber optic cable, fiber optic drop cable, optical termination and connection materials, and all ancillary and incidental materials that are single-mode and/or compatible. All materials shall meet the following requirements:
   A. Materials shall be listed with and conform to RUS 7 Code of Federal Regulations (CFR) 1755.900, 1755.901, 1755.902, and associated fiber optic test procedures (FOTPs); ANSI/ICEA S-87-640; EIA/TIA-568-B.3, 598B, 758, and Fiber Optic Connector Intermateability Standards (FOCISs); and Telcordia GR-20 core requirements.
   B. Manufacturer is currently International Organization for Standardization (ISO) 9001 certified. This requirement applies to assemblers of manufactured components, such as patch cords and termination cabinet interconnection cables.
   C. All cables and termination infrastructure shall be assembled from Corning SMF-28e and OFS All Wave or approved equivalent single-mode optical fiber.
   D. All fibers and buffer tubes shall follow TIA/EIA-598 (Optical Fiber Cable Color Coding) identification using colors. Do not use printed legends.
   E. All cables shall have been manufactured and labeled no earlier than in the third calendar month preceding NDOT's letting date of the contract.
5. Maintain and calibrate fiber optic installation and testing tools in accordance with the tool manufacturer's recommendations. Provide tool manufacturer certified calibration documentation upon Engineer's request. Installation and testing tools include but are not limited to:
   A. Fusion splicers.
   B. Cable pulling strain dynamometers and breakaway links.
   C. Cable air jetting/blowing systems.
   D. Optical time domain reflectometers (OTDRs).
   E. Optical attenuation testers (light sources and power meters).
6. Fiber optic installation and testing tools shall be operated only by Contractor personnel who have been trained and certified by the tool manufacturer. Installation and testing tools requiring certified operators include but are not limited to:
   A. Fusion splicers.
   B. Cable air jetting/blowing systems.
   C. OTDRs.
   D. Optical attenuation testers (light sources and power meters).

Fiber Optic Cable.

1. Provide 144-count fiber optic cable that meets the following requirements:
   A. All-dielectric outside plant loose tube cable with central strength/anti-buckling member.
   B. Dry water blocking materials and construction.
   C. Reverse oscillating "SZ" stranded buffer tube construction.
   D. High tensile strength yarn.
   E. Medium-density polyethylene outer jacket.
   F. 144 fiber cable with 12 active buffer tubes and 12 individual stranded fibers per buffer tube.
   G. Cable construction design that allows no more than 12 buffer tube positions.
   H. Maximum diameter of 0.62 inch.
   I. Maximum weight of 0.108 pounds per foot.

2. Provide 12-count fiber optic cable that meets the following requirements:
   A. All-dielectric outside plant loose tube cable with central strength/anti-buckling member.
   B. Dry water blocking materials and construction.
   C. Reverse oscillating "SZ" stranded buffer tube construction.
   D. High tensile strength yarn.
   E. Medium-density polyethylene outer jacket.
   F. 12 fiber cable with 1 active buffer tube and 12 individual stranded fibers
   G. Cable construction design that allows no more than 5 buffer tube positions.
   H. Maximum diameter of 0.4 inch.
   I. Maximum weight of 0.042 pounds per foot.
3. Provide Corning ALTOS All-Dielectric, Pirelli FlexLink, OFS MiDia, or approved equivalent cables.
4. Designate this cable as a trunk cable.
5. Ensure that the cable can withstand a maximum pulling tension of 600 pound-force (lbf) during installation and 200 lbf installed long term (at rest).
6. Provide cable with shipping, storage, and operating temperature range of -22°F to +158°F.
7. Provide cable with an installation temperature range of -22°F to +158°F.
8. Provide cable with outer jacket marking using the following template:
   Manufacturer's Name – "Optical Cable" – Month/Year of Manufacture – Telephone Handset Symbol – "NDOT " – "144F SM".
9. Include in the outer jacket marking the cable sequential length in accordance with the following:
   A. In English units every 2 feet.
   B. Within -0/+1% of the actual length of the cable.
   C. In contrasting color to the cable jacket.
   D. Marking font height no less than 0.10 inch.
   E. On any single length of cable on a reel, the sequential length markings do not run through "00000."
10. Ensure that fiber optic cable, with the required fiber count, conforms to RUS CFR 1755.900. Provide cable with all fibers that are usable and with a surface sufficiently free of imperfections and inclusions to meet optical, mechanical, and environmental requirements. Distinguish each fiber and buffer tube from others by means of color coding that meets EIA/TIA-598 (Optical Fiber Cable Color Coding).

<u>Fiber Optic Cable Indoor/Outdoor.</u>

1. Provide fiber optic plenum-rated cable that meets the following requirements:
   A. All-dielectric inside plant loose tube central core cable.
   B. High tensile strength yarn surrounding the central tube core.
   C. Dry water blocking materials and construction.
   D. 144 fiber cable with 12 active buffer tubes and 12 individual stranded fibers per buffer tube.
2. Provide Corning FREEDM Loose Tube All-Dielectric, Pirelli CentraLink, or approved equivalent cables.
3. Designate this cable as building entry.
4. Ensure that the cable can withstand a maximum pulling tension of 300 lbf during installation.
5. Provide cable with shipping, storage, and operating temperature range of -22°F to +158°F and an installation temperature range of 14°F to 140°F.
6. Provide cable with outer jacket marking using the following template:
   Manufacturer's Name – "Optical Cable" – Month/Year of Manufacture – Telephone Handset Symbol – "NDOT" – "144F SM."
7. Include in the outer jacket marking the cable sequential length in accordance with the following:

A. In English units every 2 feet.
B. Within -0/+1% of the actual length of the cable.
C. In contrasting color to the cable jacket.
D. Marking font height no less than 0.10 inch.
E. On any single length of cable on a reel, the sequential length markings do not run through "00000."

Fiber Optic Drop Cable.

1. Provide fiber optic drop cable that meets the following requirements:
   A. All-dielectric outside plant loose tube central core cable.
   B. High tensile strength yarn surrounding the central tube core.
   C. Dry water blocking materials and construction.
   D. 12 individual stranded fibers contained within the central tube core.
2. Provide Corning FREEDM Loose Tube All-Dielectric, Pirelli CentraLink, or approved equivalent cables.
3. Designate this cable as drop cable.
4. Ensure that the cable can withstand a maximum pulling tension of 300 lbf during installation.
5. Provide cable with shipping, storage, and operating temperature range of -22°F to +158°F and an installation temperature range of 14°F to 140°F.
6. Provide cable with outer jacket marking using the following template:
   Manufacturer's Name – "Optical Cable" – Month/Year of Manufacture – Telephone Handset Symbol – "NDOT" – "12F SM."
7. Include in the outer jacket marking the cable sequential length in accordance with the following:
   A. In English units every 2 feet.
   B. Within -0/+1% of the actual length of the cable.
   C. In contrasting color to the cable jacket.
   D. Marking font height no less than 0.10 inch.
   E. On any single length of cable on a reel, the sequential length markings do not run through "00000."

Plenum Rated Non-Metallic Corrugated Raceway.

1. Provide plenum-rated non-metallic corrugated raceway inside buildings when cable is not in rigid conduit.
2. Install to conform with NEC Articles 770 and 800.
3. Provide raceway that meets UL Standards 910 and 2024.
4. Provide 2-inch-diameter raceway.

Fiber Optic Fusion Splice.

1. Provide fusion splices for splicing of all fibers on the project. Do not provide any other type of fiber splicing.
2. Perform fusion splicing with a fully automatic portable fusion splicer that provides consistent low loss (maximum 0.10 decibel [dB]) splices. Splicer shall provide three-axis fiber core alignment using light injection and loss measurement techniques. The fusing process shall be automatically controlled. The splicer shall provide splice loss measurements on an integral display, as well as a magnified image of the fiber alignment. The Contractor shall retain ownership of the fusion splicer.

Fiber Optic Connectors.

1. Provide fiber optic angled physical contact (APC) connectors compliant with these specifications for all fiber optic infrastructure including, but not limited to, fiber optic termination cabinets, fiber optic drop panels, and fiber optic patch cords.
2. Provide only lucent connector (LC) compatible APC connectors for all fiber optic infrastructure. Provide only factory-installed APC connectors of a type other than LC when required by the network switches. Do not use field-installed connectors. Do not use adapter couplers to change connector types.
3. Use ceramic ferule connectors factory-installed with a thermal-set heat-cured epoxy and machine polished mating face. Install connectors as per manufacturer application and recommendations, including proper termination to the outer tubing (900-micron tubing, 0.12-inch fan out tubing, etc.) required for the application.
4. Use APC connectors rated for an operating temperature of -40°F to +185°F.
5. Provide connectors that have an installed insertion loss of less than or equal to 55 dB.
6. Use duplex APC connectors for all male LC connectors. Provide latching cover for two male connectors being used in a duplex configuration. Female couplers may be duplex but shall allow simplex mating connectors.
7. Label each fiber position on panels and termination cabinets containing duplex couplers with the port/position ID as shown in the Plans.
8. Provide dust caps for all exposed male connectors and female couplers at all times until permanent connector installation.

Fiber Optic Termination Cabinet.

1. Provide fiber optic termination cabinets at field junctions as shown in the Plans for termination of 144-fiber outside plant (OSP) cable.
2. Use termination cabinets that are fully compatible with all components of the fiber optic infrastructure as specified, including, but not limited to, fiber optic cable, fiber optic fusion splices, and fiber optic connectors.
3. Use wall-mount termination cabinets.
4. Provide all mounting hardware and supports to mount the termination cabinets in the locations shown in the Plans.
5. Use fiber optic termination cabinets providing 144 fiber connectors and capable of storing 144 fusion splices in splice trays.
6. Use termination cabinets that integrate the splice trays and connector modules into one compartment within one cabinet, or that house the splice trays and connector modules in separate compartments integrated into one cabinet. The closed connector housing (CCH) splice cassette is loaded with factory-terminated pigtails. Available with single-fiber splicing configurations, the cassette includes the appropriate number and type of heat-shrinks and protective tubing depending on fiber count and cable type.
7. Maximum dimensions of a complete termination cabinet shall be 16.53 centimeters (cm) high by 14.38 cm wide by 4.6 cm deep.
8. Use fiber optic termination cabinets with fully enclosed metallic construction and with a protective hinged front cover for the connector ports.
9. Provide cable access on all sides of the enclosed area behind the connector port panel.
10. Provide sufficient splice trays for storing 144 fusion splices in 12- or 24-splice increments.
11. Provide termination cabinets with fiber optic connector modules in a 12-fiber configuration of 6 rows of 1 duplex connector coupler.
12. Connector modules shall mount vertically in the termination cabinet front panel.
13. Connector modules shall:

A. Include clearly legible and permanent labeling of each of the 12-fiber connector couplers.
B. Be labeled and identified as shown in the Plans.

14. Provide factory-assembled 12 fiber termination interconnect cables (pigtail cables) to be fusion spliced to the outside plant cable and connected to the rear of the connector modules. Termination interconnect cables shall be all-dielectric, single-jacketed cable with high tensile strength yarn surrounding 12 individual 900-micron fibers following EIA/TIA-598B color identification with factory-installed connectors.
15. The splice shelf shall house and protect fusion splices of fibers to optical fiber pigtails with 6 ft of pigtail slack on each fiber. The housing shall protect the required quantity of connectors and splices on each pigtail and slack for fiber optic patch cords. The fiber pigtail slack shall be neatly coiled and secured in a manner that does not allow the minimum operational bending radius of the pigtail to be exceeded.
16. The approved type of optical connectors on the end of each pigtail shall screw into a sleeve securely mounted to a patch panel within the housing. The maximum optical loss across the connection shall not exceed 0.4 dB.
17. Provide all incidental and ancillary materials including but not limited to grommets, cable strain relief and routing hardware, splice protectors/heat shrinks, blank connector panels, and labeling materials.

Fiber Optic Closure.

1. Provide fiber optic closures (splice closures) designed for outside plant use for splicing cables.
2. Use fiber optic splice closures that are impact- and corrosion-resistant and waterproof when immersed in 10 ft of water.
3. Use fiber optic splice closures that are fully compatible with all components of the fiber optic infrastructure as specified, including but not limited to, fiber optic trunk cable, fiber optic drop cable, and fiber optic fusion splices.
4. Use a cylindrical dome-type splice closure with cable entry at one end only and a sealed single-molded piece dome body of high-density polyethylene or equivalent non-metallic material.
   A. The cable entry end shall be manufactured of a similar material as the dome body and shall seal the closure with flexible thermoplastic rubber or polymer gasket seals.
   B. The cable entry end shall include cable entrance ports that shall seal the cable and port opening with flexible thermoplastic rubber or polymer gasket seals with mechanical compression.
   C. Closures shall be re-enterable and resealable without the need for specialized tools or equipment, or the use of any additional parts.
   D. No heat shrink or caulk/encapsulate materials shall be used for sealing the assembled closure or terminated cables.
5. Provide splice closures with maximum outer dimensions of 9 inches in diameter and 23 inches in length unless otherwise approved by the Engineer.
   A. Splice closures shall provide cable entrance ports for at least five fiber optic cables.
   B. At least two cable entrance ports shall accommodate cables of at least 0.60-inch outer diameter.
   C. The closure shall allow for the storage and express of at least six unopened buffer tubes.
6. Provide a splice closure with a cable entry end with pre-template cable ports and a split-plate design permitting installation of the closure in mid-span cable segments.
7. The splice closure size shown in the Plans specifies the minimum number of fusion splices to be accommodated by the closure. With the splice closure, provide all materials to accommodate the number of splices specified by the closure size, including splice tray, storage, and organizing materials.

Fiber Optic Drop Panel.

1. Provide fiber optic drop panels designed for outside plant use for terminating drop cables in equipment cabinets.
2. Use fiber optic drop panels that include the fiber optic drop cable as an integral component.
3. Use fiber optic drop panels that are fully compatible with all components of the fiber optic infrastructure as specified, including, but not limited to, fiber optic trunk cable, fiber optic closures, fiber optic fusion splices, and fiber optic connectors.
4. Use fiber optic drop panels that are factory-manufactured assemblies of fiber optic drop cable with factory-installed fiber connectors and integral ruggedized fiber connector enclosures.
5. Use drop panels with 12 fiber (two duplex LC) connectors.
6. Use ruggedized fiber connector enclosures of thermally stable rigid plastic housings fully potted with a thermally stable epoxy filling that encapsulates the drop cable fan out, fibers, and connector bodies.
7. Use permanent labels on the enclosure with contrasting color to identify each connector body by its associated fiber number.
8. Arrange fiber connectors in rows of one duplex connector coupler. All fiber connectors shall be arranged on one of the long (vertical) faces of the enclosure.
9. Provide a unique serial number permanently attached on the enclosure body of each drop panel.
10. Provide an outer non-metallic cable strain-relief boot where the drop cable enters the fiber connector enclosure and that secures the cable to the enclosure; the strain-relief boot shall fully encircle the cable for a minimum of 2 inches from the enclosure's outer surface.
11. Use fiber connector enclosures on the drop panel that are no more than 2 inches wide and deep (the maximum dimension of the enclosure plus fiber connector body) and no more than 11 inches long.
12. Provide a 0.125-inch-thick aluminum mounting plate that secures to the fiber connector enclosure. The mounting plate shall have at least four mounting holes near the plate's corners that permit horizontal or vertical mounting flush to a panel, and are spaced appropriately for vertical mounting to an EIA equipment rack rail using two of the mounting holes.
13. Test all completed and assembled fiber optic drop panels at the point of manufacture and provide two copies of the manufacturer test documentation. Test each connected fiber in the drop panel to demonstrate compliance with all requirements for cables and connectors as detailed in these specifications. Include in the test documentation the location station number where the drop panel is to be installed, the serial number of the drop panel, the drop cable sequential length markings at each end of the drop cable, and the total drop cable distance.

Cable Labels.

1. Provide cable labels that meet the following requirements:
   A. Self-coiling wrap-around type.
   B. PVC or equivalent plastic material with ultraviolet (UV) and fungus inhibitors.
   C. Base materials and graphics/printing inks/materials designed for underground outside plant use including solvent resistance, abrasion resistance, and water absorption.
   D. Minimum size of 2.5 inches wide by 2.5 inches long.
   E. Minimum thickness of 0.010 inch.
   F. Orange label body with pre-printed text in bold black block-style font with minimum text height of 0.375 inch.
2. Pre-print the following text legibly on labels used for all fiber optic trunk cables (FO Cables):
   NDOT
   OPTICAL CABLE
3. Pre-print the following text legibly on labels used for all fiber optic drop cables (FO Drop Cables):
   NDOT
   OPTICAL DROP CABLE

4. On all cable labels, print the text specified above twice on the label with the text of the second image inverted. The end result shall be text that "reads correctly" when the label is coiled onto a cable.

Fiber Optic Patch Cords.

1. Fiber optic patch cords provided shall consist of a length of fiber optic cable terminated on both ends.
2. All patch cords shall be factory pre-connected assemblies adhering to all applicable cable and fiber specifications stated in these specifications.
3. Patch cords shall be of the appropriate length for the necessary connections, maintaining minimum bend radius, and with no residual strain at the connector or anywhere on the patch cord itself beyond self-support. Patch cords shall not have excess length beyond what is necessary for equipment connection and routing.
4. All patch cords shall be duplex zip-cord fiber cable with simplex LC connectors, except as otherwise allowed in the section concerning fiber optic fusion splices.
   A. The two connectors of each end of the patch cord shall be differentiated by different colors.
   B. Sufficient flexibility shall be provided at each end to disconnect one connector without disturbing the other, or to allow swapping of the two connectors within the same duplex coupler without disturbing the remainder of the patch cord.
   C. Strain relief and reinforcement shall be provided at the point where the duplex cable separates for the individual simplex connectors.
5. Fiber cable shall be 0.08-inch jacketed cable with high tensile strength yarn protecting the inner fiber manufactured into a duplex zip-cord configuration. All inside plant patch cords shall meet NEC jacketing requirements.
6. Connector strain relief boots shall be fixed to the outer jacket and strength yarn.
7. Yellow outer jackets shall be used for single-mode fiber.
8. No splices of any type are allowed within a patch cord assembly.

Fiber Optic Attenuator Patch Cords.

1. Fiber optic attenuator patch cords provided shall meet all requirements of the section concerning fiber optic patch cords.
2. Each fiber in the attenuator patch cord shall contain a passive optical attenuator with the following performance characteristics:
   A. Dual-wavelength capability (1,310 and 1,550 nanometers [nm]).
   B. Fixed attenuation value of 6dB ±15%.
   C. Minimum optical return loss of 40 dB.
   D. Operating temperature range no less than -30 to +65 C.

Project Submittal Program Requirements.

1. General Requirements. The Contractor shall provide project submittals for all fiber optic infrastructure as required in the section pertaining to fiber optic termination cabinets, including scheduling requirements. The project submittals for fiber optic infrastructure shall include, but are not limited to, the additional specific requirements in this subsection.
2. Fiber Optic Installation and Testing Tools
   A. Provide project submittals including manufacturer-recommended operations, maintenance, and calibration procedures for the following equipment:
      (1) Fusion splicers.
      (2) Cable pulling strain dynamometers and breakaway links.
      (3) Cable air jetting/blowing systems.
      (4) OTDRs.

(5) Optical attenuation testers (light sources and power meters).

B. Submit documentation and proof of manufacturer-recommended operator training and certification for the following equipment:
   (1) Fusion splicers.
   (2) Cable air jetting/blowing systems.
   (3) OTDRs.
   (4) Optical attenuation testers (light sources and power meters).

Installation Requirements. Install all fiber optic infrastructure according to the manufacturer's recommended procedures and specifications.

Cable Shipping and Delivery.

1. Package the cable for shipment on reels. Each package shall contain only one continuous length of cable. Construct the packaging so as to prevent damage to the cable during shipping and handling.
2. Seal both ends of the cable to prevent the ingress of moisture.
3. Include with each reel an attached weatherproof reel tag identifying the reel and cable that can be used by the manufacturer to trace the manufacturing history of the cable and the fiber. Include with each cable a cable data sheet containing the following information:
   A. Manufacturer name.
   B. Cable part number.
   C. Factory order number.
   D. Cable length.
   E. Factory-measured attenuation of each fiber.
4. Cover the cable with a protective and thermal wrap.
   A. Securely fasten the outer end of the cable to the reel head so as to prevent the cable from becoming loose in transit.
   B. Project the inner end of the cable a minimum of 6.5 ft into a slot in the side of the reel or into a housing on the inner slot of the drum, in such a manner to make it available for testing.
   C. Plainly mark each reel to indicate the direction in which it is to be rolled to prevent loosening of the cable on the reel.

Arrival On Site. The cable and reel shall be physically inspected by the Contractor on delivery and 100% of the fiber shall be tested with an OTDR for attenuation to confirm that the cable meets requirements. Test results shall be recorded and dated. Attenuation deviations from the shipping records greater than 5% shall be brought to the attention of NDOT in writing. The cable shall not be installed until completion of this test sequence and receipt of written approval by NDOT. If the OTDR test results are unsatisfactory, the reel of fiber optic cable shall be considered unacceptable and all records corresponding to that reel of cable shall be marked accordingly. The unsatisfactory reel of cable shall be replaced with a new reel of cable at the Contractor's expense. The new reel of cable shall then be tested to demonstrate acceptability. Copies of the test results shall be submitted to NDOT for approval.

Cable Handling and Installation.

1. Do not exceed the maximum recommended pulling tension during installation as specified by the cable manufacturer.
2. Continuously monitor pulling tensions with calibrated measuring devices, such as a strain dynamometer.
3. Protect all pulled installations with calibrated breakaway links.

4. Do not violate the minimum recommended bend radius during installation as specified by the cable manufacturer. Unless the manufacturer's recommendations are more stringent, use the following guidelines for minimum bend radius:
   A. 15 X Cable Diameter Short Term – During Installation.
   B. 10 X Cable Diameter Long Term – Installed.
5. Before cable installation, carefully inspect the cable reels and reel stands for imperfections or faults such as nails that might cause damage to the cable as it is unreeled.
6. Take all necessary precautions to protect reeled cable from vandals or other sources of possible damage while unattended. Any damage to reeled cable or the reel itself shall necessitate replacement of the entire cable section at the Contractor's expense.
7. Whenever unreeled cable is placed on the pavement or surface above a pull box, provide means of preventing vehicular or pedestrian traffic through the area in accordance with the approved Maintenance of Traffic provisions.
8. Keep the cable continuous throughout the pull. Cable breaks and reel end splices are permitted only as shown in the Plans.
9. Where a cable ends in an underground fiber optic closure, secure and store all unused fibers and buffer tubes in splice trays in preparation for future reel end splicing and continuation.

Cable Storage.

1. Properly store all cable to minimize susceptibility to damage.
   A. Maintain proper bend radius, both short and long term, during cable storage.
   B. Storage coils shall be neat in even length coils, with no cross over or tangling.
   C. Storage coils of different cables shall be kept completely separate except when the cables terminate in the same splice closure.
   D. Storage coils shall be secured to cable racking hardware with tie wraps, Velcro straps, or non-metallic cable straps with locking/buckling mechanism.
   E. Do not use adhesive or self-adhering tapes, metal wires and straps, or rope/cord.
2. Unless otherwise noted on the Plans, the following are the requirements for cable storage for underground applications:
   A. Trunk cable in Type A pull box – 25 ft.
   B. Trunk cable in Type B pull box – 200 ft.
   C. Drop cable in Type A pull box – 10 ft.
   D. Drop cable in Type B pull box terminated in a splice closure – 10 ft.
   E. Communications hub or Control Center (interior) – Do not store slack cable inside the communications hub building or Control Center.

Fiber Optic Fusion Splice.

1. Perform fusion splicing of all fiber optic splices as shown in the Plans.
2. Perform fusion splicing only in enclosed spaces such as splice trailers or tents specifically intended for this operation
3. Completed fusion splices shall have no more than 0.10-dB optical loss as measured in accordance with the section pertaining to fiber optic patch cords.
4. Adequately protect all fusion splices in splice trays in a splice closure or termination cabinet. Provide the splice with strain relief and protection of the stripped fiber splice in a manner recommended by the fiber and the splice tray manufacturers.
5. Use fusion splice protectors of a heat shrink tubing that protects the splice and extends over the fiber coating. Splice protectors shall be compatible with and as recommended by the fiber and the splice tray manufacturers.
6. No bare fiber may be exposed.

Fiber Optic Termination Cabinet.

1. Install only one outside plant cable per termination cabinet, including within the separate splice tray storage compartment if so equipped. Install the connector modules for fibers 1 through 144 as shown in the Plans. Equip any remaining unused connector module slots with blank panels.
2. Install all fibers, buffer tubes, and cables following minimum internal and external bend radius, proper management, routing, fastening and protection, and with no residual strain on any connector, fiber, buffer tube, or cable.
3. Install one cable buffer tube to one termination cabinet interconnect cable, matching fiber to fiber. Keep all fibers of the outside plant cable buffer tube and its corresponding termination interconnect cable complete within the same splice tray.
4. Label the front and rear of the termination cabinets with the trunk cable segment ID of the cable terminated within; use permanent clearly legible labels with a minimum of a 0.5-inch text height.
5. Label each end of termination cabinet interconnect cables to identify the 12 trunk cable fibers/buffer tube connected; use permanent overlapping cable labels with clearly legible text.

Fiber Optic Closure.

1. Install fiber optic splice closures where and of the size shown in the Plans. Install splice closures in the center ±3 ft of the entire length of stored cable coils or install at the end of cables that terminate in the pull box.
2. Store FO closures and cable coils on the pull box cable rack hooks. Keep all closures and cable coils off the bottom of the pull box. Secure closures and/or cable coils as needed to hold them in place.

Fiber Optic Drop Panel.

1. Prior to factory manufacture of fiber optic drop panels, verify the final installed location of all portions of each drop cable route from the splice closure to the equipment cabinet (including, but not limited to, the cabinet location, all conduit and pull boxes, and the splice closure location) to determine the required length of drop cable, including all splice closure and storage coils, to be factory manufactured with each drop panel. Do not use the Plans quantity for determining the drop cable length to be factory manufactured.
2. Using the drop panel mounting plate, install drop panels on the side panel or equipment cabinets. Mount the fiber optic drop panel with the connectors horizontal or facing downward and route the drop cable up or down as necessary. Route and secure the drop cable such that it is fully strain-relieved, does not violate the manufacturer's recommended bending radius, and does not interfere with the operation of or access to any cabinet equipment or electrical components.
3. Place one copy of the manufacturer test documentation in the equipment cabinet, where the drop panel is installed, and submit the other copy to the Engineer.

Cable Labels.

1. Install cable labels on all trunk and drop fiber optic cables. Clean the installed cable of all dirt and grease before applying any label.
2. Label all cables in or at every location where the cable is exposed outside of a conduit, innerduct, or pole, using the cable IDs for trunk cables or the device number for drop cables. As a minimum, install cable labels in the following locations:
    A. Within 12 inches of every cable entry to a pull box, equipment cabinet, communications hub, or the transportation management center (TMC).
    B. Within 12 inches of the exterior entry point of every fiber optic splice closure, termination cabinet, and drop panel.

C. Every 30 feet for the entire length of cable in any storage coil in pull boxes.

Fiber Optic Patch Cords.

1. Install duplex fiber optic patch cords to connect all electronic equipment with the fiber optic infrastructure. Follow port assignments as shown in the Plans.
2. Install duplex fiber optic patch cords to connect all active optical paths between fiber optic termination cabinets in communications hubs as shown in the Plans.
3. Neatly route and dress all patch cords to the connected devices and within cable management facilities.

Fiber Optic Attenuator Patch Cords. Provide fiber optic attenuator patch cords in accordance with the section pertaining to fiber optic drop panels.

Project Testing.

1. General Requirements
   A. The Contractor shall conduct a project testing program for all fiber optic infrastructure as required in the section pertaining to plenum-rated non-metallic corrugated raceways. The project testing program for fiber optic infrastructure shall include but is not limited to the additional specific requirements in this subsection.
   B. All test results shall confirm physical and performance compliance with these specifications including, but not limited to, optical fibers and fusion splices. No event in any given fiber may exceed 0.3 dB. Any event measured above 0.3 dB per splice and 0.75 dB per connector pair shall be replaced or repaired at the event point.
   C. In addition to the notification requirements of the section pertaining to plenum-rated non-metallic corrugated raceways, the tentative date, time, and location of fiber optic infrastructure testing shall be provided to NDOT no less than 7 calendar days in advance of the test. Provide confirmed date, time, and location of fiber optic infrastructure testing no less than 48 hours before conducting the test.
   D. Test result documentation shall be provided in electronic format (one copy) and printed format (three copies). Electronic formats shall be readable in Microsoft Excel or other approved application. Printed copies shall be bound and organized by cable segment.
   E. All test results shall be provided in English units of measure of length.
   F. All test result documentation shall be submitted to the Engineer within 14 calendar days of completion of the tests. The Engineer will review test documentation pertaining to fiber optic termination cabinets.
2. Pre-Installation Test
   A. A pre-installation test (PIT) shall be performed on all FO cable prior to any cable removal from the shipping reels. A PIT shall be performed on each cable reel delivered to the job site.
   B. The PIT for FO cable shall include but is not limited to:
      (1) A visual inspection of each cable and reel.
      (2) An OTDR Test and documentation as required for the standalone acceptance test (SAT) as described below, for three randomly selected fibers from each buffer tube.
      (3) An Optical Attenuation Test is not required. If the Contractor decides to perform one for its own protection, said test should be documented and documentation provided to the Engineer.
3. Standalone Acceptance Test
   A. An SAT shall be performed on all fiber optic infrastructure on this project after field installation is complete including, but not limited to, all splicing and terminations.
   B. An SAT for each fiber in each cable shall include OTDR Tests and Optical Attenuation Tests.

C. All fibers in all FO cables and FO drop cables shall be tested from termination point to termination point, including:
   (1) Fibers from FO termination cabinet to FO termination cabinet.
   (2) Fibers from FO termination cabinet to FO drop panel.
   (3) Fibers from FO drop panel to FO drop panel.
   (4) Fibers from FO termination cabinet to the end of the cable run in the last FO closure.

D. All test results shall confirm compliance with these specifications including but not limited to optical fibers and fusion splices. No event in any given fiber may exceed 0.10 dB. Any event measured above 0.10 dB shall be replaced or repaired at the event point.

E. Test documentation shall include but is not limited to:
   (1) Cable & Fiber Identification
      a. Cable & Fiber ID and Location – Physical location (device ID and station number of FO termination cabinet, FO drop panel, or cable end FO closure), fiber number, and trunk or drop cable ID for both the beginning and end points.
      b. Operator Name.
      c. Engineer's Representative.
      d. Date & Time.
   (2) Setup and Test Condition Parameters
      a. Wavelength.
      b. Pulse Width (OTDR).
      c. Refractory Index (OTDR).
      d. Range (OTDR).
      e. Scale (OTDR).
      f. Ambient Temperature.
   (3) Results of OTDR Test (each direction and averaged)
      a. Total Fiber Trace (miles).
      b. Splice Loss/Gain (dB).
      c. Events > 0.05 dB.
      d. Measured Length (cable marking).
      e. Total Length (OTDR measurement).
   (4) Test Results for Attenuation Test (each direction and averaged)
      a. Measured Cable Length (cable marking).
      b. Total Length (OTDR measurement from OTDR Test).
      c. Number of Splices (determined from as-builts).
      d. Total Link Attenuation.

F. OTDR Test
   (1) Conduct the OTDR Test using the standard operating procedure and recommended materials as defined by the manufacturer of the test equipment.
   (2) Use a factory patch cord ("launch cable") of a length equal to the "dead zone" of the OTDR to connect the OTDR and the fiber under test.
   (3) Conduct bi-directional OTDR Tests for each fiber. Calculate bi-directional averages.
   (4) Conduct all tests at 1,310 and 1,550 nm for single-mode cable.

G. Optical Attenuation Test
   (1) Conduct the Optical Attenuation Test using the standard operating procedure and recommended materials as defined by the manufacturer of the test equipment.
   (2) Conduct bi-directional Optical Attenuation Tests for each fiber. Calculate bi-directional averages.
   (3) Conduct all tests at 1,310 and 1,550 nm for single-mode cable.

Measurement.

Fiber Optic Cable (12F).
Fiber Optic Cable (12F) shall be measured in units of linear feet and paid for at the contract price per linear foot. The price bid shall include the length in feet of actual cable installed as measured from the cable sequential length markings, cable labels, patch cords, ancillary and incidental materials, testing, documentation, and all labor and equipment necessary to complete the work. No measurement for payment shall be made for cable storage amounts in excess of that required in these specifications or the Plans. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

Fiber Optic Cable Indoor/Outdoor (144F).
Fiber Optic Cable Indoor/Outdoor (144F) shall be measured in units of linear feet and paid for at the contract price per linear foot. The price bid shall include the length in feet of actual cable installed as measured from the cable sequential length markings, cable labels, patch cords, ancillary and incidental materials, testing, documentation, and all labor and equipment necessary to complete the work. No measurement for payment shall be made for cable storage amounts in excess of that required in these specifications or the Plans. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

Fiber Optic Drop Cable (12F).
Fiber Optic Drop Cable (12F) shall be measured in units of linear feet and paid for at the contract price per linear foot. The price shall include the length in feet of actual cable installed as measured from the cable sequential length markings, fiber optic connectors, cable labels, patch cords, manufacture with the fiber optic drop panel, ancillary and incidental materials, testing, documentation, and all labor and equipment necessary to complete the work. No measurement for payment shall be made for cable storage amounts in excess of that required in these specifications or the Plans. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

Fiber Optic Closure.
Fiber Optic Closure (FO Closure) shall be measured in units of each and paid for at the contract price per each. The price bid shall include cable labels, patch cords, mounting hardware, ancillary and incidental materials, testing, documentation, and all labor and equipment necessary to complete the work. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

Plenum-Rated Non-Metallic Corrugated Raceway.
Non-Metallic Corrugated Raceway shall be measured in units of linear feet and paid for at the contract price per linear foot. The price shall include the length in feet of actual raceway installed as measured by the cable sequential length markings in the raceway, hangers, tape, and any ancillary and incidental materials necessary to complete the work.

Fiber Optic Connectors.
Fiber Optic Connectors are included in the quantities of other pay items and will not be measured separately for payment.

Fiber Optic Splice, Fusion.
Fiber Optic Splice, Fusion (FO Splice, Fusion) shall be measured in units of each and paid for at the contract price per each. The price bid shall include but is not limited to all ancillary and incidental materials, testing,

documentation, and all labor and equipment necessary to complete the work. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

Fiber Optic Termination Cabinet.
Fiber Optic Termination Cabinet (FO Termination Cabinet) shall be measured in units of each and paid for at the contract price per each. The price bid shall include but is not limited to fiber optic connectors, cable labels, patch cords, splice tray, mounting hardware, ancillary and incidental materials, testing, documentation, and all labor and equipment necessary to complete the work. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

Fiber Optic Drop Panel (FO Drop Panel, 12F)
Fiber Optic Drop Panel (FO Drop Panel, 12F) shall be measured in units of each and paid for at the contract price per each. The price bid shall include but is not limited to fiber optic connectors, cable labels, patch cords, manufacture with the fiber optic drop cable, mounting hardware, ancillary and incidental materials, testing, documentation, and all labor and equipment necessary to complete the work. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

Cable Labels.
Cable Labels are included in the quantities of other pay items and will not be measured separately for payment.
Fiber Optic Patch Cords.
Fiber Optic Patch Cords are included in the quantities of other pay items and will not be measured separately for payment.

Fiber Optic Attenuator Patch Cords.
Fiber Optic Attenuator Patch Cords are included in the quantities of other pay items and will not be measured separately for payment.

Payment.
The contract unit price shall be full compensation for all work specified in this section. Payment shall be made according to standard TDOT item numbers.

Fiber optic infrastructure, except as specified below, shall be paid per linear foot or per each, as applicable, as follows:

- 25% of the contract unit price upon delivery and completion of PIT.
- Additional 35% of the contract unit price for complete installation of cables.
- Additional 30% of the contract unit price for completion of standalone testing and documentation of all fibers in linear feet and in each splice or termination/connection location, and submission of and acceptance of all test documentation.
- Final 10% of the contract unit price upon Final System Acceptance.

Fiber optic splices, fusion, shall be paid per each as follows:

- 60% of the contract unit price upon completion of the splice.
- Additional 30% of the contract unit price for completion of standalone testing and documentation of all fibers in linear feet and in each splice or termination/connection location, and submission of and acceptance of all test documentation.
- Final 10% of the contract unit price upon Final System Acceptance.

730.18—Conductors.
Traffic control conductors shall be rated at 600 volts. All conductors, except loop conductors and cables run along messengers, shall be run in conduit except where run inside poles. Where telephone circuits are introduced into controller foundations, the telephone conductors shall be encased in flexible metal conduit, and shall also conform to regulations of the Code. Fiber optic cable shall be encased in Schedule 80 PVC conduit.

Conductors for traffic loops shall be continuous No. 14 AWG (0.003224 square inch) stranded wire to the detector terminals or splice with shielded detector cable within a pull box or pole base.

Detector cable shall be 2 conductor twisted pair shielded No. 14 AWG (0.003224 square inch) stranded meeting IMSA Specification No. 19-2.

730.19—Cable.
All signal cable shall conform to applicable IMSA Specification No. 19 or 20. Stranded cable color-coded No. AWG 14 (0.003224 square inch) shall be used for all signal and accessory circuits. All circuit runs shall retain the same color identification throughout their entire length. Communications cable shall be shielded 12 pair No. 19 solid AWG meeting IMSA Specification 20-2 unless otherwise specified by the Engineer. All communication conductors shall retain the same color code throughout their entire length.

730.20—Wiring.

1. All wiring shall be terminated to screw terminals by means of lugs.
2. All splices shall be made with solderless connectors and shall be insulated with weatherproof tape applied to a thickness equal to the original insulation.
3. Cables shall be attached to messenger by means of non-corrosive lashing rods or stainless-steel wire lashings. Stainless-steel lashing wire shall not be allowed on traffic signal spans.
4. All wiring within enclosed cabinets shall be neatly formed and harnessed and shall have sufficient length for access servicing.
5. Splicing of 120-volt signal cable shall not be allowed in conduit, pull boxes, or other non-accessible locations. Splicing of any signal-related cable shall be pre-approved by NDOT.

730.21—Service Connection.
Service connection details, metering, etc. shall be coordinated with the local utility as directed by the Engineer and shall conform to NDOT's requirements. The Contractor shall be responsible for obtaining the necessary service for each installation. A remote disconnect shall be installed with a 50-amp, 2-pole switch in weatherproof housing.

730.22—Sealant.
All sealant material shall be on the qualified products list maintained by NDOT's Material and Test Division for sealing saw cuts. It shall resist the upward movement of loop and lead-in and shall exhibit stable dielectric characteristics, including a low permittivity and high dielectric strength. It shall bond to the roadway paving material, preventing entry of moisture, and shall remain flexible without melting for all anticipated temperature and weather conditions.

730.23—Strand Cable.
Span cable for suspending signal heads between pole supports shall be 7-strand, Class A, copper-covered steel wire or greater, extra high-strength (12,500-lb minimum breaking strength) grade meeting the requirements of ASTM A 475, with a minimum breaking strength as noted in the Plans. An acceptable

alternate is 7-strand steel wire with a Class A zinc coating meeting the requirements of ASTM A 475, with a minimum breaking strength as indicated in the Plans.

Strand cable for messenger wire use (other than span wire above) and for pole guy cable shall be of the diameter(s) indicated in the Plans and shall meet the requirements of ASTM A 475 for zinc-coated steel wire strand, 7-strand Siemens-Martin Grade with Class A zinc coating or greater, and high-strength (6,500-lb breaking strength) grade..

A Figure 8 cable combining the messenger cable and conductor cable in an insulated jacket is an acceptable alternative to conductor cable lashed to a messenger cable.

730.24—Bonding and Grounding.
Metallic cable sheaths, conduit, transformer bases, anchor bolts, and metal poles and pedestals shall be made mechanically and electrically secure to form a continuous system, and shall be effectively grounded. Bonding and grounding jumpers shall be copper wire or copper strap of not less than the same cross-sectional area as No. 6 AWG (0.020615 square inch).

A ground electrode shall be furnished and installed at each service point. Ground electrodes shall be one-piece lengths of copperweld ground rod not less than 8 ft in length and ½ inch in diameter, installed in accordance with the Code. Grounding of conduit and neutral shall be accomplished as required under the Code except that grounding conductors shall be No. 6 AWG (0.020615 square inch) or approved equal, at a minimum. Exposed ground conductors shall be enclosed in ½-inch-diameter conduit and shall be bonded to the electrode with a copperweld ground clamp.

730.25—Field Test.
Prior to completion of the work, the Contractor shall cause the following tests to be made on all traffic signal and lighting circuits in the presence of the Engineer:

1. Test for ground in circuit.
2. A megger test on each circuit between the circuit and the ground. The insulation resistance shall be not less than the values specified in Section 119 of the Code.
3. A functional test in which it is demonstrated that each and every part of the system functions as specified or as intended herein.
4. Testing of all detector loops and leads before and after they are sealed in the pavement to be sure there are no shorts to ground in the system and that the loop plus lead-in inductance is within the operating range of the detector.

Any fault in any material or in any part of the installation revealed by these tests shall be replaced or repaired by the Contractor in a manner approved by the Engineer, and the same test shall be repeated until no fault appears.

730.26—Inspection.
After completion of the installation and before final acceptance of the project, a full operational check of the system under actual traffic conditions shall be made as part of the inspection. The operational check shall cover a minimum time period of 30 calendar days. During this period, the Contractor shall perform any necessary adjustments and replace any malfunctioning parts of the equipment required to place the system in an acceptable operational condition at no extra compensation. All work to be performed and materials to be furnished under these specifications shall be subject to the direct supervision and inspection of the Engineer and in all respects shall meet with the Engineer's approval as conforming with the provisions and requirements prescribed herein. The Engineer and the Engineer's authorized representatives shall at all times

be given access to the work or any part thereof, and to any plant, yard, shop, mill, or factory where, or in which, any article or material to be used or furnished in connection with such work is being prepared, fabricated, or manufactured; the Contractor shall be required to provide every reasonable facility for obtaining full and sufficient information relative to the performance of the work and the character of materials, and for ascertaining that the quality of workmanship and materials is in accordance with the intent of these specifications. Warranty for the work shall begin at the time the traffic signal is activated.

The work shall be performed only in the presence of the Engineer or Inspector appointed by the Engineer, unless permission to do otherwise has first been obtained; any work thereof that is performed or constructed during the absence of the Engineer or appointed Inspector, without such permission having been so granted, either expressly or by implication, shall be subject to rejection.

The inspection of the work, however, shall not relieve the Contractor of any obligation to properly fulfill its contract as prescribed. If the work or any part thereof, or any materials used in connection therewith, is found to be defective or unsuitable at any time prior to final acceptance, the Contractor shall be required to forthwith make good or replace such defective or unsuitable work or material.

Application for an Engineer or Inspector in connection with work under these specifications shall be made by the Contractor at least 24 hours before the services thereof shall be required.

SIGNAL HEADS

730.27—Signal Heads.

A signal head consists of a signal mounting assembly, backplate, and signal face. Each vehicle signal head shall be of the adjustable, colored lens, vertical type with the number and type of lights detailed herein and as shown on the Plans; shall provide a light indicator in one direction only; shall be capable of adjustment (without attachments) through 360 degrees about a vertical axis; and shall be mounted as shown on the Plans or as specified by the Engineer. The arrangement of the lenses in the signal faces shall be in accordance with the MUTCD. All lenses shall be glass. All circular indications shall use 12-inch lenses unless otherwise shown on the Plans. All arrow indications shall use 12-inch lenses. All new vehicle signal heads installed at any one intersection shall be of the same style and from the same manufacturer. All signal heads, signal head mountings, and outside of hoods shall have one or more coats of primer followed by two coats of high-quality synthetic resin enamel of Traffic Signal Yellow or as noted on Plans and shall meet or exceed Federal Specification TTC-595 Gloss Yellow.

Louvers as specified, interior of signal hoods, and backplates shall have one or more coats of primer followed by two coats of Lusterless Black Enamel meeting or exceeding Master Painters Institute (MPI) Reference 94. All factory-enameled equipment and materials shall be examined for damaged paint after installation, and such damaged surfaces shall be repainted to the satisfaction of the Engineer. Factory-applied enamel finish in good condition and of appropriate color shall be acceptable.

Suspensions for span wire mounting of multi-faced signal heads and signal head clusters (such as a five-section signal head) shall include an approved swivel type balance adjuster for proper vertical alignment.

Signal heads shall be fabricated from die-cast bodies. Sand castings will not be acceptable.

All signal head wire entrances shall use a rubber gasket to prevent chaffing of signal cable by signal head movement.

All signal heads shall meet the minimum requirements for adjustable face vehicle traffic control signal heads as specified in ITE Technical Report No. 1 (1970) and its latest revisions.

In addition to these standards, the following shall be applicable:

Optical Units. All new red, yellow, and green vehicle signal indications, both arrow and circular, shall be 12-inch LED type and meet standards set forth by ITE for light output. All LED lenses shall have a minimum of a five-year warranty. LED voltage shall be determined by the type of controller cabinet installed.

Signal Head Mounting and Mounting Brackets. Signal heads either shall have integral serrations or shall be equipped with positive lock rings and fittings designed to prevent heads from turning due to external forces. Lock ring and connecting fittings shall have serrated contacts. Signals shall be provided with watertight fittings using neoprene washers. Each signal head shall be secured to the assembly with a tri-stud type connection.

Bracket-mounted signal heads, as shown on the Plans, shall be supported by mounting brackets consisting of assemblies of 1½-inch steel or galvanized conduit. All members shall be either plumb or level, symmetrically arranged, and securely assembled. Construction shall be such that all conductors are concealed within poles and mounting assembly. Each slip fitter shall be secured to the pole.

Directional Louvers. Where shown on the Plans, louvers shall be furnished and installed in the hoods of the signal head sections designated.

Directional louvers shall be so constructed as to have a snug fit in the signal hoods. The outside cylinder and vanes shall be constructed of a nonferrous metal or galvanized sheet steel. Louvers shall be painted with two coats of black enamel as specified in these specifications.

Backplates. Where shown on the Plans, backplates shall be furnished and attached to the signal heads. Backplates should maintain improved visibility of signals by providing a maximum of a 5-inch border around the perimeter of the signal, while also reducing effective projected area (EPA)_ as wind speed increases. The backplate shall be manufactured from extruded, exterior-grade PVC, which is chemically and mechanically bonded to a flexible rubber strip. Backplates shall properly fit on three-, four-, and five-section signal heads. Backplates are to be formed in two or more sections and bolted together, thus permitting installation after signal heads are in place.
Material:

- Ridged, exterior-grade PVC: Tensile impact strength of 75 lbf/square inch.
- Rubber polymer: Durometer of 68 Shore A Hardness.
- Hardware stainless alloys have minimum yield strength of 30 kilopounds per square inch.
- All backplate surfaces are flat and straight and are free from defects, blemishes, and excessive trimming marks.
- The material color is flat black and is consistent throughout the entire piece, with a minimum of a 2-inch yellow retro reflective border around the perimeter of the backplate.

The retro reflective border is to be made of a Type III prismatic material and shall meet ASTM D 4956 Type XI 4081 reflective specifications.

Backplates shall be AeroFlex or approved equal.

Wiring. Signal head leads shall be No. 18 AWG (0.001271 square inch) stranded with 221°F thermoplastic insulation. A separate white (common) lead shall be wired to each socket shell, and a colored lead, corresponding to the color code specified in the Plans, shall be wired to each socket terminal. Leads shall be of sufficient length to allow connection to the terminal block specified herein. Each complete signal head shall be provided with a minimum 4-point terminal block, properly mounted in a signal section. Stud type terminal blocks shall have not less than ¼-inch edge clearance to any portion of the stud. Exterior wiring shall have a 360-degree drip loop in advance of entering the head.

Spare conductors shall be provided for each signal head. Vehicular signal heads shall be wired with a 7-conductor cable to each signal head from the handhole to the signal head. Cables shall be one continuous length to each head, with no splices being permitted. The individual 7-conductor cables shall be spliced in the pole base with a 12-conductor cable run from the pole base to the controller. All spare conductors shall be terminated in the signal head and grounded in the controller cabinet. Pedestrian signals shall be wired using 7-conductor cable, and pedestrian pushbuttons shall be wired using 2-conductor shielded cable.

Pedestrian Signals. A pedestrian signal head consists of a pedestrian signal mounting assembly and a pedestrian signal face comprising a pedestrian signal housing, an LED countdown pedestrian signal face module, and a front screen.

When shown on the Plans, pedestrian signals shall conform to the following:

1. Pedestrian indications should attract the attention of and be readable to the pedestrian both day and night and at all distances from 10 ft to the full width of the area to be crossed.
2. All pedestrian indications shall be rectangular in shape and shall consist of the filled symbol messages Hand and Man. For the purposes of these specifications, the messages MAN and HAND shall be interpreted to be equivalent to the international symbols of a "Walking Figure" and "Upraised Hand," respectively. Countdown pedestrian heads shall be of the “self-learning” type, which does not require separate programming, for the HAND indication. All new pedestrian indications shall be countdown type.
3. When illuminated, the MAN indication shall be lunar white meeting ITE standards, with an opaque material obscuring all but the letters.
4. When illuminated, the HAND indication shall be Portland Orange meeting ITE standards, with an opaque material obscuring all but the letters.
5. When not illuminated, the MAN and HAND messages shall not be distinguishable by pedestrians at the far end of the crosswalk they control.
6. All pedestrian indications shall be LED type and meet ITE specifications for light output.

Indications shall have a five-year warranty at a minimum.
Countdown pedestrian signals shall conform to the following:

1. The requirements of the MUTCD.
2. Applicable provisions of the current specification of the ITE standard titled Vehicle Traffic Control Signal Heads – Part 2: L.E.D. Vehicle Traffic Signal Modules.
3. Current specification of the ITE standard titled Pedestrian Traffic Control Signal Indications.
4. Federal Communications Commission (FCC) Title 47, Subpart B, Section 15 on Emission of Electronic Noise.
5. Current NEMA Standard TS 2 for operational compatibility.

Pedestrian Signal Housings

Pedestrian signal housings shall be two-piece 16-inch clamshell mount. Housings shall be aluminum, of federal yellow color, with a black door, with dimensions as shown below:

Housing: 15.8 inches high x 17.4 inches wide x 7.3 inches in diameter.
Door (including tabs): 18.7 inches high x 18.5 inches wide x 1.8 inches in diameter.
Overall: 18.7 inches high x 18.5 inches wide x 9.1 inches in diameter.

The manufacturer shall supply certification, which includes a copy of the test report by an independent technical laboratory, as to the module compliance with ITE specifications (where it applies). The report shall also indicate that the tests were performed only after the modules received a 30-minute operational warm-up period immediately preceding the tests.

The housing door, door latch, and hinges shall be of aluminum, or approved equal. Hinge pins shall be stainless steel. The door shall be provided with a neoprene gasket capable of making a weather-resistant, dust-proof seal when closed, and shall be clamshell design.

All pedestrian signal heads, mountings outside of hoods, and pedestrian push button housings shall have one or more coats of primer followed by two coats of high-quality synthetic resin enamel of Traffic Signal Yellow, and shall meet or exceed Federal Specification TTC-595 Gloss Yellow. The interior of signal hoods shall have one or more coats of primer followed by two coats of Lusterless Black Enamel meeting or exceeding Federal Specification TT-E-489. All factory-enameled equipment and materials shall be examined for damaged paint after installation, and such damaged surfaces shall be repainted to the satisfaction of the Engineer. Factory-applied enamel finish in good condition and of appropriate color will be acceptable.

Signal Head Installation. Signal heads shall be installed with the faces completely covered until the entire installation is ready for operation.

Accessible Pedestrian Signals

The audible-tactile pedestrian signal system shall consist of all electronic control equipment, mounting hardware, push buttons, and signs, to provide both a push button with a raised vibrating tactile arrow on the button along with a variety of audible sounds for different pedestrian signal functions.

A two-wire accessible pedestrian signal (APS) system consists of push button stations (PBSs) installed on poles with existing or new pairs of button wires and a Central Control Unit (CCU) installed in the traffic cabinet. The CCU powers the PBSs over the two wires and uses digital data, including pedestrian interval information and pedestrian calls for each phase, to communicate with each PBS over the two low-voltage button wires.

Substantiating documentation for meeting ISO, NEMA, International Electrotechnical Commission (IEC), and FCC requirements shall be supplied from an outside testing services laboratory.

General Description

1. The system shall consist of a CCU and PBSs, as described below, and be capable of communicating with and programming with devices that support an iOS client application, an Android client application, or Windows PC with Bluetooth® Low Energy dongle and Windows client application, for programming the system settings.
2. The system shall be manufactured by an ISO 9001:2015 (minimum) registered company.
3. The system shall meet the requirements of Made in America and/or The Buy American Act.

Design Compliance

1. The system shall meet the functionality requirements of MUTCD 11th ed. – Section 4K and California MUTCD 2011 – Section 4E.
2. The system shall meet NEMA TS 2 Section 2.1 Temperature & Humidity requirements, or TS 4 equivalent.
3. The system shall meet NEMA TS 2 Section 2.1 Transient Voltage Protection requirements, or TS 4 equivalent.
4. The system shall meet NEMA TS 2 Section 2.1 Mechanical Shock and Vibration requirements, or TS 4 equivalent.
5. The system shall meet IEC 61000-4-4 and IEC 61000-4-5 Transient Suppression requirements.
6. The system shall meet FCC Title 47, Part 15, Class A Electronic Noise requirements.
7. The PBS enclosure shall meet NEMA 250 – Type 4X requirements.
8. The CCU enclosure shall meet NEMA 250 – Type 1 requirements.

Functional Requirements

1. The system shall support at least 16 PBSs per intersection (on at least one channel) controlled by a single base unit located in the traffic control cabinet.
2. The system shall vibrate a tactile arrow button during the WALK interval following a button push and/or every time the walk comes up.
3. The system shall have the field-selectable function known as “LOCATE TONE.” This means that during the FLASHING DON’T WALK and DON’T WALK intervals, the system shall provide a locating tone that emanates from the PBS. The system shall provide at least three different sounds to choose from.
4. The system shall have the field-selectable function known as “Extended Push Activation.” This is defined as the audible WALK message and shall only be activated and audible during the WALK interval if the button is depressed for a field-selectable minimum period of time (from 0.5 to 6 seconds). Also, for the walk and clearance intervals that follow an extended push, the volumes shall have a separately settable minimum and maximum volume level.
5. The system shall have the field-selectable function known as “Informational Message.” This means that a custom message giving the location of the street to cross and the intersection (or other information) will be vocalized only when the button is depressed for a minimum field-selectable time.
6. The system shall provide a “Wait” message that plays once the button is activated, and until the Walk cycle goes into effect. This message shall have the field-selectable option of OFF, or repeating every 4, 6, 8, or 10 seconds.
7. The system shall have standard “Travel Direction” options that can be selected at the time of installation.
8. The system shall have at least 10 field-selectable WALK sound options including a cuckoo, a chirp, an MUTCD rapid tick, or a custom voice message.
9. The system shall provide at least seven Ped-clearance sound choices including audible countdown (field selectable). The audible countdown shall represent the time remaining during the pedestrian clearance interval. Timing is automatically adjusted to the CLEARANCE INTERVAL timing, provided by the traffic controller. Due to flasher relay timing variables, audible and pedestrian (PED) head numbers may vary by approximately 1 second.
10. The system shall provide two language capabilities, selectable by user (as a field-selectable feature).
11. The PBSs shall have wireless synchronization capabilities, from button to button (including between a two-wire PBS and a three-wire PBS), matched to a phase partner. Sync distance may vary based on the environment. Pedestrian button presses are communicated between phase partners to keep the pilot LED in sync, as well as the audible messages during the Walk and Clearance PED intervals.

Wireless synchronization shall be implemented on corners that do not contain button wires. The wireless synchronization capability shall include sending standard and extended push information to allow a call to be placed from a PBS without button wires (or degraded button wires) via a phase partner PBS that has button wires to the traffic controller.

12. The system shall provide an emergency preemption message in conjunction with a preemption system (selectable feature). This feature is only available with the CCU-S (shelf-mount CCU, not the card rack version).
13. The system LOCATE TONE, WALK, and DON'T WALK audible features shall have independent assignable minimum and maximum volume limits. CLEARANCE volume level shall be controlled by WALK volume setting.
14. All sounds for all PBSs shall be synchronized.
15. The system shall have a non-visible, ambient sensing microphone located in the pedestrian station in an environmentally protected housing.
16. The LOCATE TONE volume shall adjust automatically in response to ambient noise with field-selectable adjustment levels from -30 dB below to +20 dB above ambient in 2.5-dB increments.
17. All other sound volumes shall adjust automatically in response to ambient noise with field-selectable adjustment levels from -30 dB below to +20 dB above ambient in 5-dB increments.
18. The system shall utilize high-quality digital audio technology, with a minimum 16-bit sample at a 48-kilohertz sample rate.
19. The PBS firmware and voice messages shall be updatable via Bluetooth Low Energy level 5 at a minimum. There shall be no requirement for integrated circuit (IC) chips or module hardware to be removed or exchanged in order to complete a firmware or audio update.
20. The system shall have the option to mute sounds on all crosswalks except activated crosswalk (selectable feature).
21. The system shall have a real-time clock capable of keeping time when there is no system power, for at least 2 years from the date of manufacture.
22. The system shall have the ability to have four separate program configurations with all features available, and any single configuration can be selected through an external input.
23. The system shall provide a user settable calendar function, allowing four separate configuration profiles to be configured to become active at different times of the day on a daily, weekly, or holiday basis.
24. The entire system shall be configurable from any PBS over Bluetooth Low Energy.
25. The entire system shall be configurable from the CCU over Wi-Fi or Ethernet.
26. All field access to selectable options using Bluetooth Low Energy, Wi-Fi, or Ethernet devices shall be protected using password security.
27. Each PBS shall be capable of interacting with a pedestrian app on iOS or Android smartphones, via Bluetooth Low Energy.
28. Each PBS shall be capable of interacting with the PedApp® smartphone application to allow pedestrians to remotely actuate a pedestrian call into a PBS. PedApp can be configured to help provide visually impaired and all pedestrians with location/directionality information, as well as to place calls and receive pedestrian interval information via smartphone.
29. The touchless actuation option when ordered/included in the PBS shall be capable of detecting movement within 1 to 4 inches to actuate/place a pedestrian call via the PBS.
30. The touchless actuation option shall be capable of adjusting the distance or range of detection from 1 to 20 inches.
31. The touchless actuation option shall be capable of adjusting minimum wave detection time (amount of time that a wave shall be performed before a call is activated). The setting times shall be in milliseconds (ms) and be settable to 0 ms, 50 ms, 250 ms, and 500 ms.

32. The touchless actuation option performance shall not be impeded or affected by ice buildup on the PBS.
33. The touchless actuation option – detection system shall be inconspicuous and vandal resistant.

Central Control Unit – The CCU is the control unit that provides data for the PBSs. The CCU shall be either a shelf-mount (CCU-S) or a card-rack-mount (CCU-C) assembly.

1. The CCU-S shall be installed inside the traffic cabinet and be powered by the alternate current (AC) supply mains (115 volts alternate current [VAC]).
2. The CCU powers the PBSs over two wires and uses digital data including pedestrian interval information and pedestrian calls for each phase to communicate with each PBS over the two low-voltage button wires.
3. The CCU-C shall be installed inside a 300 series traffic cabinet's input file, replacing two PED isolator boards and receiving power from the rack (24 volts direct current [VDC]).
4. The CCU-S shall provide internal power to operate up to 16 PBSs.
5. A 24-volt power brick shall power up to 16 PBSs in a CCU-C configuration.
6. The CCU shall control at least 16 PBSs.
7. The CCU shall be logically configurable to assign any PBS to one of 16 traffic/PED phases.
8. The CCU through synchronous data link control (SDLC) shall be able to place PED calls on up to eight phases.
9. The CCU-S shall receive pedestrian phase Walk, Don't Walk, and Clearance inputs from either the traffic cabinet load switches or an SDLC input.
10. The CCU-C shall receive pedestrian phase Walk, Don't Walk, and Clearance inputs from a Transport Electrical Equipment Specification (TEES) C4S connector.
11. The CCU shall be able to self-test all PBSs and put a corresponding phase into recall should a PBS assigned to a phase fail the self-test.
12. The CCU-S shall provide optically isolated general-purpose inputs.
13. The CCU-S shall incorporate four separate cable assemblies to access all functions, so any combination of the four cable assemblies can be used to access any combination of functions.
14. The CCU shall have internal storage to log several thousand events with a date-time stamp for each event.
15. The CCU shall have an internal real-time clock capable of being set in the field and propagating the time to each connected PBS.
16. The CCU firmware shall be updatable via either Wi-Fi or Ethernet. There shall be no requirement for IC chips or module hardware to be removed or exchanged to complete the firmware update.
17. The CCU shall monitor PED interval conflicts and set affected PBSs to an off/safe mode when a conflict occurs.
18. The CCU-S shall meet NEMA 250 – Type 1 enclosures requirements.
19. The CCU shall have a backlit liquid-crystal display (LCD) screen and button interface to allow placing test calls and display status.

Pedestrian Push Button Station – The PBS allows the pedestrian to place calls to the traffic controller and provides vibro-tactile feedback during the Walk cycle. This equipment is typically mounted on a pole, near the start of the crossing.

1. The PBS shall be mounted to a pole by banding or bolting.
2. The PBS shall be a single fixture that contains a 2-inch activation area, in which resides an Americans with Disabilities Act (ADA) compliant vibro-tactile push button with a raised directional tactile arrow, and a sign mounted above the button.
3. The PBS speaker shall be 8 ohms, 6 watts, and weatherproof.

4. The button shall be cast aluminum, nickel-plated, and powder-coated black around the arrow, to provide high contrast to arrow color. The PBS arrow shall allow for change in orientation to one of four directions.
5. The PBS button actuation shall use Hall Effect Sensor technology rated to greater than 20 million operations.
6. The PBS button push force shall have three adjustable pressure settings “Light, Medium, and Firm” over a range of approximately .5 LB to 3.5 lbs to activate a button push.
7. The PBS button shall pulse and vibrate at approximately 20 hertz (Hz) with a displacement factor based on pounds of force used to actuate.
8. The PBS shall have a rear-facing speaker projecting sound from front and back, providing 360-degree omnidirectional sound performance.
9. The PBS shall include internal conflict monitoring that monitors WALK and DON’T WALK input signals for conflict conditions and disables system operation and logs errors if conflict occurs.
10. The PBS firmware and voice messages shall be updatable via Bluetooth Low Energy. There shall be no requirement for the hardware to be changed out to update.
11. The system shall operate with the vendor’s client application to record and upload cumulative PED count and call data.
12. The PBS shall meet or exceed NEMA 250 type 4X enclosure requirements.
13. The PBS construction shall be:
    A. Frame and Button Cover: Cast aluminum, powder coated.
    B. Housing: Reinforced, UL-listed thermoplastic.
    C. Message Sign: Aluminum, powder coated, ink markings, or reflective vinyl sheeting.
    D. Push Button: Aluminum, nickel plated, powder coated.
14. Electronic circuits (printed circuit board assemblies) shall be in a thermoplastic housing/enclosure having a UL 94-V0 flammability rating. The housing/enclosure shall provide NEMA 250 type 4X protection to all covered components.
15. At time of order, customer shall be able to specify sign size and message sign markings to be either the International Walking Person or the Informational Explanations for the three distinct pedestrian displays (WALK, DON’T WALK, and PED CLEARANCE) that a pedestrian would see on an active pedestrian signal.
16. The PBS shall be a modular design with a separate speaker compartment that can be field-replaced.
17. A two-wire PBS shall include a three-position terminal block to support the capability of operating as a three-wire PBS (three-wire pedestrian head-based system) by adding a control unit in the pedestrian signal head that converts 115 VAC to 24 VDC, and a three-wire cable that carries power, data, and ground wires from the control unit to the PBS.
18. The PBS shall have Bluetooth Low Energy communication that allows a pedestrian to use an application to obtain PED status information, and to place a PED call when in proximity to a button without having to touch/push the button.

Field Programming via Client Application (Apple iOS v9.0 or higher devices, or Android 5.0 or a PC with Windows 8 or 10)

1. The system shall use Bluetooth Low Energy 5 or higher technology to program firmware and audio voice messages, and to communicate to other buttons or external devices.
2. The system shall be password protected through the programming/configuration interface.
3. The iOS, Android, and PC applications shall be upgradable.
4. The iOS, Android, and PC applications shall notify the user when a newer version of the application is available.
5. The iOS, Android, and PC applications shall notify the user when newer PBS and CCU firmware is available.

6. The iOS, Android, and PC applications shall provide the mechanism to download the latest PBS and CCU firmware.
7. The iOS, Android, and PC applications shall be capable of setting all volumes and features of the APS system specific to the PBSs.
8. The iOS, Android, and PC applications shall be capable of setting/updating configuration options for a single PBS or all PBSs on the intersection for most functions from a single PBS or CCU (global updating).
9. The iOS, Android, and PC applications shall be capable of storing, modifying, loading, and emailing PBS configuration settings, audio files, and health logs.

When shown on the Plans, the APS shall comply with the MUTCD, Chapter 4 and shall conform to the following:

1. Size: 5 inches x 3.75 inches x 5 inches.
2. Weight: 3 lbs.
3. Humidity range: 5 to 95% relative humidity.
4. Color: Federal Yellow.
5. Output: Cuckoo (north/south) (Duration 0.6 seconds ±20%, Frequency 1,100 Hz ±20%, and Frequency Deviation +120 Hz ±20%) and Peep-Peep (east/west) (Duration 0.2 seconds ±20%, Frequency 2,800 Hz ±20%, Frequency Deviation -800 Hz ±20%).
6. Voltage: 115 Volts AC (± 22%).
7. Power: 60 Hz, 3 Watts.
8. Temperature Range: -35º F to +165 º F.
9. Output: 90dB at 1 watt/3 feet.

Measurement. The APS shall be measured in units of each and paid for at the contract price per each. The price bid shall include furnishing, installing, warranties, full operation, and configuring the APS equipment including push buttons, CCUs, mounting hardware, power cable, cabinet equipment, user manuals, testing, warranties, and any and all other equipment required to complete installation of the unit in accordance with applicable standards, specifications, and requirements. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

CONTROLLERS – GENERAL

730.28—Controllers.

A controller shall consist of the complete electrical mechanism for controlling the operations of traffic control signals, including the timing mechanism and necessary auxiliary equipment, mounted in a cabinet. Depending on the type of controller cabinet, the controller shall be either rack-mounted or shelf-mounted as specified on the Plans.

The controller unit shall be compatible with NDOT's current central software. See NDOT's current Qualified Products List (QPL) for approved controllers. The controller shall be fully compliant with the Advanced Traffic Controller (ATC) 5.2b and proposed ATC Standard 6.10. The controller shall support Linux-based software.

Control features are to include:

1. The controller unit shall meet the environmental requirements as set forth in Section 2 of the NEMA Standards Publication No. TS 2-2003 or later revision.
2. The controller shall be 10/100 Base T Ethernet ready.
3. The controller unit shall be solid state, digital based upon microprocessor design.

4. The controller shall utilize an input/output interface set forth in Section 3.5 of NEMA Standard Publication TS 2-2003 or later revision for malfunction management units and detector racks.
5. NEMA Section 3.5.2 shall be used for input/output functions for terminal facilities, detectors, and auxiliary devices.
6. The controller shall be capable of operating as a TS-2 type A 1 or type A 2.
7. The following interface connectors shall be accessible from the front of the controller:
   A. Connector A shall mate with MS3116( )-22-55S.
   B. Connector B shall mate with MS3116( )-22-55P.
   C. Connector C shall mate with MS3116( )-24-61P.
      (1) Synchronous Data Link Control (SDLC) – 15 pin metal shell D sub-miniature (gold-plated female contacts).
      (2) Recommended Standard (RS) 232 – 25 pin metal shell D sub-miniature (gold-plated female contacts).
      (3) Registered Jack (RJ)-45 10/100 Base T Ethernet Port.
8. If input/output or communications functions in addition to those covered in TS 2-2003 are requested in the Plans and supplied, an additional connector may be used.
9. Programming Methods: The methods listed below shall be available for controller unit programming:
   A. Manual data entry via the front panel keyboard.
   B. Data downloading via a central system.
   C. Data downloading from a personal computer.
   D. Data downloading from one controller unit to another using the serial port of each controller unit.
   E. Data downloading via a USB flash drive.
   F. Flashable firmware via a computer or USB drive.
10. Controller functionality is to include:
   A. 16 phases, 8 configurable concurrent groups in 4 timing rings.
   B. 16 vehicle overlaps that can be configured as normal, green / yellow, protected-permissive left turn (PPLT) / flashing yellow arrow (FYA).
   C. 16 pedestrian phases that can be configured as pedestrian overlaps.
   D. Exclusive pedestrian operation.
   E. Dynamic max operation.
   F. Extendable walk and pedestrian clearance.
   G. Advanced walk.
   H. Bike input and green timing.
   I. Adaptive red clearance.
   J. Transit signal priority.
   K. Emergency and railroad preemption.
11. Coordination features are to include:
   A. 120 coordination event plans, each with its own cycle, offsets, split timing, coordinated phases, vehicle and pedestrian recall, and phase omits.
   B. Offset and split entries displayed in percent or seconds.
   C. Automatic permissive periods.
   D. Fixed or floating force-off.
   E. Crossing arterial coordination.
12. The controller shall have all of the following keyboard-entered values or parameters:
   A. Phases to start in.
   B. Phase display to be on.
   C. Overlap display start-on condition.
13. Normal start-up display shall be main street green phase(s), with concurrent overlaps green.

14. The controller shall have a backlit liquid crystal display to provide an English language menu for programming or reading all controller features. The dynamic displays for real-time operation shall be able to display the following values for each ring or phase(s) concurrently:
    A. Per Phase Display:
        (1) Phase Vehicle Call.
        (2) Phase Pedestrian Call.
        (3) Phase is Next in Service.
        (4) Phase is in Service.
        (5) Phase Pedestrian Intervals in Service.
    B. Per Ring Display:
        (1) Ring Gapped Out.
        (2) Ring Maximum Green Termination.
        (3) Ring was Force Off Terminated.
        (4) Ring Maximum Green II in Effect.
    C. Ring Phase in Service Operating:
        (1) Lock Call.
        (2) Non-Lock Call.
        (3) Minimum Recall.
        (4) Maximum Recall.
        (5) Pedestrian Recall.
        (6) Non-Actuated Mode.
    D. Per Ring Display of Timing Values (Real Time). The following values shall be selectable display the current value in a real-time mode:
        (1) Minimum Green Interval.
        (2) Passage Timer.
        (3) Pedestrian Interval Timing.
        (4) Maximum Green Timer.
        (5) Time Before Reduction Timer.
        (6) Time to Reduce Timer.
15. It shall be possible to inspect and alter any currently programmed value while the controller is in operation without affecting the field operation. The controller shall continue to operate the intersection as values are inspected or altered. This requirement does not apply to ring structure or other programmed values that require the controller to perform a start-up sequence.
16. All controller firmware shall be flashable and software shall be supplied with revisions of firmware to flash into the controller. NDOT requires ongoing firmware support for the lifecycle of the product.

All operator-entered data shall be stored on a USB flash drive or secure digital (SD) card.

Documentation

1. A schematic wiring diagram and maintenance manual shall be provided for all equipment.
2. If a separate operations manual is published, it shall also be provided. All documentation shall be provided in two hard copies and in PDF electronic format.
3. The manual shall show in detail all circuits and parts. Such parts shown shall be identified by common name and part number.
4. Any manufacturer unique components shall be identified as such.

Training. When four or more controller assemblies are provided under a contract, the Contractor will provide a training secession for up to eight staff members. This session shall be within Davidson County and include:

1. 4 hours of classroom instruction.

2. 4 hours of laboratory instruction.
3. Theory of operation.
4. Detailed troubleshooting techniques.
5. Use of technical data including parts identification.

Software. The controller shall meet, as a minimum, all applicable sections of the NEMA Standards Publications for TS 2, National Transportation Communications for ITS (Intelligent Transportation Systems) Protocol (NTCIP) 1202 Version 03B, and ATC standard 6.25. Controller versions shall be available to comply with NEMA TS 2 Types 1 and 2. Current NDOT-approved software shall be loaded onto the controller. The software shall have the following features:

1. Advanced coordination such as adaptive and responsive timing.
2. Transit signal priority.
3. Alternate timing for bicycles, pedestrians, or special vehicles.
4. Supports NTCIP.

730-29—Controller Cabinets.

Controllers shall be housed in a rigid, weatherproof cabinet, constructed, finished, and equipped as follows, and as shown on the Standard Details. Controller cabinets shall be NEMA TS 2 or ATC as specified in the Plans. Cabinets shall be wired to TS 2 Type 2 standards and shall support 16 channels with plugins.

NEMA TS 2 Cabinets

1. Material
   A. All cabinets shall be of weather-tight construction fabricated from aluminum sheet a minimum of 0.125 inch thick or cast aluminum alloy a minimum of 0.25 inch thick.
   B. Painting of cabinets is not required unless required in the Plans.
   C. All pad-mounted cabinets shall be 44 inches x 26 inches x 55 inches.
   D. Cabinets shall me the Standards Publication No. TS 2-2003 or later revision unless a different size is required in the Plans.
   E. All pole-mounted cabinets shall be 36 inches x 50 inches x 18 inches unless a different size is required in the Plans or approved by NDOT.
   F. All pole-mounted cabinets shall be equipped with a removable bottom panel to facilitate optional pad mounting.
   G. All shelves and panels shall be mounted on U-channel type rails and be fully adjustable by loosening panel bolts.
   H. Cabinet main back panel shall be an 8 over 8 load switch configuration and shall be sized to fit in both 36-inch-wide and 44-inch-wide cabinets. All power, neutral, and ground connections shall be labeled with color-coded silkscreen or industrial smudge-proof stickers. All controller input and output functions shall be grouped in logical order.
   I. Cabinet main back panel shall have a hinged-type device at the bottom of the panel to facilitate the lowering of the panel for inspection of the rear wiring without removal of shelving.
   J. All feed through terminals shall be soldered. The use of spade-type connectors will not be accepted.
   K. All pad foundations shall be built to Section 7, Figure 7-2 of NEMA Standards Publication No. TS 2-2003 or later revision.
   L. Cabinet shall include 14” Din Rail on right side for mounting of Ethernet switches, fiber equipment, etc.
2. Doors
   A. Cabinets shall have a hinged front opening door, which shall include substantially the full area of the front of the cabinet.

B. The door shall be equipped with a positive holdfast device to secure the door in at least two open positions: one position at approximately 90 degrees and the other at 120 degrees or more.
C. The holdfast device shall be easily secured and released without the use of tools.
D. Cabinets shall also be equipped with a switch compartment and the manual switches specified in this section and shall have a hinged front opening auxiliary door. Each door shall have a gasket to provide a weatherproof seal when closed.
E. The main door shall have a lock as specified in the Plans or by NDOT. Two keys shall be provided for each lock.
F. The auxiliary door shall have a standard police sub-treasury lock.

3. Cabinet Mounting – Cabinets shall be mounted as shown on the Plans or Standard Details.
4. Ventilation—Unless otherwise specified, ventilation shall be provided as follows:
   A. All cabinets shall be ventilated through an internal baffle located in the top of the cabinet.
   B. Inlet ventilation openings shall be filtered.
   C. Cabinets shall be provided with two independently controlled exhaust fans.
   D. Exhaust fans shall be electric with ball or roller bearings and a capacity of at least 100 cubic feet per minute.
   E. The fans shall be mounted in a rain-tight housing attached to the plenum inside the top of the cabinet.
   F. Each fan shall be controlled by thermostats having a temperature differential between turn-on and turn-off of 15°F (0, +5°F), adjustable for turn-on through a minimum calibrated range of 100° to 150°F.
5. Auxiliary Equipment—Except for cabinets used in special applications, all cabinets shall be fitted with the following:
   A. No less than two shelves shall be provided to support controller and auxiliary equipment.
   B. All terminal panels shall be arranged for adequate electrical clearance.
   C. One ground fault receptacle and a minimum of a four-position surge type strip located on the left side of the cabinet, mounted so as not to interfere with shelf space.
   D. LED-type lighting mounted on the plenum and under the lower shelf controlled by a door switch.
   E. Wetted mercury switches are not acceptable; install Crydom A2475 solid state relay or equivalent.
   F. Circuit breakers for:
      (1) Main power input to provide all power associated with normal operation (40 amps).
      (2) Equipment power to provide power to all associated cabinet equipment (15 amps).
      (3) Flasher power input to provide all power associated with flash operation (15 amps).
      (4) Service power to provide power for the lamp and duplex receptacle (10 amps).
      (5) Service power to provide power to street name signs.
   G. Copper ground buss (minimum of two 12-position bars).
   H. The Malfunction Management Unit (MMU) sampling inputs shall be terminated at the closest tie point to the field termination of the signal displays.
   I. Where required to perform specified functions, general purpose relays shall be provided.
   J. A minimum of 24 available bare ground positions tied to AC Common Return.
   K. Earth (driven) ground tie point to terminate a single No. 4 AWG (0.03286 square inch) copper ground.
   L. Tie point to tie all ground systems within the cabinet to a single reference point. All grounds (AC – return, chassis, and logic ground) shall be referenced to a single ground point at the electric service.
   M. Isolate logic ground from AC – return and earth ground. Provide ped isolation devices to protect logic ground input to the cabinet.

N. A panel behind the auxiliary door to contain the following switches:
   (1) An Automatic Flash switch wired when in the Flash position, that causes the cabinet to provide Flash Operation and Stop Time shall be applied to the controller.
   (2) Switch to activate Manual Control Enable.
   (3) Manual control pushbutton switch with 4-foot minimum cord. Cord shall attach to a 2-position terminal strip via fork-type connectors. Terminal strip to be located on the backside of the police panel.

O. A panel mounted inside the main door to contain the following switches:
   (1) A technician Stop-Time switch to apply Stop Time to both controller rings.
   (2) An Interval Advance switch, enabled only by the Stop Time switch, to be momentary pushbutton switch to apply Interval advance to the timer.
   (3) A Signal On-Off switch that will remove the AC power applied to the signal heads for normal operation while the controller continues to operate.
   (4) A Signal Normal/Flash switch to enable intersection flash when in the Flash position.
   (5) 16 individual phase vehicle and 8 pedestrian detector test switches located on the ped isolation unit to be toggle type of the On-Off-Momentary type located on the left side of the cabinet above the detector panel or on the tech panel to place:
      a. No call – Call provided by detectors.
      b. Locked detector call.
      c. Momentary detector call.
   (6) Switch terminals on back of main cabinet door shall be insulated or shielded so that no live parts are exposed.
   (7) Tech panel shall have a clear fold-down Lexan panel to protect the switches from accidental activation

P. Leads to the auxiliary door switches shall be no less than No. 18 AWG (0.000127 square inch) stranded.

Q. All connections within the cabinet that have AC voltage shall be protected with a clear Lexan cover to prevent accidental shock.

6. Wiring—The cabinet shall be wired to TS 2 Mode "B" standard. The back panel shall be labeled to reflect Mode "B" operation. The cabinet shall be wired according to the following:
   A. Controllers shall be wired for 8 vehicle movements, 4 pedestrian phases, and 4 overlaps (16 phases). Sixteen NEMA input and output indicating load switches and bases shall be provided. There shall be 4 – 2-channel detection cards for each of the 8 vehicle phases.
   B. Detector rack (8 position) shall be wired and labeled as described in the TS 2 specification (Table 5-9, configuration 2).
   C. Channels 1, 3, 5, and 7 green and yellow circuits shall be terminated at a load resistor. Pedestrian channels 9, 10, 11, and 12 green circuits shall be terminated at a load resistor. Load resistors shall terminate via fork-type connectors.

7. Power Supply—The cabinet shall include a power supply meeting the requirements of NEMA TS 2 specification. The cabinet power supply shall provide all direct current (DC) voltages to the cabinet and be monitored as 24 volts 1 & 2. The controller 24 VDC line shall not be terminated in the cabinet or be monitored. The power supply shall be completely enclosed in an aluminum housing, shall be shelf mounted, and shall provide the following voltage and current outputs:
   A. +12 VDC ± 1 VDC, 2.0 Amps.
   B. +24 VDC ± 1 VDC, 2.0 Amps.
   C. 12 VAC, 0.25 Amps.
   D. Outputs shall be fused with slow blow fuses of the ratings indicated.
   E. AC power input shall be protected against over current with a 2-amp slow blow fuse.

F. LED indicators on the front panel shall denote the presence of 12 VAC, 24 VDC, and 12 VDC, and the 60-Hz reference signal test points for logic common and +24 VDC shall also be provided on the front panel.

8. Bus Interface Unit (BIU)—The cabinet shall include a BIU and detector rack as defined in Section 8 of NEMA Standards Publication No. TS 2-2003 or later revision. The BIU shall be a NEMA designated BIU2 as listed in Table 8-1 of the TS 2 specification. The detector rack vehicle outputs shall be wired in parallel with the BIU to accomplish use of the detectors with or without use of the BIU by plugging or unplugging the vehicle input suppressors.
9. Lightning Protectors and Interference Suppressors—Ample lightning protectors to provide effective defense against high transient voltages caused by lightning discharges or other sources shall be provided. Each controller cabinet shall be furnished with the following surge protection devices:
   A. Main power suppressor shall be EDCO SHA-1250 or approved equal with contact wired to Alarm 1 for all but flasher or remote detector cabinets and shall have the following characteristics:
      (1) Peak Surge Current: 20,000 Amps.
      (2) Clamp Voltage: 250 volts.
      (3) Response Time: Voltage NEVER exceeds 250 volts.
      (4) Continuous Current: 10 Amps at 120 VAC.
      (5) It shall be socket mounted allowing replacement in less than 2 minutes.
   B. Power protector for controller flasher, flashing beacon, and remote detector cabinets shall have the following characteristics:
      (1) Peak Current: 15,000 Amps.
      (2) Power Dissipation: 15 watts.
      (3) Peak Voltage: 212 volts.
   C. Controller detector input terminals (vehicle and pedestrian) shall be terminated at a plug-in surge suppressor, EDCO PC-642C-030 or equivalent, and have the following characteristics:
      (1) Peak Surge Current: 400 amps differential mode.
      (2) Response Time: 40 nanoseconds.
      (3) Input Capacitance: 35 power factor (pf) typical.
      (4) Clamp Voltage: 30 volts maximum (either mode).
   D. Auxiliary relays and fan shall be provided with a resistor/capacitor circuit to suppress generated noise.
   E. Radio frequency (RF) filter shall be provided in controller cabinets and shall provide filtering of RF noise over the range of 60 Hz through 20 megahertz (MHz). The RF filter may be incorporated as part of the main power suppressor.
10. Cabinet shall include a sliding storage drawer mounted under the lower shelf in accordance with the following:
   A. Approximate exterior dimensions of 1.75 inches high x 16 inches wide x 14 inches in diameter.
   B. Telescoping drawer guides to allow full extension from the rack cage.
   C. Opening storage compartment lid to access storage space for cabinet documentation and other items.
   D. Supports a weight of 25 lb when extended.
   E. Non-slip plastic laminate surface attached to the compartment lid that covers a minimum of 90% of the surface area of the lid.

Auxiliary Devices. All auxiliary devices shall meet the requirements of Section 6 of the TS 2 specification with the following additions:

1. Load Switches—Each cabinet shall be provided complete, with the necessary number of NEMA TS 2 load switches and flash transfer relays to fully populate the cabinet. Unused switches and relays will become spares. Load switches shall meet the following requirements:
   A. Shall meet NEMA TS 2 Standards.
   B. Shall have front-face-mounted LED indicators to indicate the "On" condition of both the input and output circuits.
   C. Shall utilize replaceable "cube" type circuitry or encapsulated discrete component construction. No unencapsulated discrete component construction shall be acceptable.

Malfunction Management Unit. All cabinets shall be supplied with an MMU that meets the requirements set forth in Section 4 of the NEMA Standards Publication No. TS 2-2003 or later revision. The MMU shall be the 16-channel type and shall have the following features:

1. Liquid crystal display to show all data in English language format.
2. Capable of being configured to work in a NEMA TS 2 12-channel mode.
3. Shall monitor all Green/Yellow/Red/Walk field display outputs.
4. Shall be installed with controller 24 VDC monitor not latched.
5. Shall be installed with the controller voltage monitor not latched.
6. Front panel mounted over-current protection (no internally mounted fuses are acceptable).
7. Front panel mounted reset switch.
8. The MMU shall log all faults as to the:
   A. Date of fault.
   B. Time of fault.
   C. Fault condition.
   D. Power failure.
9. The MMU shall store fault conditions in non-volatile memory for user retrieval.
10. The monitor shall be able to store at least 10 such faults.
11. The internal time clock shall automatically adjust for Daylight Savings Time changes.
12. Time and date shall be updated from the controller unit.
13. There shall be a keyboard method for the user to display and clear the stored event log.
14. There shall be an Ethernet Communication port (RJ-45) on the MMU to allow the print or save to a laptop all data or communication back to the TMC. The laptop Ethernet switch shall interface with the MMU via a standard cat6 cable. (Printer and laptops to be supplied by others.)
15. The MMU shall be equipped with a 15-pin metal shell D sub-miniature (gold-plated female contacts) for SDLC communication.
16. No functional field display shall be permitted unless monitored by the MMU.

Advanced Traffic Controller Cabinets

This section sets forth the minimum requirements for High-Voltage (HV) ATC Cabinet (ATCC). The cabinet assembly shall meet, as a minimum, all sections of ATC 5301 Standard Publication No. v02.02 dated March 18, 2019, or the most recent version. Additionally, the manufacturer shall be in compliance with the Customs Trade Partnership Against Terrorism (CTPAT), with active and ongoing/continuing employee training as part of the manufacturing processes for critical and secure transportation infrastructure equipment. UL Bulletin of Research No. 23, "Rain Tests of Electrical Equipment." Where differences occur, this specification shall govern.

General

The ATCC is built to meet the ATC 5301 v02.02 ATCC Standard. The ATCC uses high-speed serial communications, providing modern features such as simplified wiring, cabinet space availability, and more. Benefits of the ATCC include advanced diagnostics, enhanced safety, and long-term true cost of ownership,

making it a sound investment for any agency. The ATCC supports both 120-VAC and 48-VDC LED signals, while high-density switch packs and quad detector modules allow for up to 32 channel signal outputs and 120 detector inputs. The ATCC provides both voltage and current monitoring of all signal outputs, including ultra-low-power LEDs.

The cabinet dimensions shall vary depending on location, foundation, right-of-way, maintenance access, and the Plans:

- Existing NEMA Type P/R Foundations: Install Type 350i or 356i ATCC, dependent on height of existing foundation.
- Proposed Foundation: Install Type 356i ATCC on new foundation per NDOT standards.

This specification describes the 120-VDC low-voltage Model 350i ATCC.

1. General ATC Configuration
   The ATCC shall include Service Assembly, Input Assembly, Output Assembly, Communication and Power Bus Assembly, Field Input Termination Assembly, and Field Output Termination Assembly.

   The ATCC configuration shall include the following:
   - Cabinet housing defined by the ATC 5301 Standard.
   - Electronic door locks.
   - Cabinet ventilation consisting of dual fan panel assembly.
   - Air filter.
   - Cabinet lighting.
   - Cabinet finish.
   - EIA cabinet cage – 2.
   - Drawer shelf.
   - Communication and power bus assembly.
   - 32 channel output assembly.
   - 16 channel field output termination assembly – 2.
   - 24 channel input assembly – 2.
   - 24 channel field input termination assembly – 2.
   - Service assembly (32 channel configuration) with main surge arrestor.
   - Auxiliary display unit.
   - ATCC power supply.

   The following plug-in devices shall be provided with each ATCC:
   - 16 High-Density Flash Transfer Relays (HDFTRs).
   - 16 High-Density Switch Packs (HDSPs).
   - 16 High-Density Output Suppressors.
   - 2 High-Density Flasher Units (HDFUs).
   - 1 ATCC Cabinet Monitor Unit.
   - 4 Serial Interface Units (SIUs).
   - 4 Dual Channel DC Isolator Cards (242L).

2. Cabinet Housing
   The housings shall include, but not be limited to, the following:
   - Enclosure.

- Doors.
- Gasketing.
- Lifting Eyes and External Bolt Heads.
- Latches and Locks.
- Ventilation.
- Hinges and Door Catches.
- Police Panel.
- Cage Supports and Mounting.

A. Housing Construction
The housing shall be rainproof. It shall have two front and two rear doors, each equipped with a lock and handle. The enclosure top shall be crowned to prevent standing water.

B. Material Thickness
The enclosure, doors, lifting eyes, gasket channels, police panel door, spacer supports, and all supports welded to the enclosure and doors shall be fabricated of 0.125-inch minimum thickness aluminum sheet. The filter shell, filter trough, fan support, and police panel enclosure shall be fabricated of 0.080-inch minimum thickness aluminum sheet. The spacer supports shall have the option to use 0.059-inch minimum stainless-steel sheet.

C. Welds
All exterior seams for enclosure and doors shall be continuously welded and shall be smooth. All edges shall be filled to a radius of 0.03125 inch at a minimum. Exterior cabinet welds shall be done by gas tungsten arc TIG process only. ER5356 aluminum alloy bare welding electrodes conforming to AWS A5.10 requirements shall be used for welding on aluminum. Procedures, welders, and welding operators shall conform to the requirements and practices in AWS B3.0 and C5.6 for aluminum. Internal cabinet welds shall be done by gas metal arc MIG or gas tungsten arc TIG process.

D. Aluminum Surface Protection

Anti-Graffiti Paint
If anti-graffiti paint is requested, each stage in the process shall be as follows:

- Perform treatment with a moderately acidic, liquid cleaner concentrate for thorough cleaning.
- Clean water rinse from reverse osmosis system (< 2,500 parts per million [PPM]).
- Clean water rinse from reverse osmosis system (< 500 PPM).
- Apply a conversion coating to form an excellent base for bonding powder to parts and producing good resistance to corrosion.
- Clean water rinse from reverse osmosis system (< 800 PPM).
- Clean water rinse from reverse osmosis system to decrease any solids on surfaces (< 100 PPM).
- Apply a final seal rinse to enhance corrosion resistance.
- Convey through a dry-off oven at a cycle of 10 to 20 minutes at 380º F to eliminate any trapped water and gases in the parts.
- Apply polyester dry powder at 90,000 volts for maximum mil transfer. Thickness of the powder coating shall nominally be 2 to 5 mils.

- Convey into the cure oven for a thermal setting [cure] cycle of 10 to 20 minutes at 380 to 425ºF.

E. NDOT, at its option, may require the vendor to submit written certification of compliance to the requirements listed in this section of the specification.

F. Enclosure Door Frames and Door Seals
The enclosure door frames shall be double flanged out on all four sides and shall have strikers to hold tension on, and to form a firm seal between, the door gasketing and the frame. The dimension between the door edge and the enclosure external surface when the door is closed and locked shall be 0.156 inch (±0.08 inch).

G. Gasketing
Gasketing shall be provided on all door openings and shall be dust tight. Gaskets shall be 0.25-inch minimum thickness closed cell neoprene or silicone (BOYD R-108480 or approved equal) and shall be permanently bonded to the metal. A gasket top and side channels shall be provided to support the top gasket on the door to prevent gasket gravitational fatigue.

H. Lifting Eyes and Exterior Bolt Heads
The housing shall be provided with two lifting eyes for placing the cabinet on its foundation. Each eye opening shall have a minimum diameter of 0.75 inch. Each eye shall be able to support a weight load of 1,000 lbs. All bolt heads shall be tamperproof type.

I. Door Latches and Locks

Latching Handles
The latching handles shall have provision for padlocking in the closed position. Each handle shall be a minimum of 0.75-inch-diameter stainless steel with a minimum 0.5-inch shank. The padlocking attachment shall be placed 4.0 inches from the handle shank center to clear the lock and key. An additional 4.0-inch minimum gripping length shall be provided.

Latching Mechanism
The latching mechanism shall be a three-point draw roller type. The pushrods shall be turned edgewise at the outward supports and have a cross section of 0.25 inch thick by 0.75 inch wide at a minimum.

Locks and Handles
When the door is closed and latched, the door shall be locked. The lock and lock support shall be rigidly mounted on the door. In the locked position, the bolt throw shall extend a minimum of 0.25 ± 0.03125 inch into the latch cam area. A seal shall be provided to prevent dust or water entry through the lock opening.

Locks
The locks shall be electronic to allow NDOT to configure and monitor access to each cabinet. One key shall be supplied with each lock. The keys shall be removable in the locked position only.

Bolt Heads

The locks shall have rectangular, spring-loaded bolts. The bolts shall have a 0.281-inch throw and shall be 0.75 inch wide by 0.75 inch thick (tolerance is ±0.035 inch).

Center Latch Cam
The center latch cam shall be fabricated of a minimum thickness 0.1875-inch steel or aluminum. The bolt surface shall horizontally cover the cam thickness. The cam shall be structured to only allow the door to open when the handle is moved toward the center of the door.

Rollers
Rollers shall have a minimum diameter of 0.875 inch with nylon wheels and steel ball bearings.

Hinges
Stainless-steel hinges (two bolts per leaf) shall be provided to bolt the enclosure to the doors. Each door shall have four hinges per door. Each hinge shall be 3.5-inch minimum length and have a fixed pin. The pin ends shall be welded to the hinge and ground smooth. The pins and bolts shall be covered by the door edge and not be accessible when the door is closed. A ground strap between the door and the main cabinet housing shall be required when 120-VAC devices are mounted on the door.

Door Catches
Front and rear doors shall be provided with catches to hold the door open at both 90 and 165 (±10) degrees. The catch minimum diameter shall be 0.375-inch aluminum rods. The catches shall be capable of holding the door open at 90 degrees in a 60-mile-per-hour (mph) wind acting at an angle perpendicular to the plane of the door.

J. Police Panel
A police panel assembly shall be provided to allow limited control access. The panel door shall be equipped with a lock and master police key. The front and back of the panel shall be enclosed with a rigid metal covering so that no parts having live voltage are exposed. The panel assembly shall have a drain to prevent water from collecting within the assembly. The drain shall be channeled to the outside. The cabinet shall have one switch provided and labeled “SIGNALS ON / OFF” and one switch provided and labeled “FLASH / AUTO.” The MANUAL CONTROL ENABLE ON / OFF switch and a receptacle for the INTERVAL ADVANCE cord shall be provided. An INTERVAL ADVANCE cord, 6 feet in length, shall be provided.

K. Rack Cage
Two standard rack cages shall be installed inside the housing for mounting of the ATC and cabinet assemblies. The EIA rack portion of the cage shall consist of four continuous, adjustable equipment mounting angles. The mounting angle nominal thickness shall be 11-gauge plated steel. The mounting angles shall be tapped with 10 to 32 threads with EIA universal spacing. The mounting angle shall comply with standard EIA-310-B and shall be supported at the top and bottom by either welded or bolted support angles to form a cage. The mounting angles shall provide holes to mount the side panels.

L. Cage Connection
The cage shall be bolted to the cabinet at four points via the housing cage supports and four points via associated spacer brackets (top and bottom).

M. Cage Location
The cage shall be centered within the cabinet door opening(s).

N. Cage Mounting Supports
Cage mounting supports shall be provided on either side, level with the bottom edge of the door opening, for horizontal support and bolt attachment; side cage supports shall be provided for the bracket cage supports and attachments.

O. Clearance between Rails
Clearance between rails for mounting assemblies shall be 17.75 inches.

P. Housing Ventilation
Housing ventilation shall include intake, exhaust, filtration, fans, and thermostat.

Q. Intake and Filter
The louvered vent depth shall be a maximum of 0.25 inch. A removable and reusable air filter shall be housed behind the left front door vents and right rear door vents. The filter filtration shall cover the vent opening area. A filter shell shall be provided to fit over the filter and to provide mechanical support for the filter. The shell shall be louvered to direct the incoming air downward. The shell sides and top shall be bent over a minimum of 0.25 inch to house the filter. The filter resident in its shell shall be held firmly in place with a bottom trough and spring loaded upper clamp. No incoming air shall bypass the filter. The bottom filter shall be formed into a waterproof sump with drain holes to the outside housing. The filter shall be 16 inches wide by 12 inches high by 0.875 inch thick. The filter shall be an ECO-AIR Product E35S or approved equal.

R. Fans
Each electric fan shall be equipped with ball or roller bearings and shall have a minimum capacity of 100 cubic feet of free air delivery per minute. Two DC-powered fans shall be mounted within the housing and protected with a finger guard. A Fan Test switch shall be provided.

S. Temperature Controlling
The fans shall be thermostatically controlled and shall be manually adjustable to turn on between 32º F and 140º F with a differential of not more than 20º F between automatic turn on and off. The fan circuit shall be protected at 125% of the fan motor ampacity. The manual adjustment shall be graded in a 20º F increment scale. The thermostat shall be an Omega KT01101141900 or approved equal.

T. Cabinet Lights
The cabinet shall be equipped with two LED lights activated by door switches and equipped with fuses.

3. Model 350I ATCC Assemblies

A. Output Assembly (32-Channel)

The Output Assembly shall be a 6U high rack mounted assembly. The Output Assembly shall house 16 Model 2202-LV-MC HDSPs / Flasher Units (FUs) and shall provide 96 output circuits.

The Output Assembly shall accommodate two Model 2218 SIUs to provide interface and control via system SB1/SB2.

The Output Assembly shall house one model 2212-HV Cabinet Monitor Unit (CMUip), the main contactor, stop time switch, flash / auto switch, one circuit breaker, and momentary 24 VDC bypass switch. The main contactor shall be located at the back of the Output Assembly access door. Circuit breakers and toggle switches shall be equipped with a guard.

B. Field Output Termination Assembly (2qty 16-Channel)
Each Field Output Termination Assembly shall be coupled with the 32-channel Output Assembly and shall house eight Model 21XBXHL-48VDC HDFTRs. The HDFTRs and Flash Program Blocks (FPBs) shall be provided to control and select the color (red, yellow, or dark) during ATC (LV) cabinet flash mode. HDSP suppressors shall be provided at the field terminals for the protection of the HDSP. Each HDFTR position shall be labeled with the number of its associated HDSP (1-16). Each FPB position shall be labeled with the number of its associated channel (1-16).

The Field Output Termination Assembly shall be provided with 16qty 6-position Phoenix Contact terminal block model number 18-04-94-6 plugs and 18-61-19-6 sockets or approved equal. Each Load Terminal Block receptacle shall be labeled with the number of its associated channel (1-16). Additional labels shall be provided to clearly indicate which terminals correspond to the red, yellow, and green switch pack outputs. The color of these labels shall match the color of their associated output (red, yellow, or green). Each 16-Channel Field Output Termination Assembly shall be mounted across the EIA rails, and it shall swing down to provide access to the HDSP suppressors.

C. Input Assembly (2qty 24-channel)
The Input Assembly shall be a 3U high rack mounted assembly providing 12 slots of 22/44 pin printed circuit board (PCB) sockets. One Model 2218-MC SIU shall be provided and mated to a DIN 96-pin connector. The SIU shall provide interface and control between the controller and the input devices via system SB1/SB2. The Input Assembly shall house either 2-channel or 4-channel detection modules. The Input Assembly shall house twelve 2-channel detection modules, or six 4-channel detection modules, or a combination of 2- and 4-channel detection modules up to 24 channels. Each Input Assembly shall be equipped with an Opto Input Card. The Opto Input Card shall be equipped with four LED indicators and four toggle switches. Activation of switches 1-4 shall place a call into SIU Opto 1-4 input, respectively.

D. Field Input Termination Assembly (2qty 24-channel)
Each 24-channel Field Input Termination Assembly shall be coupled with each 24-channel Input Assembly and shall have positions for landing 24qty, two-wire inputs and their associated earth ground wires. The Field Input Termination Assembly shall have positions for 12 detection module suppressors. The detection module suppressors shall be supplied with the cabinet if procurement requires. The 24-channel Field Input Termination Assembly shall be mounted across the EIA rails, and it shall swing down to provide access to the back of the assemblies mounted in the opposite side.

E. Service Assembly (32-channel)
The Service Assembly shall be a 3U high rack mounted assembly. It shall house two Model 2202-HV-MC HDSPs / FUs, cabinet suppressor filter, 7-position utility and battery backup system (BBS) landing wire terminal, ground fault circuit interrupter (GFCI) with Type A/C USB connection, one convenience outlet NEMA 5-15 format, one convenience outlet NEMA 6-15 format, eight HDFU output fuses, four HDFU spare fuses, five circuit breakers, and a raw AC+ and an AC- terminal block having four screw terminals. Circuit breakers shall be equipped with guards.

F. Communication and Power Bus
Communication and Power Bus shall include eight DB25 d-submodular socket connectors to interconnect the SB1/SB2 communication ports of the assemblies and controller. It shall include an internal termination circuit at the end of the connections (S8) to prevent radio frequency signal reflection. It shall include one Phoenix Contact plug block or approved equal to bring the DC power to the Bus; such power shall be distributed to the ATC (HV) Cabinet Assemblies through seven Phoenix Contact receptacle blocks or approved equal. The copper traces for the DC voltages shall support at least 10 amps.

The AC Clean Power Bus shall also include eight NEMA 5-15 receptacles to provide AC Clean Power to the ATC (HV) Cabinet Assemblies, the controller, and cabinet power supply. SB1/SB2 and DC/Clean Power Bus shall be mounted across the EIA rails, and it shall swing down to provide access to the back of the assemblies mounted in the opposite side.

G. Drawer Shelf Unit
A telescopic slide-out drawer to store document shall be provided. The drawer shelf unit shall be mounted across the EIA rails and shall have a non-conductive top, locking provision, and pulling handle or lip.

H. ATCC Components
<u>Model 2202-HV-MC High-Density Switch Pack / Flasher Unit</u>
The HDSP-FU shall be compact, pluggable, modular PCB-based, and equipped with a DIN connector. The HDSP-FU shall be compatible with ultra-low power LED signal heads, and it shall have a current monitoring feature for each output of each channel. The HDSP-FU shall use real-time standardized high-speed serial bus #3 (SB3) communications with the cabinet monitor unit to send a complete set of root-mean-square (RMS) voltage and load current measurements. The HDSP-FU shall be 4.5 inches in height and 6.5 inches in diameter and shall be equipped with a handle, reset push button switch, six red, yellow, green (RYG) LED indictors, four flasher LED indicators, one power LED indicator, and two Rx/Tx LED indicators. The HDSP-FU can function as either a switch pack (HDSP) or as a flasher unit (HDFU).

When installed in the Output Assembly, the HDSP shall provide two RYG channels of operation (six outputs). When installed in the Service Assembly, the HDFU shall function as a four-output flasher.

Model 2212-HV-MC Cabinet Monitor Unit

The CMUip shall be compact, pluggable, and modular. The CMUip shall use real-time standardized 614.4-kilobits per second (Kbs) SDLC communications with the ATC to transfer command and response data on Serial Bus #1 (SB1). The CMUip shall be capable of monitoring up to 32 physical switch pack channels (RYG) and shall have four optional virtual channels. The CMUip shall provide a Flasher Alarm feature. The CMUip shall analyze the ATC output commands and field input status to isolate the failure source by channel and color. The CMUip configuration programming shall be provided by an interchangeable Datakey non-volatile memory device. This rugged key shall store all CMUip configuration parameters and shall eliminate programming using jumpers, diodes, or DIP switches. The CMUip shall maintain a non-volatile event log recording the complete intersection status as well as time stamped previous fault events, 48-VDC line events, configuration changes, monitor resets, cabinet temperature, and true RMS voltages and currents for all field inputs. The signal sequence history log stored in non-volatile memory graphically shall display up to 30 seconds of signal status prior to the fault trigger event with 50-milliseconds (ms) resolution to ease diagnosing of intermittent and transient faults.

Model 2218-MC Serial Interface Unit

The Model 2218-MC SIU shall be compact, pluggable, and modular. The SIU shall use real-time standardized 614.4-Kbs SDLC communications with the ATC to transfer command and response data on SB1. The SIU shall be equipped with 54 programmable input/out pins, four optically isolated input pins, one line sync reference input pin, and four address select input pins. The optically isolated inputs shall work with either 12 VAC or 24 VDC. The SIU outputs shall be rated at 150-milliamps (mA) continuous sink current. Each output shall provide a 500-mA typical current limit, shall be rated to 50 volts, and shall utilize a voltage clamp for inductive transient protection. The SIU shall be equipped with a front panel LED indicator that can report the current SIU assembly address assignment of the SIU for cabinet configuration verification.

Model 2220-MC Auxiliary Display Unit

The Auxiliary Display Unit (ADU) shall be installed in a 1U height 19-inch rack space and shall provide a menu-driven user interface to the enhanced features of the CMUip monitor including the built-in Diagnostic Wizard. The ADU shall provide 32 channels of RYG LED indicators that display full intersection status and 32 Blue fault status LED indicators that shall identify faulty channels. The ADU shall provide proper electrical termination to SB3. The ADU shall have a 4-line by 20-character menu-driven liquid crystal display with backlight and heater. The ADU built-in Diagnostic Wizard shall automatically pinpoint faulty signals, offer troubleshooting guidance, and isolate and identify problems. The ADU shall be equipped with Event Logging displaying the CMUip time-stamped non-volatile event log records with the complete intersection status as well as AC Line events, monitor resets, temperature, and true RMS voltages and currents.

Monitor Key Programming Tool (optional)

The Programming Tool provides the capability to read and write data from the CMUip Datakey device. The Monitor Key software shall be compatible with the CMUip-2212-LV-MC

Model 21XBXHL-48VDC High-Density Flash Transfer Relay
The HDFTR shall have a hermetically sealed cover and shall be moisture proof. The HDFTR shall be filled with dry nitrogen to protect contacts from corrosion and to prevent condensation. The HDFTR shall have a shock-/impact-resistant metal can cover with solid and bend-proof pins. The HDFTR contacts shall be rated at 120 VAC at 5 amps. The coil of the HDFTR shall be rated at 48 VDC. The HDFTR shall have an LED indicator to display contact transfer position.

Main Contactor
The main contactor (MC) shall be mercury free and shall be rated at 48 VDC. The coil of the MC shall be rated at 48 VDC. The MC shall be equipped with an input indicator and shall have single pole single throw normally open (SPST- NO) contacts. The MC shall be placed on a removable panel for maintenance access.

Service Assembly Cabinet Suppressor-Filter
The cabinet shall be equipped with a cabinet suppressor–filter. The unit shall incorporate the use of warning and failure indicators and shall have a dry relay contact remote sensing circuit. The unit shall be modular and pluggable with a 6-position Beau 5406 connector. The unit shall be rated at a continuous service current of 15 amps and maximum clamp voltage of 390 VAC. The unit dimensions shall be 3.5 inches high x 3.5 inches wide x 2.8 inches in diameter.

High-Density Output Suppressors
The HDSP suppressor shall be modular and pluggable. The unit shall be epoxy encapsulated and equipped with 9-position 0.2-inch Phoenix Contact connector or approved equal. The unit shall be able to protect 6 circuits. The device operating voltage shall be 120 VAC and clamping voltage shall be 340 VAC. The unit dimensions shall be 2 inches high x 0.7 inch wide x 2 inches in diameter.

Model PS-2216-24 Cabinet Power Supply
The cabinet power supply (CPS) shall be installed in a 1U height 19-inch rack space. The CPS shall be rated at 168 watts, 48 VDC at 1 amp, and 24 VDC at 5 amps. The CPS shall use modern switching technology and provide full output regulation across changes in AC line voltage and output load over the full operating temperature range of -34º C to +74º C without the need for a fan. Power Factor Correction shall be provided. The CPS shall have separate LED indicators that display AC input status, DC output status, and associated fuse integrity. The CPS outputs shall be fused for over-current protection and shall be protected against voltage transient suppressor.

4. ATCC Electrical, Environmental, and Testing Requirements

A. General
The requirements called out in this specification in association with equipment evaluation are a minimum and shall not limit the testing and inspection to ensure compliance.

B. Certification
These test procedures shall be followed by the manufacturers, which shall certify that they have conducted inspection and testing in accordance with this specification.

C. Inspection

A visual and physical inspection shall include mechanical, dimensional, and assembly conformance of all parts of this specification.

D. Environmental and Electrical
All components, where applicable, shall properly operate within the following limits unless otherwise noted:
- Applied Line Voltage: 90 to 135 VAC.
- Frequency: 60 ±3.0) Hz.
- Humidity: 5% to 95%.
- Ambient Temperature: -34.6°F to +165.2°F.
- Shock: Test per Specification MIL-STD-810G Method 516.6.
- Vibration: per Specification MIL-STD-810G Method 514.6.

E. Commencement Operation
All circuits, where applicable unless otherwise noted, shall commence operation at or below 90 VAC as the applied voltage is raised from 50 to 90 VAC at a rate of 2 (±0.5) volts/second.

F. Equipment Compliance
All equipment shall be unaffected by transient voltages normally experienced on commercial power lines. Where applicable, equipment purchased separately from the cabinet (which normally is resident) will be evaluated for compliance.

G. Power Line Surge Protection
The power line surge protection shall enable the equipment being tested to withstand (nondestructive) and operate normally following the discharge of a 25-microfarad (μF) capacitor charged to ±2,000 volts, applied directly across the incoming AC line at a rate of once every 10 seconds for a maximum of 50 occurrences per test. The unit under test will be operated at 68°F ± 41°F and at 120 (±12) VAC.

H. Operating
The equipment shall withstand (nondestructive) and operate normally when one discharge pulse of ±300 volts is synchronously added to its incoming AC power line and moved uniformly over the full wave across 360 degrees or stay at any point of line cycle once every second. Peak noise power shall be 5 kilowatts with a pulse rise time of 500 nanoseconds. The unit under test will be operated at 68°F ±41°F and at 120 (±12) VAC.

I. UL Requirements
Equipment shall comply only with the requirements of UL Bulletin of Research No. 23, “Rain Tests of Electrical Equipment.”

J. Operational Conditions
All equipment shall continue normal operation when subjected to the following:

Low Temperature Test
With the item functioning at a line voltage over Electrical Range the Device in its intended operation, the ambient temperature shall be lowered from 68°F to 34.6°F at a rate of not more than 64.4°F per hour. The item shall be cycled at -34.6°F for a minimum of 5 hours and then returned to 68°F at the same rate.

High Temperature Test
With the item functioning at a line voltage over Electrical Range the Device in its intended operation, the ambient temperature shall be raised from 68°F to 165.2°F at a rate of not more than 64.4°F per hour. The item shall be cycled at 165.2°F for 5 hours and then returned to 68°F at the same rate. The test shall be repeated with the line voltage at 135 VAC.

Normal Operation
All equipment shall resume normal operation following a period of at least 5 hours at -34.6°F and less than 10% humidity and at least 5 hours at 165.2°F and 22% humidity, when 90 VAC is applied to the incoming AC.

Humidity and Ambient Temperature
The relative humidity and ambient temperature values in the following table shall not be exceeded.

Ambient Temperature/ Dry Bulb (in ºF)	Relative Humidity (in percent)	Ambient Temperature/ Wet Bulb (in ° F)
-34.6 to 33.98	10	1.04 to 108.86
33.98 to 114.8	95	108.86
119.84	70	108.86
129.92	50	108.86
140	38	108.86
149.72	28	108.86
160.16	21	108.86
165.2	18	108.86

K. Quality Control/Final Acceptance Testing
A complete quality control/final test report shall be supplied with every ATCC. The test report shall indicate the name of the tester and shall be signed by a responsible manager.

L. Cabinet Print
Wiring diagram sheets for the cabinet shall be furnished in a weatherproof plastic pouch placed in the cabinet. Cabinet wiring diagrams shall be non-fading.

5. Warranty

A. ATC Cabinet and Assemblies
The ATCC is covered by a standard two-year warranty from the date of shipment. The manufacturer warrants its products to be free of defects in workmanship and/or material. Repair or replacement of any units found to be defective within the first 24 months from the date of delivery shall be according to the following:

- The first 12 months shall be covered with full replacement of defective products.

Before returning any products, the customer shall call the manufacturer representative to start the Return Material Authorization process. The customer must prepay all freight, insurance, and other transportation costs to send the product back to the manufacturer for warranty coverage verification. Repair, replacement, and shipment back to the customer shall be covered as part of the warranty coverage.

B. ATCC Components
All ATCC components are covered under the manufacturer's standard warranty.

730-30—Communications Equipment.

This section specifies the communications equipment needed for communication to NDOT's network and central software. Depending on the available infrastructure, each location may require a specific configuration as specified in the Special Provisions, shown on the Plans, or directed by the Engineer.

1. Ethernet Switch
   A. Copper – Etherwan 3575 or approved equal (only applicable for traffic signals with copper interconnect)
      (1) Hardened managed 6-port 10/100base-tx + 2-port gigabit combo small form-factor pluggable (SFP) switch with 2-port copper pair extender.
      (2) Fully managed switch capabilities with Layer 2 features.
      (3) 12- to 48-VDC input voltage security – MAC address filtering; enable/disable port; IEEE802.1X LAN access control.
      (4) Ethernet Ports
      • 10/100BASE-TX: 6 ports.
      • 10/100/1000BASE-T and 100/1000BASE-X SFP combo: 2 ports.
      (5) Ethernet Extender Ports
      • RJ-11 and Terminal Block port: 2 ports.
      • Cable: Telephone wire No. 24 AWG (minimum 0.02-inch diameter, 1-pair wire).
   B. Fiber Switch – Cisco Industrial Ethernet 3300 series switch IE 3300 8U2X
      (1) 2 10-Gig SFP ports and 8 Copper Gigabit Ethernet ports on the base with PoE/PoE+, UPoE (60W 802.3bt type 3).
      (2) Network Advantage (-A) – Layer 3 (IPv4 and IPv6) feature set that includes dynamic routing, VRF, Cisco TrustSec, MACsec-256 bit.
      (3) Cisco DNA Advantage – At least 3-year subscription license for Cisco Catalyst Center Software-Defined Access (SD-Access) Extended Nodes.
      (4) SFPs – 1 Gbps and 10 Gbps. Plans shall specify quantities and rating.
      (5) Power supply – PWR-IE480W-PCAC-L.

2. VPN Firewall – Cisco Meraki Z4C or approved equal. This device shall only be used where there is no fiber optic communication and basic network connectivity for traffic controller is required.
   A. Built-in Wi-Fi 6.
   B. Built-in LTE cellular capabilities.
   C. 6-gigabit Ethernet ports.
   D. Built-in PoE+ capabilities.

3. VPN Firewall – Cisco Meraki Z3 or approved equal. This device shall only be used where there is no fiber optic communication and traffic cameras are required.
   A. 4-gigabit Ethernet ports.
   B. 1 PoE-enabled port.
   C. 1 USB (cellular failover).
   D. Auto VPN for intelligent site-to-site VPN connectivity.
   E. Power supply – 50 watts (54 volts/0.92 amp).

4. Cellular Modem – Cisco Meraki MG21 or approved equal. This device shall only be used where there is no fiber optic communication and traffic cameras are required.

A. 2-gigabit Ethernet ports.
B. Built-in category (CAT) 6 LTE connectivity.
C. Power supply – 12 volts/1 amp, 48-57 volts DC/0.35 amps.
D. Patch Antenna – Meraki MG21E.

5. Cellular Modem – Cisco Meraki MG41 or approved equal. This device shall only be used where there is no fiber optic communication and traffic cameras are required.
   A. 2-gigabit Ethernet ports.
   B. Built-in CAT 18 integrated cellular.
   C. Power supply – 12 volts/1 amp, 48-57 volts DC/0.35 amps.
   D. Patch Antenna – Meraki MG41E.

All Meraki dashboard licenses should be purchased for a 5-year term.

Measurement. The Communication Equipment shall be measured in units of each and paid for at the contract price per each. The price bid shall include furnishing, installing, and configuring the communication equipment, providing warranties, mounting hardware, serial port cables or connectors, power cable, user manuals, testing, and any necessary items for full operation in accordance with applicable standards, specifications, and requirements. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

FLASHING SCHOOL SIGNALS

730.31—Flashing School Signals.

Flashing school signals shall conform to the following:

1. The signal shall produce two alternate flashing lights within the marginal limits of a school speed limit sign. Details of the sign construction shall be as specified on the Plans. Sign colors shall conform to the MUTCD and be constructed of materials complying with these specifications.
2. The two lenses shall be LED, yellow in color, and a minimum of 12 inches in diameter.
3. The flasher unit shall be the two-circuit type to provide alternating equal on-off operation. The flashing mechanism shall produce between 50 and 60 flashes per minute through two 120-volt, 60-cycle AC, 15-ampere circuits. The flasher shall be of solid-state construction and to NEMA standards.
4. The unit shall be wired for external circuits.
5. The signal shall be actuated by a momentary key switch (key number Chicago Lock Co. No. 2382). The timing device shall be digital (National Controls Corp. Model TMM-0999M-461, or equal) and located in a remote mounted control cabinet.
6. Where an illuminated speed limit indication is specified on the Plans, the numeral message shall be illuminated in Portland Orange in a rectangular lens and illuminated only during the period when the signal produces two alternately flashing amber lights.

DETECTORS

730-32—Detectors.

Detectors shall be used for actuating signal phases of traffic-actuated controllers and shall be of the type specified in the Plans.

1. Lightning protection shall be EDCO SRA6LCA916 or an approved equivalent.
   A. The lightning protection unit must withstand repeated 400-ampere surges on a 9 x 20 microsecond waveform.

B. The unit must be 2-stage device capable of clamping a minimum of (100-) 300-ampere surges to 25 volts within 40 nanoseconds. The surge shall be applied across the 2 detector leads.

2. Inductive Loop Detectors
   A. Loop amplifiers shall be rack-mounted 2-channel units that meet the requirements of Section 6 of NEMA Standards Publication No. TS 2-2003 or later revision.
   B. The loop detector amplifier shall be Type CC as listed in Table 6-1 of NEMA Standards Publication No. TS 2-2003 or later revision. There shall be 4 – 2-channel detection cards for each of the 8 vehicle phases.
   C. The detector rack shall be wired and labeled as defined in Table 5-9, Configuration 2 of NEMA Standards Publication No. TS 2-2003 or later revision.
   D. The loop detector amplifier shall be fully automatic, requiring no adjustments to effect operational ability other than setting of the operating frequency and sensitivity. The amplifier shall:
      (1) Sense any legal motor vehicle traveling at speeds up to 65 mph.
      (2) Have both a "Pulse" and "Presence" Output:
         a. Pulse output shall generate an output of 125 ±25 milliseconds for each vehicle entry.
         b. Presence output shall provide a continuous output for up to 60 minutes as long as a vehicle is within the detection zone.
      (3) Provide at least four user-selectable sensitivity ranges.
      (4) Be supplied with at least three frequency ranges for crosstalk minimization.
      (5) Have a front-face-mounted indicator to indicate active output of the internal relay. This indicator shall indicate the presence of:
         a. Normal output.
         b. Delayed output.
         c. Extended output.
      (6) Have a front-panel-mounted "Reset" switch that when pressed shall cause the unit to completely re-tune itself.
      (7) Have delayed or extended timing features with the following ranges:
         a. Delayed output of 0 to 30 seconds in 1-second increments.
         b. Extended output of 0 to 10 seconds in 1/4-second increments.
      (8) Have internal diagnostics to determine the operational ability of the loop. These diagnostics shall determine if a loop is opened or shorted and shall provide a visible indication of such condition. Additionally, if such a condition occurs, the amplifier unit shall default to a "constant" output.
      (9) Provide output by a mechanical relay, which shall be "off" to provide an output.
      (10) Have all delay functions wired to the associated plan green phase to inhibit that function during controller green phase.
      (11) Be able to operate with loop lead-in lengths of at least 2,000 ft.

730.33—Video Detection.

This section specifies the minimum requirements for Video Detection System (VDS) equipment furnished and installed. The work shall consist of providing all labor, materials, equipment, and incidentals necessary to furnish, install, and test video detection equipment. This work consists of furnishing and installing video detection equipment complete and ready for service.

1. The VDS shall consist of power supply, hard-wired video cameras, all necessary video and power cabling with end connectors, mounting brackets, lightning protection as recommended by the manufacturer, and video detection processors/extension modules capable of processing the number of camera and phase combination video sources shown on the Plans or in the purchase order. A

sufficient number of cameras shall be provided to process vehicle presence, passage, and system detection zones as shown on the plans or listed on the purchase order.

2. Warranty
   A. A 36-month warranty or the manufacturer's standard warranty, whichever is greater, shall be provided for all VDS components.
   B. The warranty period begins on the date of installation to the project. Each system shall be marked with a permanent label or stamp indicating the date of installation.
   C. The warranty shall include technical support available from the supplier, at no cost, via telephone within 4 hours of the time a call is made 7 days a week, from factory-certified personnel or factory-certified installers.
   D. The warranty shall include updates to video detection processor and application software from the manufacturer without charge.
3. General Capabilities and Performance Requirements
   A. Camera systems provided shall be able to transmit National Television System Committee (NTSC) video signals up to 1,000 ft.
   B. Furnished VDS configuration shall utilize video processors with one or more video inputs and one video output, responding to specific site applications, camera locations and detection zones shown on the project Plans.
   C. Video processors provided shall plug directly into TS-1 and TS-2 detector racks without adapters.
   D. Extension modules provided shall allow detection zones from one camera to be routed to other card slots.
   E. Remote programming and monitoring capability from a distant TMC are mandatory.
   F. VDS shall be Ethernet compatible with an RJ45 port.
4. Interface
   A. Provide video inputs that accept RS170 (NTSC) signals from an external video source. Provide a Bayonet Neill-Concelman (BNC type interface connector located on the front of the video processing unit.
   B. Provide an LED indicator to indicate the presence of the video signal. The LED indicator shall illuminate upon valid video synchronization and turn off when the presence of a valid video signal is removed.
   C. Provide one video output per processor module. The video output shall be RS170 compliant and shall pass through the input video signal. The video output shall have the capability to show text and graphical overlays to aid in system setup. The overlays shall display real-time actuation of detection zones upon vehicle detection or presence. Control of the overlays and video switching shall also be provided through the serial communications port. The video output interface connector shall be BNC or RCA type. If an RCA connector is used, an RCA to BNC adapter shall be provided.
   D. Provide a serial communications port on the front panel. The serial port shall be compliant with RS-232 or RS-422 electrical interfaces and shall use a DB9 or RJ45 type connector. The serial communications interface shall allow the user to remotely configure the system and/or to extract calculated vehicle/roadway information.
   E. Furnish interface software. The interface protocol shall support multi-drop or point-to-multipoint communications. Each VDS shall have the capability to be individually IP addressable either built in or with third-party video server units.
   F. Provide open collector contact closure outputs meeting NEMA TS 2 requirements. The open collector output will be used for vehicle detection indicators; discrete outputs will be used for alarm conditions.

G. Provide LED status indicators on the front panel. The LED indicators shall illuminate when a contact closure output occurs. Provide one output LED for each contact closure output.
H. Provide a mouse compatible port (PS-2 or USB) on the front panel of the video processing unit. The mouse port shall be used as part of the system setup and configuration. Provide a compatible mouse with each video detection system.

5. Functionality
   A. Detection zones shall be programmed via an on-board menu displayed on a video monitor and a pointing device connected to the video detection processor. The menu shall facilitate placement of detection zones and setting of zone parameters or to view system parameters.
   B. The video detection processor shall detect vehicles in real time as they travel across each detection zone.
   C. The video detection processor shall have an RS-232 (DB9 or RJ45) port for communications with an external computer.
      (1) The video detection processor port shall be multi-drop capable.
      (2) It shall be possible to upload and save all configuration data including loop placement and save the file on a computer.
      (3) It shall be possible to download a configuration file from a computer to the detection device.
      (4) The video detection processor shall accept new detection patterns from an external computer through the RS-232 port when the external computer uses the correct communications protocol for downloading detection patterns.
   D. Provide a Windows™-based software designed for local and remote connection with video capture, real-time detection indication, and detection zone modification capability.
   E. The video detection processor shall send its detection patterns to an external computer through the RS-232 port.
   F. The video detection processor shall default to a safe condition, such as minimum recall, fixed recall, or constant call on each active detection channel, in the event of unacceptable interference with the video signal, low-visibility conditions, or power failure.
   G. A user-selected output shall be active during the low-visibility condition that can be used to modify the controller operation if connected to the appropriate controller input modifier(s). The system shall automatically revert to normal detection mode when the low-visibility condition no longer exists.
6. Vehicle Detection
   A. A minimum of 24 detection zones per camera input shall be possible, and each detection zone shall be capable of being sized to suit the site and the desired vehicle detection area.
   B A single detection zone shall be able to replace multiple inductive loops and the detection zones shall be OR'ed as the default or may be AND'ed together to indicate vehicle presence on a single phase of traffic movement.
   C. Placement of detection zones shall be done by using a pointing device, and a graphical interface built into the video detection processor and displayed on a video monitor, to draw the detection zones on the video image from each video camera. Detection zones created in this manner shall be compatible with the PC-based software provided with the system.
   D. The video detection processor's memory shall be non-volatile to prevent data loss during power outages.
   E. When a vehicle is detected crossing a detection zone, the corners or entire zone of the detection zone shall flash/change color on the video overlay display to confirm the detection of the vehicle.
   F. It shall be possible to record the operation of the unit in real time with the detection zones operating.

G. Detection shall be at least 98% accurate in good weather conditions, with slight degradation acceptable under adverse weather conditions (e.g., rain, snow, or fog) that reduce visibility.
H. The video detection processor shall maintain normal operation of existing detection zones when one zone is being added or modified.
I. The video detection processor shall output a constant call on any detector channel corresponding to a zone being modified and shall resume normal operation upon completion.
J. Detection zones shall be directional to reduce false detections from objects traveling in directions other than the desired direction of travel in the detection area.
K. The video detection processor shall process the video input from each camera using a microprocessor at 30 frames per second at 1 volt peak to peak, 75 ohms, or EIA 170 NTSC video standard.
L. The video detection processor shall output minimum recall, fixed recall, or constant call for each enabled detector output channel if a loss of video signal occurs. The recall behavior shall be user selectable for each output. The video detection processor shall output a constant call during the background "learning" period.
M. Detection zone outputs shall be configurable to allow the selection of presence, pulse, extend, and delay outputs. Timing parameters of pulse extend and delay outputs shall be user definable between 0.1 to 25.0 seconds in increments of 0.1 second.
N. Up to six detection zones per camera view shall have the capability to count the number of vehicles detected and to measure classification and speed. The data values shall be internally stored within the processor module for later retrieval through the RS-232 port. The data collection interval shall be user definable in periods of 5, 15, 30, or 60 minutes or by intersection cycle. Real-time data shall be retrieved from the PC-based software provided with the system.

7. Camera
A. Cameras shall be completely compatible with the video detection processor and shall be certified by the manufacturer to ensure proper system operation.
B. The detection system shall produce accurate detector outputs under all roadway lighting conditions, regardless of time of day. The minimum range of scene luminance over which the camera shall produce a usable video image shall be the minimum range from nighttime to daytime, but not less than the range 0.009 to 930 foot-candles (0.1 lux to 10,000 lux).
C. The camera shall use a color charge-coupled device (CCD) sensing element with resolution of not less than 470 lines horizontal and 400 lines vertical.
D. The camera shall include mechanisms to compensate for changing of lighting by using an electronic shutter and/or auto-iris lens.
E. The camera shall include a motorized variable focal length lens with factory preset focus that requires no field adjustment. Zooming of the camera lens to suit the site geometry shall be accomplished by means of a portable interface device designed for that purpose. The horizontal field of view shall be adjustable from 8.1 to 44.3 degrees. Camera configuration shall be customized for each approach based on field site conditions and the project Plans. One interface device shall be supplied at no additional cost.
F. The camera electronics shall include automatic gain control (AGC) to produce a satisfactory image at night.
G. The camera shall be housed in a weather-tight, sealed enclosure. The housing shall be field rotatable to allow proper alignment between the camera and the traveled road surface.
H. The camera enclosure shall be equipped with a sunshield. The sunshield shall include a provision for water diversion to prevent water from flowing in the camera's field of view.
I. The camera enclosure shall include a thermostatically controlled heater to ensure proper operation of the lens shutter at low temperatures and prevent moisture condensation on the

optical faceplate of the enclosure. The heater shall directly heat the glass lens and require less than 5 watts over the temperature range.

J. Power consumption of the camera shall be 15 watts or less under all conditions.

K. The camera enclosure shall be equipped with separate, weather-tight connections for power and setup video cables at the rear of the enclosure. These connections shall allow diagnostic testing and viewing of video at the camera while the camera is installed on a mast arm or pole using a lens adjustment module furnished under this bid item.

L. The video signal output by the camera shall be in accordance with NTSC standards.

M. All necessary mounting brackets shall be mounted to pole shafts, mast arms, or other structures to mount cameras as indicated on the project Plans. Mounting brackets shall result in a fixed-position mounting. Mounting hardware shall be of the Astro Bracket type with a minimum of 6-ft height adjustment. Mounting brackets shall be included at no additional cost.

8. Video Cable
   A. The cable provided shall be as recommended by the manufacturer for optimal video detection performance. Coaxial cable can be used between the camera and the video detection processor in the traffic signal controller cabinet and shall be Belden 8281 or equivalent. The signal attenuation shall not exceed 0.78 dB per 100 ft at 10 MHz.
   B. Nominal outside diameter shall be approximately 0.305 inch.
   C. Coaxial cable shall be suitable for installation in conduit and in an exposed sunlight environment; 75-ohm BNC plug connectors shall be used at both the camera and cabinet ends. The coaxial cable, BNC connector, and crimping tool recommended by the manufacturer of the VDS shall be used and installed per the manufacturer's recommended instructions to ensure proper connection.
9. Power Cable
   A. Power cable for 120-VAC cameras shall be rated for 194 F, 300-volt, No. 16 AWG, stranded, three-conductor cable with a nominal outside diameter of approximately 0.330 inch. Conductor insulation color code shall be black, white, and green. Outside jacket shall be black.
   B. Power cable for 28-volt cameras shall be the cable recommended by the manufacturer.
   C. Camera power cable shall be suitable for installation in conduit and in an exposed sunlight environment, and be UL listed.
   D. The power and video cable may be installed under the same outer jacket.
10. Surge Protection
   A. Surge protection devices shall be provided for all new or added video detection devices as recommended by the manufacturer.
   B. Coaxial cable shall be protected with an inline surge suppressor as recommended by the manufacturer or with a panel-mounted surge suppressor as recommended by the manufacturer or approved equal, installed and grounded per the video detection manufacturer’s recommendations.
11. Physical and Environmental Specifications
   A. VDS Processor—Provide a VDS processor that operates reliably in a typical roadside traffic cabinet environment. Provide internal cabinet equipment and a video detection system processor that meet the environmental requirements of NEMA TS 2-2003 Section 2.
   B. Video Camera Sensor
      (1) Operating ambient temperature range: -30°F to 140°F. Additionally, include a heater to prevent the formation of ice and condensation in cold weather. Do not allow the heater to interfere with the operation of the video camera sensor electronics, or cause interference with the video signal.
      (2) Vibration: Meet the requirements of TS 2-2003 Section 2.1.9.
      (3) Shock: Meet the requirements of TS 2-2003 Section 2.1.10.

(4) Acoustic Noise: Provide a video camera sensor and enclosure that can withstand 150 dB for 30 minutes continuously, with no reduction in function or accuracy.

12. Training
    A. Furnish two 8-hour training sessions.
    B. Prior to training, submit resume and references of instructor(s). The instructor shall be factory trained on the equipment and have a minimum of 3 years of instructor experience on the VDS. Also submit an outline of the training course in a Training Plan. Submit the Training Plan within 90 calendar days of Contract Notice-to-Proceed. Obtain approval of the Training Plan from the Engineer. Explain in detail the contents of the course and the time schedule of when the training will be given.
    C. Training shall cover the operation, setup, and maintenance of the VDS as part of the Contract or purchase order.
    D. Furnish all handouts, manuals, and product information.
    E. For the training, use the same models of equipment furnished for the project. Furnish all media and test equipment needed to present the training.
    F. Training shall be conducted in the Nashville area. Training instructor(s) shall be manufacturer-certified, experienced in the skill of training others, and have conducted a minimum of three, 2-day trainings on VDSs.
13. Installation Requirements. All equipment shall be installed according to the manufacturer recommendations, the Plans, and as follows:
    A. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer's recommendations and standard practices.
    B. The Contractor shall furnish all tools, equipment, materials, supplies, cabling, and manufactured hardware, and shall perform all operations and equipment integration necessary to provide complete, fully operational communications equipment as specified herein, within the Plan set, and/or in the Contract Documents. It is the responsibility of the Contractor to ensure that its equipment performs its required function when installed.
    C. The Contractor shall provide the Engineer with a written inventory of items received and the condition in which they were received. Once received, the equipment becomes the Contractor's responsibility. The Contractor shall provide all labor and equipment necessary to move inventory out of the designated storage facility and to transport it to the installation location. All equipment shall be installed according to the manufacturer recommendations or as directed by the Engineer.
14. Testing Requirements. Testing shall include, but not be limited to, the following general requirements:
    A. The Contractor shall conduct a project testing program for all video detection equipment. The project testing program shall include but is not limited to the additional specific requirements in this subsection.
    B. All test results shall confirm physical and performance compliance with this specification.
    C. A pre-installation test shall consist of an inspection of all supplied equipment for damage and completeness of parts and manuals.
    D. An SAT shall consist of a complete check of the system after installation.
    E. A conditional acceptance test shall include programming of all functions and integration to the traffic controller inputs.
    F. One-hour videos shall be made of each approach and compared to actual detection calls.
    G. Thirty-minute videos shall be made starting 15 minutes prior to sunrise and sunset for each approach and compared to actual detection calls.
    H. All videos shall be date and time stamped.

I. All videos shall be provided to the Engineer with a summary of the results including total calls, missed calls, and false calls.
J. All test results must meet a 98% accuracy requirement.
K. The burn-in period will start after successful completion of the conditional acceptance test.
L. All test result documentation shall be submitted to the Engineer within 14 calendar days of completion of the tests. The Engineer will review test documentation and inform the Contractor of any exceptions noted.
M. Any failure of the equipment including but not limited to lost calls, loss of program data, or excessive false calls shall cause the burn-in period to start over.

15. Measurement.
A. The VDS shall be measured in units of each and paid for at the contract price per each. The price bid shall include furnishing, installing, warranties, full operation, and configuring the VDS including the mounting hardware, cables, serial port cables or connectors, power cable, user manuals, testing, warranties, and any and all other equipment required to complete installation of the unit in accordance with applicable standards, specifications, and requirements. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

730.34—Radar Detection System.

This section specifies the minimum requirements for RDS equipment furnished and installed. The work shall consist of providing all labor, materials, equipment, and incidentals necessary to furnish, install, and test the RDS. This work consists of furnishing and installing radar detection equipment complete and ready for service.

1. System Components
A. Each sensor shall be mounted to a pole or mast arm using a stainless-steel multi-angle bracket that includes etched markings to facilitate accurate sensor horizontal and elevation angles.
B. Central control unit (CCU) for Sensor connection to the traffic signal controller can be achieved by Ethernet communications.
C. Sensor setup and configuration to be performed via a web browser using the web-server functions stored within the in-cabinet CCU and/or off site in the Traffic Management Center.

2. Sensor Unit

The sensor shall operate in the 24GHz range as permitted by local rules and regulations. The system shall have the required FCC Part 15, NEMA certifications for use in a traffic cabinet environment. The main components of the radar sensor shall include:

A. Shall allow for forward-fire operation for detecting of both approaching and receding traffic simultaneously. Up to 12 lanes should be possible.
B. Shall allow for both stop bar and advanced detection simultaneously with an advanced detection range up to 1000ft line of sight. All detection shall be lane by lane and/or vehicle classification basis.
C. Shall be able to detect passenger vehicles up to 656ft (200m) from sensor location.
D. Shall be able to classify up to 7 classes: pedestrian, Bicycle, Motorbike, Passenger Car, Transporter, Truck/bus, Long Truck.
E. Shall be capable to detect stationary objects.
F. Shall include optional video camera for monitoring and troubleshooting of the device.

3. System Detection Zones and Outputs

The sensor system should exhibit the following user operational characteristics:

A. The sensor should be able to support a minimum of 32 detection zones.
B. The sensor shall be able to support up to 64 output channels per sensor.
C. The sensor shall have a configurable Event Trigger mechanism for each zone to:
   (1) Presence detection
   (2) Speed detection
   (3) Vehicle class
   (4) Queue length estimation
   (5) Custom trigger – combination of above events.
   (6) Bicycle timing and detection
D. The sensor shall be able to map detection zones to output channels in any type of configuration (one to one or one to many).
E. The sensor shall be able to support the configuration of lanes lines to follow the curvature of the actual road to optimize lane by lane detection.
F. The sensor shall be able to define channel output extend and delay functionality.
G. The sensor shall be able to minimize or mitigate adjacent lane or cross traffic detection through the placement of polygons or areas of no interest to be excluded from detection movement.
H. The sensor shall have fail-safe capabilities that can detect RF interference, pitch and roll misalignment, rain or snow, and other sensor blind conditions that would otherwise impact the sensor's performance. Upon detection of one or more of the preceding conditions, the sensor shall provide configurable outputs to the controller to signal that the controller should fall back to fixed-timed programming, on a sensor-by-sensor basis.

4. Central Control Unit (CCU)
The CCU sensor shall be supplied by the RDS manufacturer and installed in the traffic signal cabinet. The CCU shall include the following:
A. The CCU shall be supplied in one of the three form factors. Users may choose one form factor for use within their controller cabinet system:
   (1) Standard One (1) Rack Unit (1U) 19" rack format. There shall be brackets to allow the CCU to be mounted under shelves where a 19" frame is not available.
   (2) Shelf-Mount format; TS1 version. The CCU shall be able to stand up on available shelf-space within the cabinet. All connections shall be made from the front of the CCU, including connections to separate RDPs located within the cabinet.
   (3) Shelf-Mount format; TS2 version. The CCU shall be able to stand up on available shelf-space within the cabinet. All connections shall be made from the front of the CCU, and no external RDPs will be required.
B. An Ethernet communications port shall be provided on the front panel. The Ethernet port shall be compliant with IEEE 802.3 and shall use a RJ-45 type connector mounted on the front panel of the CCU. The Ethernet communications interface shall allow the user to remotely configure the system and/or to extract calculated vehicle/roadway information. The interface protocol shall be documented or interface software shall be provided. The RDS shall have the capability to be addressable. The RDP shall support data rates of up to100Mbps.
C. The CCU shall:
   (1) provide an SDLC connection to the Traffic Controller. The connector shall be a 'D-15' type, in compliance with NEMA TS-2 specifications.

5. Installation

A. The cable to be used between the camera and the CCU in the traffic cabinet shall be provided by the manufacturer. This cable shall be suitable for installation in conduit or overhead with appropriate span wire. The manufacturer's instructions must be followed to ensure proper connection.
B. The cabling between the traffic cabinet interface (CCU) and the sensor head shall be a continuous run and shall not include the use of power injectors, signal boosters, or repeaters between the two devices.

6. Warranty
   A. The supplier shall provide a limited three-year warranty on the RDS.
   B. During the warranty period, technical support shall be available from the supplier via telephone, and this support shall be available from factory-certified personnel or factory-certified installers.
   C. During the warranty period, updates to the RDS firmware shall be available from the supplier without charge.

7. Installation
   A. The cable to be used between the camera and the CCU in the traffic cabinet shall be Cat5e or Cat6, shielded, direct burial. This cable shall be suitable for installation in conduit or overhead with appropriate span wire. Shielded RJ45 connectors shall be used where applicable. The Cat5e or Cat6 cable, RJ45 connector, and stripping and crimping tool shall be approved by the supplier of the VDS, and the manufacturer's instructions must be followed to ensure proper connection.
   B. The cabling between the traffic cabinet interface (CCU) and the sensor head shall allow distances of up to 1,000 ft. The cabling between the traffic cabinet interface (CCU) and the sensor head shall be a continuous run and shall not include the use of power injectors, signal boosters, or repeaters between the two devices.
   C. The radar sensor assembly shall be installed by factory-certified installers as recommended by the supplier and documented in installation materials provided by the supplier. Proof of factory certification shall be provided.

8. Warranty
   A. The supplier shall provide a limited three-year warranty on the RDS.
   B. During the warranty period, technical support shall be available from the supplier via telephone within 4 hours of the time a call is made by a user, and this support shall be available from factory-certified personnel or factory-certified installers.
   C. During the warranty period, updates to RDP software shall be available from the supplier without charge.

9. Maintenance and Support
   A. The supplier shall maintain an ongoing program of technical support for the RDS. This technical support shall be available via telephone or via personnel sent to the installation site upon placement of an acceptable order at the supplier’s then-current pricing and terms of sale for on-site technical support services.
   B. Installation or training support shall be provided by a factory-authorized representative and shall be a minimum of IMSA-Level II Traffic Signal Technician certified.
   C. All product documentation shall be written in the English language.

10. Measurement
    A. The RDS shall be measured in units of each system and paid for at the contract price per each. The price bid shall include furnishing, installing warranties, full operation, and configuring the RDS including the mounting hardware, radar units, CCUs, power cable, user manuals, testing, warranties, and any and all other equipment required to complete installation of the unit in accordance with applicable standards, specifications, and requirements. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

TRAFFIC SIGNAL SUPPORTS

730.35—Cantilever Signal Supports.
This specification applies to the manufacture of steel poles and mast arms for the support of traffic signals. The height of poles, shaft dimensions, and wall thickness shall meet the design requirements and mounting height of traffic signals as set forth in these specifications and in the Plans. Bracket arm lengths are indicated in the Plans. All signal supports shall meet NDOT's guidelines and shall be in conformance with applicable streetscape guidelines concerning the type of poles to be used. The Contractor shall submit shop drawings for all signal supports, stamped and sealed by an engineer registered in the State of Tennessee, to NDOT for review and approval. Designs shall be in compliance with current American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals. These standards apply to strain pole supports as well.

The poles shall consist of a straight or uniformly tapered shaft, cylindrical, or approved geometric shape, in cross section, having a base welded to the lower end and complete with anchor bolts. All castings shall be clean and smooth with all details well defined and true to pattern. Steel castings shall conform to ASTM A 27, Grade 65-35. Gray iron castings shall conform to ASTM A 126, Class A. All mast arms shall be compatible with the poles in material, strength, shape, and size.

Anchor Base. An anchor base of one-piece cast steel or steel plate of adequate strength, shape, and size shall be secured to the lower end of the shaft. The base shall telescope the shaft and be welded at the top and bottom faces with continuous fillet welds so that the welded connection shall develop the full strength of the adjacent shaft section to resist bending action. Each base shall be provided with a minimum of four holes to receive the anchor bolts. Cast steel bases shall be provided with removable cast iron covers for anchor bolts and tapped holes for attaching covers with hex head cap screws.

A welded frame handhole, 5 x 10 inches at a minimum and located 1.5 ft above the base, shall be provided. A 0.5-inch, 13 UNC grounding nut shall be welded to the inside of the pole at a point readily accessible for wiring.

Shaft. The shaft shall be fabricated from the best, hot-rolled basic open hearth steel, and shall have only one longitudinal electrically welded joint and may have electrically welded intermediate transverse full penetration circumferential joints, at intervals of not less than 10 ft. The shaft shall be longitudinally cold-rolled to flatten the weld and increase the physical characteristics so that the metal will have a minimum yield strength of 48,000 psi. Where transverse full penetration circumferential welds are used, the fabricator of the shaft shall furnish to the Engineer certification that (1) all such welds have been radiographed and ultrasonically tested by an independent testing laboratory using a qualified Nondestructive Testing (NDT) technician and (2) the NDT equipment has been calibrated annually.

The shaft shall be fitted with a removable pole cap, a J-hook wire support welded inside near the top, and a flange plate assembly to match that welded to the butt end of the mast arm.
Mast Arms. Mast arms shall be fabricated and certified in the same manner as the upright shafts and shall have the same physical characteristics.

The mast arms shall meet the design requirements necessary to support rigidly mounted traffic signals as designated in the Plans. All arms shall include a removable cap at the tip, grommeted wire outlets, and signal hanger assemblies of the type and number shown on the Plans, and a flange plate welded to the butt end to provide a rigid connection to the mast. The assembly shall be constructed so that all wiring can be concealed internally. A 5-ft rise for the mast arm from the signal support is required per NDOT guidelines. The Contractor shall submit shop drawings for all signal supports and mast arms, stamped and sealed by an engineer registered in the State of Tennessee, to NDOT for review and approval.

Mast arms shall be connected to the upright pole at a height necessary to provide a minimum clearance of 15 ft, 0 inch under the traffic signal heads or backplates and a maximum clearance of 25 ft, 7.2 inches to the top of the traffic signal heads. Separate signal heads shall be installed to provide these same clearances.

Finish. Steel poles, mast arms, and hardware shall be galvanized in accordance with ASTM A 123.

All steel and cast iron components, hardware, and threaded fasteners, except anchor bolts, shall be galvanized after fabrication in accordance with ASTM A 123, A 153, or A 385, as applicable.

730.36—Steel Strain Poles.
Steel strain poles shall consist of a uniformly tapered or equivalent upright shaft fitted with a removable pole top, J-hook wire support, and 45-degree wire inlet near the top; a span wire clamp; a 5- x 8-inch handhole with reinforced frame and cover; bent anchor bolts; and any other accessories to make a complete installation. The pole and all of its component parts shall be designed to support tethered traffic signals of the type and number indicated on the Plans, suspended from a span wire assembly. The poles shall be fabricated and certified in the same manner as the upright shafts as outlined in Section 730.35.

The shaft length shall be determined by the Contractor as required to meet field conditions and vertical clearances of signal heads over the roadway. The signal head clearance shall be a minimum of 15 ft., 0 inch under the traffic signal heads or backplates and a maximum of 25 ft, 7.2 inches to the top of the traffic signal heads. The span wire shall be fastened no closer than 1 ft, 6 inches from the top of the pole.

Unless otherwise specified, all strain pole traffic signal supports shall be provided with a one-piece anchor-type base. The base shall be fabricated from drop forged or cast steel of sufficient cross section to fully develop the ultimate strength of the poles. The base shall be fastened to the pole by means of a welded connection and shall develop full strength of the pole. The base shall be provided with a minimum of four holes of sufficient size to accommodate the proper size anchor bolts that are capable of resisting at yield strength stress and the bending moment of the shaft at its yield strength stress. Removable cast iron covers for the anchor bolts shall be provided.

The shaft shall be fabricated from material providing a minimum yield strength of 48,000 psi after fabrication.

Finish. Steel poles and hardware shall be galvanized in accordance with ASTM A 123.

All steel and cast iron components, hardware, and threaded fasteners, except anchor bolts, shall be galvanized after fabrication in accordance with ASTM A 123, A 153, or A 385, as applicable.

730.37—Pedestal Support Signal Poles.
The pedestal poles shall consist of one upright pole with suitable base and any other accessories or hardware as required to make a complete installation.

All poles shall be made of one continuous piece from the top of the base connection for the entire height of the pole. The cross section shall be either cylindrical or octagonal and may or may not be uniformly tapered from butt to tip.

The cross section at the tip shall have a 4.5-inch outside diameter.

Type "A" Pedestal (Aluminum). Pedestals shall be of a uniform octagonal or cylindrical cross section of the tubular tapered type fabricated of one full-length sheet.

Bases shall be octagonal or square in shape, of the ornamental type fabricated of cast material. A handhole shall be provided in each base.

Caps shall be of the nipple or tenon type mounting fabricated of cast material.

Bases shall be furnished with four steel anchor bolts of sufficient size and length to securely anchor the base to the concrete footing. The shaft shall be welded to the cast metal base. Refer to the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals (current edition).

Type A pedestal shaft shall be fabricated from aluminum tubing 6063-T4 heat treated to T6 temper after fabrication, and meeting ASTM B 221.

Type A anchor base shall be made of sand-cast aluminum alloy 356-T6 meeting ASTM B 26 – SF 70A-T5 specifications.

Type "B" Pedestal (Steel). Pedestal shall be fabricated from a 4.5-inch (outside diameter) seamless steel pipe.

Bases shall be octagonal in shape of the ornamental type fabricated of cast or malleable iron and shall have a minimum height of 12 inches. The top opening of the base shall be threaded to receive the shaft. A handhole shall be provided in each base.

Bases shall be furnished with four steel anchor bolts of sufficient length to securely anchor the base to the concrete footing.

730.38—Camera Poles and Structures.
This section specifies the minimum requirements for equipment poles furnished and installed in accordance with these specifications and the Plans. This work shall consist of furnishing, installing, and testing 50’galvanized steel camera poles with foundations in accordance with these specifications and the TDOT Standard Specifications for Road and Bridge Construction.

1. Materials
   A. Galvanized Steel Poles—A 50-ft closed-circuit television (CCTV) pole and foundation, conduit, connections, clamps, anchor bolts, shoe bases, and all other members shall be designed and fabricated in accordance with the standards and requirements listed below. Design and materials

documentation shall be furnished as part of the approval request submittal. Certifications shall be furnished upon request by the Engineer.

(1) 2009 AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals including all interims and updates shall be met. Design life shall be 50 years for all poles. The "Fatigue," "Galloping Loads", and "Truck-Induced Gust Loads" category do NOT apply to the poles.

(2) Poles shall be designed to withstand the specified forces including those produced by a 90-mph wind with a 1.14 gust effect factor.

(3) The Contractor shall submit manufacturer's shop drawings, layout drawings, and specifications for equipment and appurtenances for the approval of the Engineer 90 calendar days after notice to proceed.

(4) Fabricator: The Fabricator shall be certified under Category I, "Conventional Steel Structures" as set forth by the American Institute of Steel Construction Quality Certification Program. Proof of this certification shall be required.

(5) Welding: All welding shall be in accordance with Sections 1 through 8 of the AWS DI. 1 Structural Welding Code.

(6) Tackers and welders shall be qualified in accordance with the AWS Structural Welding code.

(7) Tube longitudinal seam welds shall be free of cracks and excessive undercut, performed with automatic processes, and be visually inspected. Inspection records shall be furnished to the Engineer.

(8) Longitudinal welds suspected to contain defects shall be magnetic particle inspected. All circumferential butt-welded pole and arm splices shall be ultrasonically and radio graphically inspected. Inspection records shall be furnished to the Engineer.

(9) Camera Pole System shall consist of a pole, anchor bolts, base plate, ground rod array, and communication and power conduits to the nearest pull box, grounding conduit, spare conduit, and foundation as shown in Plans.

(10) Design computations for the camera poles shall be complete and shall include but not be limited to the following:
   a. Consideration for all parts of the structure.
   b. Consideration of all possible loading combinations including wind and ice loads.
   c. Design stresses and allowable stresses for all components that comprise the proposed structure.
   d. The top of the pole deflection shall not exceed the following: 1-inch deflection from center (2-inch deflection diameter) due to 30-mph (non-gust) winds for the 50-ft poles.
   e. All complete shop drawings and design computations shall bear the stamp of a registered Professional Engineer.
   f. Shop drawings shall be approved prior to fabrication. Approval of the shop drawings does not relieve the Contractor of responsibility for the design, fabrication, and erection of the structure.
   g. The Engineer reserves the right to reject a pole design if the calculated deflection exceeds that specified herein.
   h. The foundation design shall be based on actual soil conditions from soil borings conducted by the Contractor. The cost of the soil borings shall be included in the cost of the pole.

(11) The calculations shall include a pole, base plate, and anchor bolt analysis. The pole calculations shall be analyzed at the pole base, at 5-ft pole intervals, and at each slip joint splice.

(12) For each pole as shown in the Plans, the following information shall be given:
   a. The pole's diameter, thickness, section modulus, moment of inertia, and cross sectional area.

b. The centroid, weight, projected area, drag coefficient, velocity pressure, and wind force of each trapezoidal pole segment.
c. The axial force, shear force, primary moment, total moment, axial stress, bending stress, allowable axial stress, allowable bending stress, and combined stress ratio at each elevation.
d. The pole's angular and linear deflection at each elevation.

(13) Handholes:
a. The handhole openings shall be reinforced with 2-inch-wide hot-rolled steel bar. The opening shall be rectangular and 5 inches x 8 inches nominal.
b. The cover shall be 11-gauge steel and shall be secured to a clip-on lock with a tamper-proof screw.
c. The reinforcing rim shall be provided with a 0.5-inch tapped hole and 0.5-inch hex head cap screw for grounding.
d. Handholes on poles with pole-mounted cabinets and transformers shall be placed toward oncoming traffic. For all other poles, handholes shall face away from traffic.

(14) Pole Top Junction Box: All 50-ft camera poles shall have a pole top connector box fastened to the pole top for cable strain relief.

(15) Cable Supports (J-Hooks and Eyelets): Top and bottom J-hooks and eyelets shall be located within the pole directly aligned with each other.

(16) Base Plate:
a. Base plates shall conform to ASTM A572.
b. Plates shall be integrally welded to the tubes with a telescopic welded joint or a full penetration butt weld with backup bar.
c. Plates shall be hot-dip galvanized.

(17) Anchor Bolts:
a. Anchor bolts shall conform to the requirements of AASHTO M314-90 (105 ksi minimum yield). The upper 12 inches of the bolts shall be hot-dip galvanized per ASTM A153.
b. Each anchor bolt shall be supplied with two hex nuts and two hardened washers.
c. The strength of the nuts shall equal or exceed the proof load of the bolts.
d. The top nut shall be torqued so as to produce 60% yield stress of the anchor bolt.
e. The Contractor shall not grout between the bottom of the base plate and the top of the concrete foundation.

2. Installation Requirements. All equipment shall be installed according to the manufacturer's recommendations and the Plans. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer's recommendations and standard practices.

A. Poles. Standards and posts for the camera poles shall be installed as indicated on the Plans and shall be installed in accordance with the National Electric Safety Code and ASSHTO requirements.

B. Foundations:
(1) The Contractor shall submit a design for pole foundations that has been sealed by a registered Professional Engineer.
(2) The foundation design shall adhere to the prescribed loading and wind deflection as specified in the TDOT Standard Specifications.
(3) The foundations shall be constructed in accordance with the TDOT Standard Specifications and shall adhere to the approved shop drawings for the loading specified.
(4) If soil conditions require the use of any shoring, casings, or sonotube for proper installation of the foundations, the cost of the shoring, casings, or sonotube shall be included in the cost of the pole and foundation.

C. The dimensions and reinforcing steel shall be in accordance with the requirements of the Plans and specifications.

D. The cast-in-place concrete pole foundation shall cure a minimum of 28 calendar days before any load is applied to the foundation. The Engineer may approve early installation of the pole based on the results of a 7-day test.
E. Conduit shall be installed in the pole foundation for access and include conduit to the nearest pull box as shown on the Plans.
F. A minimum of one 2-inch spare conduit shall be installed in all pole foundations as shown in the Plan Typical Details. Spare conduits in pole foundations shall be sealed with blank duct plugs.
G. Grounding System
   (1) The Contractor shall supply and install a grounding system with ground rod array at the base of all poles as shown on the Plans.
   (2) The ground rod array system shall be connected to the pole through an appropriate ground clamp.
   (3) A No. 6 AWG copper stranded bonding wire shall be installed between the pole and the field cabinet providing a common ground system for each site.
   (4) All ground bonding wires shall be unspliced.
H. The installation method for the CCTV poles and cameras shall be such that the camera can be rotated as needed around the pole for optimum placement.

3. Measurement. CCTV Pole and Foundation (50-ft pole) shall be measured in units of each and paid for at the contract price of each. The price bid shall include a 50-ft steel strain pole, foundation, conduit inside foundation and to the nearest pull box, wiring between camera and field cabinet, connections to support structures, and satisfactory completion of testing and training requirements, and all work, equipment, and appurtenances as required to effect the full operation including remote and local control of the CCTV site complete in place and ready for use. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.
4. Payment. The contract unit price shall be full compensation for all work specified in this section. Payment shall be made under:

Item No.	Description	Unit
730-38	CCTV Pole 50-Ft Pole Height	Each

The CCTV pole shall be paid per each as follows:

- 25% of the contract unit price upon complete installation of foundations.
- Additional 45% of the contract unit price upon delivery of poles or structure to the site.
- Final 30% of the contract unit price upon complete installation of poles or structure.

730.39—Wooden Pole Signal Supports.
Wooden poles shall be class II 35 ft in length or as described in the Plans and shall meet the requirements of Subsection 917.11 of the Standard Specifications. Poles shall be set to the depth shown in the Plans and fitted with all necessary hardware to make the installation complete.

The signal head clearance shall be a minimum of 16 ft, 6 inches to the bottom of the traffic signal heads or backplates and a maximum of 25 ft, 0 inch to the top of the traffic signal heads. The span wire shall be fastened no closer than 2 ft, 0 inch from the top of the pole.

Guying Components—Guy clamps shall be steel, three-bolt type, 6 inches in length, and of the proper strand size to fit the wire used. The clamp bolts shall have upset shoulders fitting into the clamp plate. Substitution of the cable grip is subject to approval by the Engineer.

Guy wire shall be attached to the pole with a 5/8-inch-diameter x 12-inch-long single-strand bolt with approved guy wire attachment hardware and 2- x 2-inch square cut washers, lock washer, and square nut.

Sidewalk guy fittings shall consist of 2-inch-inner-diameter standard galvanized steel pipe of the required length with a malleable iron pole plate and guy clamp. The pole plate shall be fastened to the pole with a 5/8-inch-diameter thru bolt and 0.5-inch lag screws.

All guying components and hardware shall be galvanized in accordance with ASTM A 123 or A 153.

Anchors for guys shall be of the pressed steel four-way expanding fluke type or of the steel or malleable iron sliding plate type. The minimum unexpanded diameter shall be 8 inches, and the minimum expanded area shall be 110 square ft. Anchors shall be coated with a black asphaltic paint.

Guy anchor rods shall be drop-forged steel, 0.75 inch in diameter and a minimum of 7 ft in length, threaded, of the single thimble eye type, with a square anchor bolt nut.

730.40—Pole Location.
All signal support poles shall be installed at locations shown on the Plans or where directed by the Engineer.

MISCELLANEOUS SYSTEMS

730.41—CCTV Camera Systems.
This section specifies the minimum requirements for CCTV camera systems furnished and installed. The CCTV camera system will provide TMC personnel with live streaming video of the roadway network via CCTV cameras installed at locations shown in the Plans.

1. Materials
   All materials furnished, assembled, fabricated, or installed shall be new, corrosion resistant, and in strict accordance with all of the details shown in the Plans and described in these specifications.

   The CCTV camera system shall comply with the following minimum materials specifications:

   A. General Capabilities and Performance Requirements. Overall CCTV camera system capabilities and performance requirements include the following:
      (1) All outdoor cameras shall be tamper-proof with vandal-resistant housings , capable of being surface or flush mount according to the surface it is being mounted to.
      (2) Outdoor cameras shall be color, IP, PoE 802.3af, and capable of recording in H.264 or H.265 format.
      (3) The outdoor cameras shall have a day night cut filter and be able to operate in temperatures ranging from -40°F to 120°F.
      (4) Outdoor cameras shall be complete with weatherproof housing and internal heater/blower/wiper as required for suitable operation under varying environmental conditions. Hood extensions and shields shall be provided where required to prevent picture degradation due to direct sunlight or lamp glare.
      (5) Outdoor camera brackets and hardware shall be furnished with weather-resistant coatings to prevent corrosion and staining. The housings shall be capable of mounting on poles parapets, and walls.
      (6) Pan-tilt-zoom (PTZ) cameras shall be color, IP, PoE, with a minimum resolution of 1080 pixels (p_, and capable of a minimum of a 35x optical zoom, and high-speed with low light

day/night operation capability with 360 degrees rotation in less than 3 seconds. Domes will mount on poles, parapets, and walls located to provide optimum unobstructed viewing of the area under surveillance. PTZ cameras will have the ability to mask portions of view through software and remote programming.

(7) Camera resolution shall be:
   a. Outdoor Dome Camera – 1920x1080 (high-definition television [HDTV] 1080p) to 320x180.
   b. Frame Rate: 50/60 frames per second (fps) (50/60 Hz) in 1080p.

(8) Standard of Acceptance:
   c. Axis Q6100-E, Axis Q6135-LE PTZ, or approved equal.

B. All cameras shall have a three-year warranty (minimum).

2. Installation Requirements. All equipment shall be installed according to the manufacturer's recommendations, the Plans and as follows:
   A. Materials and associated accessories/adapters shall not be applied contrary to the manufacturer's recommendations and standard practices.
   B. All materials needed to permanently mount the CCTV camera to the support structure as indicated in the Plans shall be included.
   C. Power, video, and data cables and all ancillary equipment required to provide a complete and fully operational CCTV system shall be furnished and installed.
   D. All wiring shall be verified to meet NEC requirements where applicable.
   E. Cameras shall be mounted in positions that allow 360-degree continuous rotation.

3. Measurement
   CCTV Camera System shall be measured in units of each and paid for at the contract price per each. The price bid shall include furnishing, installing, system integration, training, documentation, and testing of a complete CCTV camera system including the CCTV camera assembly, pan and tilt (PT) unit, zoom lens, enclosure, Cat6 cable (video, data, power), surge suppressors and conduit between the camera and the cabinet, connections to support structures, attachment hardware and brackets, and all incidental items to provide and install the CCTV camera system as intended. The price bid shall also include all system documentation including shop drawings, operation and maintenance manuals, wiring diagrams, block diagrams, and other materials necessary to document the operation of the CCTV camera system. This price shall be full compensation for all labor, tools, materials, equipment, and incidentals necessary to complete the work.

4. Payment. The contract unit price shall be full compensation for all the work specified in this section. Payment shall be made under:

Item No.	Description	Unit
725-41	CCTV Camera System	Each

The CCTV camera system shall be paid per each as follows:

- 50% of the contract unit price upon approval of bench test component, bench test system, and pre-installation test results.
- Additional 20% of the contract unit price upon approval of site SAT results.
- Additional 20% of the contract unit price upon approval of conditional system acceptance test results.
- Final 10% of the contract unit price upon final system acceptance.

730.42—LED Illuminated Street Name Sign.

1. Scope. This section describes specifications and requirements for LED internally illuminated street name signs (single or double faced) that will be attached to traffic signal mast arms. The sign installation details are shown in the Plans.
2. General. The Contractor shall provide the required signs as shown in the Plans and as per the guidelines stated in this document. The signs shall include all mounting accessories, housing, door, sign face, fasteners, LED light source, gaskets, and peripherals as per the Plans. All signs shall be clearly legible and shall show the same shape and similar color by both day and night. The sign shall have an easy access service door that swings open and away from the sign body.
3. Hardware
   A. The sign shall be rigid mount directly to the signal mast arm with no moving parts. Sign bracket shall be able to be leveled to accommodate mast arms that are not level.
   B. All external screws, nuts, and locking washers shall be stainless steel. All materials furnished shall be new, first quality, and used in accordance with the highest industry practices.
4. Materials
   A. All parts shall be made of corrosion-resistant materials or shall be plated to resist corrosion. All materials used in construction shall be resistant to fungus growth and moisture-related deterioration.
   B. The signs shall have the message as shown on the Plans. The face legend shall consist of continuous piece diamond-grade translucent vinyl applied over the polycarbonate sign face having the appearance of a white legend on a green background unless otherwise specified on the Plans. Color and letter size and style shall be consistent with the requirements of the MUTCD.
   C. Wiring shall be accomplished using three-conductor cable.
5. Sign Body
   A. The body of the sign shall consist of an aluminum (6000 series or approved alternative) one-piece box-type enclosure and separate hinged door assembly. The top of the sign body shall include drip rails to prevent water from entering the electrical housing. All seams shall be continuously welded, or provide alternatively approved weatherproofing, to ensure a watertight seal. A minimum of three 0.25-inch drain holes shall be located in the bottom of the sign body, a maximum of 1 ft from each end of the sign.
   B. The sign shall have a removable face. The door shall be one-piece frame construction. A continuous steel hinge shall mount the door to the housing.
   C. Sign faces must be able to be removed from the sign and be changed while still installed on the pole. The sign face shall be 1/8-inch white or clear polycarbonate as designated by the Engineer.
   D. Signs shall have airlock fasteners/thumbscrews to secure the door to the sign body.
   E. UL-listed foam gasket shall seal the sign between the door and the sign body, and between the face panel and doorframe.
6. Photocell. All internally illuminated LED signs installed at an intersection shall be controlled by one photocell. This device shall turn the unit ON during the hours of darkness. The photocell needs to be mounted so street lighting, auto headlights, and other light sources will not interfere with its operation. The preferred location is inside the traffic control cabinet, above the main door, just below the screened vent.
7. Dimensions. The sign assembly shall be capable of being constructed in standard length from 4 ft up to 8 ft. The height of the sign shall be a minimum of 12 inches and a maximum of 24 inches. The overall thickness of the sign shall be a maximum of 9.5 inches.
8. Environmental
   A. The sign and power supply shall be able to withstand and operate at temperature extremes of -40ºF to +120 ºF.

B. The sign shall have a front panel that is UV, weather, abrasion, and impact resistant.
C. The sign shall be designed and constructed to prevent deformation or failure due to fatigue, shock, vibration, and wind loads up to 110 mph in conformance with the requirements of the AASHTO LTS-4 2001.
D. The sign shall be tested and certified for exclusion of water test and strain relief test.

9. Finish
   A. The color of the exterior of the sign assembly shall be glossy black. All exterior surfaces of the sign assembly shall be powder-coat painted in accordance with Military standards MIL-C-24712 and MIL-1-45208A.
   B. The interior of housing shall be painted white. The front panel shall be replaceable so that maintaining agencies have the option to supply their own sheeting and electrocut film for the sign faces.
10. LED Light Engine System/Panel
   A. The LED light engine shall be a single, self-contained device for installation in the sign housing. The LED light engine shall be mounted within the inner portion of the housing.
   B. There shall be sufficient quantity of white LEDs to uniformly illuminate the viewing area. The failure of one LED shall not reduce the light output by more than 8% per foot of the sign face.
   C. The LED Edge Lit Internally Illuminated Street Name Sign modules shall be composed of LEDs with a minimum viewing angle of 110 degrees mounted on rugged, secure, non-corrosive material consuming no more than 6 watts per linear foot. The thermal resistance path from the LED to the most external surface of the aluminum extrusion shall be no more than 20 degrees per watt at an ambient temperature of 77ºF to reduce wear and tear on the individual LEDs and to extend usable lifetime. The LED light modules shall be sufficient coupled directly to the aluminum extrusion using stainless-steel mounting screws.
   D. The LED light engine panel shall consist of a circuit board comprising an insulated aluminum substrate, with a minimum thickness of 0.125 inch. The assembly and manufacturing processes of the LED light engine shall be designed to ensure that all LEDs and electronic components are adequately supported to withstand mechanical shocks and vibrations in compliance with the specifications of ANSI C136.31-2001 Standards. All interconnections between LED light modules shall be hard-soldered connections, or approved alternative, to eliminate thermal fatigue and microcracking associated with power cycling.
   E. The manufacturer name and date of manufacture along a quality control tracking sticker shall be mounted on the inside of the LED light engine panel.
   F. There shall be one power supply for the sign. The sign shall have an input voltage of 120 VAC. The input voltage will then be reduced and power-conditioning circuitry shall be provided so that the LED's current will operate at the manufacturer's recommended specifications.
   G. There shall be one separate 15-amp circuit breaker for all signs at the intersection, located in the signal control cabinet on the power panel to feed termination panel. Internally illuminated street name signs shall be wired to a separate 6-position terminal block and a separate 6-position ground bar located in the controller cabinet.
11. Manufacturer. The manufacturer agrees, upon the request of the Engineer, to deliver a sample of each assembly to be supplied in compliance with these specifications for inspection and testing before acceptance. After completion of the test, the sample shall be returned.
12. Training
   A. Prior to the acceptance of the first unit, training shall be provided for NDOT's engineering, maintenance, and operations staff at a facility located in Nashville. The training shall include all material and manuals required for each participant.
   B. The training shall be provided for a minimum of 1 hour for at least 10 engineering, maintenance, and operations personnel. The training shall include a complete demonstration of the operation and

capabilities of the system. This session should include a complete review of any field adjustments or calibration of the equipment that may be necessary for optimum performance and should stress day-to-day operation and isolation of problems down to the unit level.

13. Warranty
    A. All components shall carry a five-year warranty from the date of acceptance against any imperfections in workmanship or materials.
    B. The LED light engine shall be fully guaranteed for three years from the date of acceptance. The LED light engine shall be guaranteed free of workmanship or material defects for a period of five years from the date of acceptance.
14. Repairs. Any repairs made by a manufacturer or representative shall be documented and returned with units when warranty repaired. This documentation shall include an explanation of the exact repairs made and identification of parts replaced by part number and circuit number. All warranty repairs shall be completed within 30 calendar days of delivery of the equipment to the designated repair depot.
15. Maintenance. All equipment shall be designed for ease of maintenance. All component parts shall be readily accessible for inspection and maintenance. The only tools and test instruments required for maintenance by maintenance personnel shall be simple handheld tools and basic meters.
16. Documentation. The Contractor shall submit two sets of complete schematics, operating manuals, and maintenance manuals for each device/equipment type. The maintenance manuals shall include complete subcomponent parts listing and diagnostics procedures.

COMPENSATION

730.43—Method of Measurement.
Measurement for traffic signals shall be on a per-item basis for each item to be furnished and installed, as specified herein and shown on the Plans.

With regard to items for signal head assemblies, each item to be furnished and/or installed shall be distinguished with a code number as follows:

1. The first digit is the number of faces per assembly.
2. The second digit indicates the number of 12-inch lenses per assembly (including arrow lenses).
3. The third digit is the quantity of 8-inch lenses per assembly.
4. The letter "A" indicates an arrow lens and the digit following the "A" indicates the number of 12-inch arrow lenses per assembly.
5. The letter "H" or "V" indicates the arrangement of arrow signal lenses to be horizontal or vertical with respect to solid ball indications.

   EXAMPLE:
   1 5 0 A 2 H
   Digits indicate the following:
   1 = one face
   5 = five 12-inch senses
   0 = zero 8-inch lenses
   A2 = two 12-inch arrow lenses
   H = arrow lenses placed horizontally with respect to circular indications

<u>Removal of Signal Equipment</u>
Items of equipment or material designated or required for removal shall be measured as a lump sum for each intersection. Removal and salvage of all signal heads, poles, control equipment, cabinets, span wire, cable, etc., to be performed at an intersection shall be included as a unit cost per each intersection. This includes

the cost of returning salvable equipment to NDOT for proper disposal. Salvable items will be determined by the Engineer or his or her representative.

Signal Head Assembly (includes pedestrian signal heads)
Signal heads of the type indicated in the Plans shall be measured by the individual assembly complete in place, per each. This item shall include the signal heads, terminals, lamps, attachment hardware, cable connection, and testing.

Pull Box
Each pull box of the type required shall be measured as one complete unit, installed, per each. This item includes the pull box, excavation, backfilling, crushed stone base, and other incidental items as called for in the Plans or standard drawings.

Electrical Service Connection
Electrical service connections shall be measured on a per each signal installation basis. This item includes the electrical service supplied to the weatherhead by the local utility, all necessary materials and labor for connection of the electrical service from the controller to the weatherhead, the wiring of the controller and detectors, and all incidentals necessary to render a complete and operable system. Each connection shall include an external disconnect. Electric service is to be obtained by the Contractor through a written request to the Nashville Electric Service. This request should include electric loads and/or the number and types of signal lenses. The request shall be submitted once the signal, including the controller cabinet, is ready for electrical inspection and shall be submitted in a timely manner so as to activate the traffic signal as scheduled.

Signal Cable
The length of signal cable of each size (number of conductors) installed shall be measured in linear feet to the nearest foot from point to point along the routing for each cable.

Horizontal measurements shall be made by center-to-center measurement from:

1. Pole to pole.
2. Pole to signal head (when terminating in a signal head).
3. Pull box to pull box.
4. Pull box to pole.
5. Pull box to pole-mounted or base-mounted controller.

For cable inside mast arms, measurement shall be made from the center of vertical support to the signal head where the cable terminates.
Vertical measurement shall be made by one of the following:

1. For cable inside poles or conduit risers, the distance from ground level to the point of attachment of the span wire.
2. For cable inside mast arm supports, the distance from ground level to the mast arm connection.
3. For cable to pole-mounted controller from:
   A. Ground level to bottom of controller.
   B. Bottom of controller to point of attachment of span wire.
4. For cable to pole-mounted signal head or pushbutton from:
   A. Ground level to bottom of signal head or pushbutton.
   B. Bottom of signal head or pushbutton to point of attachment of span wire.

No additional allowance shall be made for slack length, length inside equipment or supports (except as noted), length for the required 360-degree drip loop, and similar instances where additional length of cable is required.

Span Wire

Span wire assembly, tether wire assembly, and messenger cable by type shall be measured in linear feet to the nearest foot. The measurement shall be made from center to center of poles. These items include attachment hardware, strain insulators, and other hardware shown in the Plans as part of the assembly. No additional allowance shall be made for slack length and other instances where additional length of wire is required.

Steel Conduit Riser Assembly

Conduit riser assemblies shall be measured per each for each size conduit riser installed on the outside of a pole, as required in the Plans. This item includes conduit, weatherhead, condulet, fittings, nuts, washers, banding, clamps, grounding, and other items necessary for installation.

Conduit

Conduit shall be measured in linear feet to the nearest foot for each size and type of conduit installed. Underground conduit shall be measured along the conduit by one of the following:

1. From the face of curb to the center of a pull box, pole, or controller foundation.
2. From center to center of pull boxes.
3. From center to center of a pull box and a pole or controller foundation.
4. From center to center of pole foundations or pole foundation and controller foundation.

Three feet shall be added to the above measurements for each entry to a pull box or pole foundation and each exit of a pull box or pole foundation. Three feet shall be added to the measurement for each capped extra entry (conduit stub) or exit to a pull box or pole foundation installed, as directed in the Plans. Three feet shall be added to the measurement for each connection between underground conduit and aboveground riser. Three feet shall be added to the measurement for each entry or exit to a foundation for a base-mounted controller.

This item includes, unless noted otherwise on the Plans, trenching, backfilling, sealing, capping, fittings, bushings, banding, grounding, and other accessories and hardware required for installation of the conduit system.

Vehicle Loop Detector (Amplifier)

Vehicle detector loop amplifier shall be measured per each unit and include the cable and associated hardware necessary to electrically connect the amplifier to the controller and loop lead-in. Two and four channel card rack type amplifiers shall be measured per each unit and include the cable, card rack(s), and associated hardware necessary to electrically connect the amplifiers to the controller and loop lead-ins.

Shielded Detector Cable

Two-conductor shielded detector cable installed between the controller cabinet and the loop detector wires shall be measured in linear feet to the nearest foot. Horizontal measurements (overhead and underground) shall be made by one of the following:

1. From center to center of pull boxes.
2. From center to center of pull box and pole.
3. From center to center of poles.
4. From center to center of pull box or pole and controller foundation.

Vertical measurements shall be made by one of the following:

1. From ground level to the point of attachment of span wire, inside pole, or conduit riser.
2. From the bottom of controller cabinet to the point of attachment of span wire.
3. From ground level to the bottom of controller.

No additional allowance shall be made for slack length, length inside equipment or supports (except as noted), splices, and similar instances where additional length of cable is required.

Saw Slot

Length of saw slot for installation of detection loop and lead wiring shall be measured in linear feet to the nearest foot. Measurement for detection loops in the traffic lanes shall be made based on the loop size specified in the Plans, i.e., the nominal length plus the nominal width times two. No additional allowance shall be made for saw overruns to obtain full depth of saw slot or diagonal cuts to prevent sharp bends in the loop wire. Measurement of saw slot for detection loop leads shall be made from the conduit entry at the face of curb or edge of pavement and along the route of the lead-in to the detection loop. For new construction or for projects where roadway resurfacing is involved, saw cuts for detection loops shall be made in the binder course.

This item includes backing rods, or polyethylene foam sealant, loop sealant, and any other incidentals necessary to render a complete and operable system.

Loop Wire

Length of loop wire for installation of detection loops and lead-ins shall be measured in linear feet to the nearest foot. Measurement shall be made from the pull box or pole to the detection loop, around the loop the required number of turns, and back to the pull box, pole, or point of splice. No additional allowance shall be made for slack length, length inside equipment or supports, splices, and similar instances where additional length of wire is required.

This item includes electrical connections, testing, and any other incidentals necessary to render a complete and operable system.

Controller

Controllers shall be measured as one complete unit, installed, per each. This item includes all auxiliary equipment indicated in the Plans to provide signalization control as specified in the Plans, and all hardware necessary for installation.

Cabinet

Cabinets shall be measured as one complete unit, installed, per each. This item includes all hardware to mount a pole-mounted cabinet to the signal support pole, or the foundation required for a base-mounted cabinet.

Wood Pole

Wood poles, of the type and size indicated in the Plans, shall be measured per each, installed.

Guying Device

Guying devices, of the type indicated in the Plans, shall be measured per each, installed. This item includes the guy wire, anchor, clamps, and all other components indicated in the Plans necessary for installation.

Steel Strain Pole

Steel strain poles of the type and size shown in the Plans, shall be measured per each, installed, unless provided for the project by NDOT. This item includes the pole, foundation, anchor bolts, grounding, and all other hardware indicated in the Plans necessary for a complete installation. In those instances where the poles are to be provided, the Contractor is responsible for providing a foundation with anchor bolts and for installing the pole on this foundation.

Cantilever Signal Support
Cantilever signal supports, of the type and size shown in the Plans, shall be measured per each, installed, unless provided for the project by NDOT. This item includes the vertical pole shaft, mast arm, foundation, anchor bolts, grounding, and all other hardware indicated in the Plans necessary for a complete installation. In those instances where the poles are to be provided, the Contractor is responsible for providing a foundation with anchor bolts and for installing the cantilever signal support on this foundation.

Service Cable
Two conductor power service cable of the type and size indicated in the Plans shall be measured in linear feet to the nearest foot, installed. Horizontal runs shall be measured center to center of poles. Vertical runs shall be measured from the ground to the weatherhead inside a pole or conduit riser, from the ground to the bottom of the controller, or from the bottom of the controller to the weatherhead. This item includes all necessary attachment hardware. No additional allowance shall be made for slack length or other instances where additional length of cable is required.

Pedestrian Pushbutton with Sign
Pedestrian Pushbutton with Sign shall be measured as one complete unit, in place, per each. This item includes the pushbutton, sign, mounting hardware, wiring of pushbutton, testing, and all other incidentals necessary for a complete installation.

Pedestrian Signal Display with Pushbutton and Sign
Pedestrian Signal Display with Pushbutton and Sign shall be measured as one complete unit, in place, per each. This item includes the signal heads, terminals, lamps, cable connections, pushbutton, sign, all attachment hardware, testing, and other incidentals necessary for a complete installation.

730.44—Basis of Payment.
The unit price to be paid shall include the cost of furnishing and installing, complete in place, each of the various types of equipment required by the Summary of Quantities that are a part of the Plans. Total payment shall be payment in full for all materials, labor, equipment, and incidentals necessary to produce a completely operative and finished installation of a traffic signal or traffic signal system as shown on the Plans and as herein specified, including restoration of pavements, sidewalks, and appurtenances damaged or destroyed during construction and tests. This payment shall be issued once a Notice of Acceptance letter has been prepared for the installation. Full compensation for all additional materials and labor not specifically shown or called for, which are necessary to complete the traffic signal installation or traffic signal system described, shall be considered and included in the total payment for the system and no additional allowance shall be made therefore.

(end of TDOT 730N spec)