ALABAMA DEPARTMENT OF TRANSPORTATION

General Application Special Provision

DATE: January 9, 2023 GASP No. 22-GA0012

EFFECTIVE DATE: June 1, 2023

SUBJECT: Intelligent Transportation Systems (ITS).

Alabama Standard Specifications, 2022 Edition, SECTION 729 and SECTION 893 shall be replaced by the following:

SECTION 729
INTELLIGENT TRANSPORTATION SYSTEMS

729.01 Description.

This Section shall cover the work of furnishing, installing and testing Intelligent Transportation Systems (ITS).

Descriptions and definitions of the equipment, words and terminology used in the furnishing and installing of Intelligent Transportation Systems (ITS) equipment are given in the Manual of Uniform Traffic Control Devices (MUTCD) and the publications of the Institute of Transportation Engineers (ITE), the National Electrical Manufactures Association (NEMA), the National Fire Protection Association (NFPA), and the International Municipal Signal Association (IMSA).

729.02 Materials.

All materials furnished for use shall conform to the requirements given in **Section 893** and the requirements shown on the Plans, and/or listed on the Alabama Department of Transportation (ALDOT) "*Materials, Sources, and Devices with Special Acceptance Requirements Manual*" (MSDSAR). All furnished materials and equipment shall be new and free from defects. Existing equipment shall only be used if shown on the Plans to be re-used.

729.03 Construction Requirements.

(a) General.

ITS devices/equipment (i.e., cabinets, cameras, Dynamic Message Signs, Vehicle Detection Systems, etc.) shall NOT be mounted on structural members until erection or final placement of the structure (i.e., Overhead Sign Bridge, ITS Pole, etc.).

1. Drawings and Specifications.

   Installations shall comply with the regulations of the latest edition of the National Electrical Code (NEC) (a.k.a. NFPA 70), the latest edition of the National Electrical Safety Code (NESC) (a.k.a. ANSI/IEEE C2), and local Utility regulations.

2. Material and Equipment Lists, Shop Drawing Approval.

   Material and equipment listings shall be submitted to the Design Bureau's Traffic Engineering Division for approval within thirty (30) calendar days after the issuance of the "*Notice to Proceed*". Material and equipment lists shall include catalog cutouts or published data sheets and shall be completed on the Department's Material Submittal Form D-40. Material Submittal package(s) and Form D-40 shall be electronically completed and submitted in accordance with Traffic Engineering Division's procedures as outlined in the Form D-40 quick help guide and instruction documents. All components required for a complete system, sub-system and/or pay item shall be listed on the Form D-40 as defined in the form's instruction documents. Partial listings or incomplete shop drawings for any individual pay item, system, or sub-system will not be accepted for consideration and shall be returned for correction without review.

   Any changes to the approved material and equipment lists must be requested in writing through proper channels.

If requested by the Engineer, the Contractor shall submit for inspection and approval samples of both the specified and proposed substitute items at no cost to the Department. The Department will not be liable for any equipment purchased or work done, or any delay incurred before such approval. Failure of the Engineer to note unsatisfactory equipment as received will not relieve the Contractor from responsibility.

Manufacturers' warranties and guaranties furnished on equipment used in the work shall be delivered to the Engineer; likewise, instruction sheets and parts lists shall be delivered to the Engineer upon receipt of the equipment.

Throughout the entire project, the same manufacturer shall make all units of any one item.

3. Supporting Structures and ITS Poles.

Supporting Structures and ITS Poles used for mounting the equipment shall conform to the requirements given in **Section 718** and **Section 891**.

Concrete ITS Pole with metal tenon extension shall be installed per the manufacturer's recommendations and as shown on the Plans.

4. As-Built Drawings.

The Contractor shall submit as-built documentation of work provided in accordance with this Specification upon completion of the Burn-In Period as required in **Sub-Article 729.03(s), "*Burn-In*"**. As-built submittal packages are to be neat, legible, and orderly. All electronic/digital copies shall be submitted via Department approved media. Except for standard bound materials, bind all letter-size (8.5 inch x 11 inch) documentation, including ledger-size (11 inch x 17 inch) drawings folded to letter-size (8.5 inch x 11 inch), in logical groupings in loose-leaf binders of 3-ring, plastic comb, or plastic coil/spiral type. All binders and media shall have typed labels affixed identifying its contents.

The following documents, at a minimum and as they are applicable, shall be included: [Contractor shall furnish at least two (2) sets of bound documentation.]

a. User/Operation Manual.

The Contractor shall furnish a manual containing detailed operating instructions for each different type or model of equipment.

The Contractor shall deliver two (2) hard copies and one (1) electronic searchable copy of each User/Operation Manual to the Engineer upon completion of the Project. The User/Operation Manuals shall be for the ITS electronic equipment and any software provided on the Project. The User/Operation Manuals should be grouped into the following ITS component areas: camera, VDS, network devices and other equipment.

b. Maintenance Procedures Manuals.

The Contractor shall furnish a manufacturer's manual containing detailed preventative and corrective maintenance procedures for each different type or model of equipment.

c. System Connection Diagrams.

The Contractor shall furnish diagrams showing the ITS site detailing the wiring between devices.

d. Drawings.

The Contractor shall furnish a corrected set of plans showing in detail all changes made during construction from the original plans. These corrected drawings shall also include: (a) schematic wiring/circuit diagrams; (b) cabinet wiring diagrams; (c) actual route location and depth of conduits, encasements and CommBoxes; and, (d) aerial cable route locations including poles and pole attachment heights (at a minimum). Cable and conduit route locations shall be collected in Department approved GPS format with a horizontal tolerance of ±6 inches {15 cm} and a vertical tolerance of ±12 inches {30 cm}. These readings for cable and conduit are to be taken every 50 feet {15 m} and at changes in direction unless otherwise directed by the Engineer. GPS readings shall also be taken at the top center of installed CommBoxes. Resulting field survey data shall be provided in an ESRI ArcGIS shapefile format and include any necessary descriptive fields. These corrected drawings and field survey shall be furnished as an electronic copy.

These corrected drawings should not be finalized for submittal until after all equipment and materials have been installed at their final location and a successful Acceptance Test has been completed.

Along with these corrected drawings, all testing documentation and test results as required within the Specification shall be included in the as-built submittal package.

e. ALDOT OSP Database Forms.

The Contractor shall provide the Department with completed Outside Plant (OSP) Database Forms which document fiber optic cable and ITS device installation information. These ALDOT forms should be supplied in PDF file format to the Contractor by the Engineer at the Pre-Construction meeting. These forms are to be printed and hand-completed by the appropriate technician (i.e. Fiber Optic Technician for fiber optic cables; and ITS Technician for ITS device/equipment) in the field at each site as corresponding form installation occurs, unless otherwise directed by the Engineer. The Engineer shall field verify submitted forms for accuracy; and then transmit acceptable forms to the Area Traffic Management Center Supervisor for OSP database entry. Copies of these forms should also be sent to Design Bureau's Traffic Design ITS Group for their records. If any data is missing or any questions regarding form entries are noted at data entry, the forms in question will be returned to the Contractor for corrective action. The Contractor must complete these forms and submit them in a timely manner for review and entry. Otherwise, the Acceptance Test and Burn-In will be subject to being held up.

5. Approved Intelligent Transportation System Devices and Materials.

Some materials and equipment required to be furnished under this Section will be standard production type products. Acceptance will be made by the Engineer based on selected confirmation tests, the manufacturer's certification of the materials and equipment, and visual inspection at the job site. Approved devices are shown on the Department's **List VI *"Approved Intelligent Transportation System Devices and Materials"***. Information concerning this list is given in **Sub-Article 106.01(f), *"Use of Materials with Special Acceptance Requirements"*** and **ALDOT-355, *"General Information Concerning Materials, Sources, and Devices with Special Acceptance Requirements"***.

6. Coordination of Work.

Coordination with roadway work and with bridgework shall be of prime importance to prevent undue damage to completed items of work and to existing facilities. Any damage to existing facilities caused by the installation of the material or equipment required under this Specification shall be repaired by the Contractor at no additional cost to the Department.

The Contractor shall field verify equipment locations with the Engineer prior to installation.

7. Restoration of Site.

During the installation of the underground systems, removal of brush, trees, fencing, and other obstructions within the right-of-way shall comply with **Section 201** and shall be paid for separately under that Section. Landscaping shall be restored to original or better condition if disturbed.

8. Excavating and Backfilling.

Excavation required for the installation and placement of conduits, foundations, CommBoxes, ITS poles and other appliance shall be performed in such manner as to cause the least possible injury to pavement, curbs or other improvements.

Trenches shall not be excavated wider than necessary for the proper installation of the required conduits, wires and/or fiber optic cables. Excavating shall not be performed until immediately before installation of conduit and other appliances. The material from the excavation shall be placed in a position where the least interference with the surface drainage will occur. Any trenches required for construction shall be backfilled the same day. Surplus excavated material shall be removed from the site the same day and disposed of by the Contractor, or as directed by the Engineer.

Compaction shall be accomplished to the extent necessary to prevent future settlement of the backfill.

The Contractor shall be required to restore any areas disturbed by his work to their original condition without additional cost to the Department.

9. License and Certifications.

The Contractor responsible for the performance of the work shall be licensed as a General Contractor authorized to perform electrical work by the Alabama State Licensing Board for General Contractors and in good standing.

At least one out of every three persons in each work crew shall be a Journeyman licensed by the Alabama Electrical Contractors Board and in good standing. Journeymen shall be present and shall

have direct involvement with all work required for the installation and operational testing of electrical materials and equipment.

The Contractor shall submit copies of the General Contractor license, Journeyman licenses and certifications to the Engineer as a part of the submittal of the list of materials proposed for installation. Work shall not begin on the installation of electrical materials or equipment until copies of the licenses and certifications have been approved by the Engineer.

Fiber Optic related work shall be completed by qualified Fiber Optic Technicians as defined in **Item 729.03(b)1** ***"Fiber Optic Technician Qualifications"***.

(b) Fiber Optic Cable.

The Contractor shall assemble and install all necessary material and equipment and furnish a working fiber optic cable as shown on the Plans and as specified within the Specifications. All items that are required to complete the installation and ensure a fully functional and operational system shall be supplied by the Contractor.

All optical fibers within each and every cable shall be usable and shall be 100% attenuation-tested by the manufacturer. The minimum information required within these attenuation testing results are defined in the materials section of this Specification (see **Item 893.02(a)6, *"Quality Assurance and Packing"*** for details on the "*cable reel data sheet*"). The cable reel data sheet shall be provided with each reel and affixed within the reel wrapping. When the cable reel is received from the manufacturer, a copy of the cable reel data sheet (a.k.a. "*manufacturer's certified test report*") along with any other shipping documentation shall be submitted to the Engineer. The cable reel tag is to be delivered to the Engineer upon its removal during cable installation. Once the documentation is no longer needed for their use, the Engineer should forward these items (or a copy) to the ALDOT Region TSM&O Engineer for their permanent records and for fiber optic database storage.

The Contractor shall insure fiber optic cable is stored in temperatures that meet the manufacturer's recommendations.

1. Fiber Optic Technician Qualifications.

The Fiber Optic Technician qualifications shall be submitted with the Material Submittal package for approval. The Contractor shall have the Engineer's approval of the Fiber Optic Technician's qualifications prior to commencing work. These technicians shall be in possession of their certification at all times and show this certification as often as asked by the Engineer. The Department reserves the right to revoke the approval of any technician not demonstrating the skill and knowledge to perform at accepted industry standards. Failure to provide proof to the Engineer will result in a stop work being placed upon fiber optic work until such a time that proof of meeting these Fiber Optic Technician Qualification requirements are met. Contract time will not be stopped if the Contractor is unable to provide adequate proof or qualified staff.

Only technicians that meet all these requirements shall perform fiber work including splicing, terminating fiber, and testing of fiber.

Technician performing fiber terminations, splicing, and testing shall have:

a. Education:

Attended and successfully completed at least one four (4) day class on installation of fiber optic products conducted by major manufacturer of fiber products or an accredited/approved firm or organization. The entity conducting the training, along with the class and materials, shall be current and accredited for certification by one of the following United States based certification organizations: Electronics Technicians Association (ETA), The Fiber Optic Association (FOA), or International Municipal Signal Association (IMSA). Fiber Optic Technicians shall maintain their certification and be in good standing with the applicable certification organization while performing such work on ALDOT projects. Technicians with expired or suspended certification shall not be allowed to conduct work.

b. Work History:

Technicians shall have a minimum of two (2) years of work experience with one year continuous for splicing, terminating and testing fiber optic cable. Work experience shall be within the last 5 years. The applicant shall submit a resume providing a summary of qualifications and a general description of professional experience, education and training in the fiber optic installation techniques (termination, splicing and testing). The applicant shall also provide a work record for

the previous two years detailing specific project, types of installations, testing and a customer reference for each project. The applicant should include as much additional detail as reasonable to facilitate approval.

2. Fiber Optics Material Installation.

It shall be the Contractor's responsibility to protect reeled fiber optic cable from vandals or other sources of possible damage while unattended. The sections of cable intended for duct installation are produced to meet specific length requirements. Any damage to the cable sections may require replacement of the entire section, at the discretion of the Engineer.

The Contractor shall be responsible for damage to the cable during handling and placing, and responsible for all cost to replace damaged fiber optic cable. The cable manufacturer's specifications regarding tensile strength, pulling capacity, and bending radius, etc. shall not be violated.

Whenever unreeled cable is placed on the pavement or surface above a manhole, the Contractor shall provide barricades or other means of preventing vehicular or pedestrian traffic through the area.

The "*figure-eight*" configuration shall be used when installing fiber optic cables. Fiber optic cable should not be coiled in a continuous direction except for lengths of 100 feet {30.5 m} or less. The preferred size for the "*figure-eight*" is about 25 feet {7.6 m} in length, with each loop 9 feet {2.7 m} to 14 feet {4.3 m} in diameter. Traffic cones spaced 10 feet {3.0 m} apart are useful guides during "*figure-eighting*". When "*figure-eighting*" long lengths of cable, care should be taken to relieve pressure on the cable at the crossover of the eight.

On projects where a fiber optic cable is to be mechanically or hand pulled, a "*Pull Tape*" as specified in **Sub-Article 893.10(d)** shall be factory or field installed within conduit for the purpose of attaching to, and the pulling of said cable. PULL ROPES NOT SPECIFICALLY DESIGNED FOR FIBER OPTIC AND ELECTRICAL CABLE INSTALLATION SHALL NOT BE USED ON ANY ALDOT PROJECT.

If a mechanical pulling machine is used, it shall be equipped with a monitored or recording tension meter. At no time shall the cable manufacturer's recommended maximum pulling tension be exceeded. The fiber optic cable's central strength member and aramid yard shall be attached directly to the pulling eye/pulling grip in accordance with the cable manufacturer's Standard Operation and Installation Procedures (SOP). Contractor shall use cable manufacturer approved pulling grips to ensure that the cable's optical and mechanical characteristics are not degraded during installation.

a. Installation and Standard Operation Plan.

i. Manufacturer's Operation and Installation Procedures.

The Contractor shall install in accordance with the cable manufacturer's Standard Operation and Installation Procedures (SOP). These procedures shall be provided upon the request of the Engineer.

ii. Contractor's Installation Plan.

The Contractor shall submit to the Engineer for approval a detailed installation plan for all fiber optic cable installed as part of this project. The Contractor shall have the Engineer's written approval prior to commencing any fiber optic cable installation.

This installation plan shall include all proposed end-to-end cable splice points which shall be in a CommBox that was already designated as a splice point. The Contractor will be required to limit the amount of splice points within the network and maximize the length of each cable run. Reel lengths and end-to-end cable splice points shall be submitted by the Contractor and approved by the Engineer prior to the ordering of the fiber optic cable.

b. Designated Cable Slack (Maintenance Coil).

Throughout the fiber optic cable installation, the Contractor shall be required to pull and store excess cable slack at designated intervals. The following lengths of slack cable shall be minimums used unless otherwise shown on the Plans:

CommBox with Splice Closure	75 ft. {23 m} per cable end
CommBox without Splice Closure	150 ft. {46 m} per cable
Pull Box	100 ft. {30 m}
ITS Cabinet/Controller Cabinet	10 ft. {3 m}
Hub Building	100 ft. {30 m}
TMC/Transportation Control Center (TCC) (OSP Entrance)	100 ft. {30 m}

c. Slack Storage.

The Contractor shall not leave slack cable lying free on the ground, bottom of a CommBox, bottom of a pull box, or floor of a Hub/TMC/TCC. Only during the actual pulling process will this be allowed. If channeling rack is not available on existing, the Contractor may leave slack upon approval of the Engineer.

d. Aerial Lashing.

Aerial cable shall be lashed to a separate stranded steel messenger wire within a Medium Density Polyethylene (MDPE) jacket. The fiber optic trunk cable shall not be lashed to messenger wire also used for signal heads or other similar items.

e. Riser Duct.

Riser duct shall be in accordance with RISER ASSEMBLY requirements within this Specification and as shown on the Plans.

3. Fiber Optic Cable Tag and Labeling.

a. General.

The Contractor shall label all fiber optic cabling with a unique identification in a permanent and consistent manner that is approved by the Engineer prior to installing fiber cable. The Engineer shall provide the Contractor with the identifications to be used. Fiber optic cable tag labels shall meet the material requirements within this Specification and as shown on the Plans. The Contractor shall provide these unique cable tag identifications on all test results or fiber related documents provided to the Engineer.

Metal or non-metal fiber optic cable tags are to be primarily used within CommBoxes, ITS Cabinets, and Hub Buildings. Special non-metal aerial fiber optic cable tag labels are to be used for aerial installations. Cable tag labels shall be affixed to the cable per the manufacturer's recommendations; and shall be affixed in a manner which will not cause damage to the fiber. Handwritten labels shall not be allowed.

The Contractor shall install cable tags within 1 foot {0.3 m} of each splice and/or termination point. Each tag label shall identify the cable type, fiber count, and each fiber optic cable origination and termination points (or next ITS site that the cable is connecting).

b. Aerial Fiber Cable Labeling.

Aerial fiber optic cable tags shall meet the material requirements within this Specification and as shown on the Plans.

Aerially-mounted fiber optic cable tags shall be placed at 500 ft. {152 m} increments linearly along the fiber optic cable path and shall be identifiable as ALDOT fiber when viewed from ground level.

A "*proof check*" sample, of quantity one, shall be produced and provided to the Engineer prior to procurement of the remaining units. The Contractor is required to obtain the Engineer's approval of the "*proof check*" sample prior to subsequent procurements by the Contractor. If the Contractor does not obtain approval prior to subsequent procurements, the Contractor assumes the risk of the aerial fiber optic cable tags being rejected even after installation. No payment shall be made to the Contractor if the aerial fiber optic tag is rejected.

4. Fiber Optic Testing.

The Contractor shall supply all equipment, materials and software necessary to perform the test as specified within the Specifications. Fiber optic testing shall be performed by certified Fiber Optic Technicians approved as specified within the Specifications.

Test for attenuation, decibel loss, shall be measured in dB/km. The Contractor required fiber tests shall be done by a certified Fiber Optic Technician in the presence of the Engineer or his/her designee.

a. Fiber Optic Test Methods.

i. Power/Light Meter Test.

A typical Power/Light Meter Test consists of the following steps/conditions:

- Connect the light source to the terminated fiber at the location identified by the Engineer. Connect a power meter to the other end of the fiber at the location identified by the Engineer. Record the results in accordance with standard industry practice and submit the test report to the Engineer.
- Use the light frequencies of 1310 nm and 1550 nm for single-mode unless otherwise directed by the Engineer.
- Perform the test bi-directionally.

A Project Inspector shall witness and approve the results before final acceptance by the Engineer.

ii. Optical Time Domain Reflectometer (OTDR) Test.

OTDR shall be used for fiber testing as a means of determining the integrity of the fiber strands. A launch cable of a length exceeding the "dead zone" of the OTDR or a factory "*fiber box*" of 246 feet {75 m} minimum with no splices within the box shall be used for testing with the OTDR. If a patch cable is utilized, the length of patch cable shall be stored on a fiber storage bobbin with a 5 inch {127 mm} minimum diameter. Termination of the fiber for testing shall be the factory fiber via "*lab splice*", mechanical splice, or fusion splice, bare fiber adapter, or mechanical termination. Supplemental patch cables and barrel connectors to transition between connector types shall not be allowed. The traces shall demonstrate dB/km loss not to exceed +3% of the factory test documentation that came with that reel of fiber or 1% of the cable's published production dB loss per km as specified within the Specifications plus the maximum OTDR error level as noted by the manufacturer of the OTDR (typically +2%). The OTDR should be calibrated to show anomalies of 0.1 dB minimum. When a "*gainer*" appears in an OTDR trace, that strand shall be bi-directionally tested. Each trace shall include the following data:

- The trace itself with a launch transition not to exceed 6 dB;
- *Measurement results* - cursor, marker, distance between cursor and marker, total loss between launch point and end of fiber, attenuation calculation in dB/km;
- *Cable information* - fiber identification (if not the filename), cable identification (reel number and manufacturer's identification reel number), OTDR location, end of fiber location, operator identification, date shot, time shot; and,
- *Set up parameters* - wavelength, pulse width, refractory index, range, and horizontal scale.

b. Fiber Optic Test Times (Milestones).

The following fiber optic testing times/milestones should be observed and/or documented to the satisfaction of the Engineer.

i. Manufacturer's On-Site Testing.

The cable manufacturer shall provide necessary documents to validate test equipment along with test results delivered and provide to the Engineer upon cable delivery.

ii. General Receiving Test.

The Contractor shall provide the ALDOT Region TSM&O Engineer the fiber cable manufacturer's OTDR test results and Power/Light Meter readings for each strand of outdoor fiber (i.e., trunk, drop, aerial, and armored) prior to performing the fiber optic cable receiving test.

Prior to any work, the Contractor shall certify to the Engineer that any and all fiber optic cable that is to be used on said project has been delivered to the work site and/or the Contractor's storage facility and meets the requirements as specified within the Specifications and was

undamaged during shipping. Compliance with this requirement shall be accomplished in the following manner.

The Contractor is recommended to OTDR test each fiber strand per loose tube on each reel of cable 14 days prior to installation.

The Contractor and Engineer shall jointly inspect and test all reels of cable for damage prior to installation. The fiber optic cable shall meet the following factory attenuation criteria:

- Fiber cable attenuation specified herein for 1310 nm and 1550 nm,
- Strand lengths are consistent in the OTDR reports,
- Launch Transition < 0.6 dB, and
- No event shown in the OTDR trace > 0.10 dB.

Upon completion of these test procedures, the Contractor shall issue to the Engineer all test data as specified and a "*Letter of Quality Assurance*" from said Contractor stating that the fiber cable has been delivered to the construction site and/or the Contractor's storage facility and meets the requirements as specified within the Specifications.

Upon the Engineer's acknowledgment of the receipt and acceptance of the Letter of Quality Assurance, the Contractor may commence installation of said cable at the Contractor's risk. No fiber optic cable shall be installed prior to the receiving test and the acceptance of the Engineer.

iii. Existing Fiber Testing.

The Contractor shall test any existing fiber cable to be used on the project before beginning any fiber work on those fibers. Existing dark fibers, whether to be used on the project or remain dark, shall be OTDR tested. Testing of any existing fiber strands that are currently lit shall be coordinated with the Engineer for scheduling when the lit fiber may be taken offline for testing. A minimum of seven (7) calendar day notice shall be given to the Engineer before testing lit existing fibers. These fiber test reports shall be submitted to the Engineer for review and acceptance.

iv. Installation and Post Fiber Testing.

As the cable is pulled off the reel, it shall be carefully inspected for jacket defects. If defects are noticed, the pulling operation shall be stopped immediately. The Contractor shall submit to the Engineer the proposed corrective action to be taken for review and acceptance.

Armored fiber optic cable shall be properly grounded upon cable installation. This grounding system shall be tested in accordance with the Specifications.

Post installation testing ensures the integrity of the fiber strands have not been damaged during the installation process. Once the fiber cable has been installed, the Contractor shall OTDR test each fiber strand before proceeding to splicing and/or terminations. These OTDR test results shall be compared to the receiving OTDR test results for determining if any fibers were damaged by the Contractor's work during construction. In such case that there is damage done during construction the Contractor shall be responsible for all equipment, materials and labor to repair the damage to the satisfaction of the Engineer at no additional cost to the Department. The Engineer has the final determination of what constitutes damage during construction. At minimum, no event shall exceed 0.10 dB post installation. The process for repair and/or replacement of cable shall be submitted to the Engineer for review and acceptance prior to conducting the work. Repaired and/or replaced cable shall be retested to ensure compliance with standards. Test reports shall be submitted to the Engineer for review and acceptance.

v. Termination/Splicing Complete Testing.

Upon completion of the installation of fiber cables, drop cables, splices, and termination of cable ends; dependent on the project requirements as shown on the Plans, each fiber terminated and spliced shall be OTDR and Power/Light Meter tested.

The Contractor shall review the OTDR and Power/Light Meter results to ensure the fiber attenuation, splice loss, and connector pairs meet the requirements as specified within the Specifications. The reviewer (also a certified Fiber Optic Technician) shall be different from the certified Fiber Optic Technician who performed the installation and tests. The Contractor shall clean, polish, re-terminate, and/or re-splice in order to bring the results within specified tolerances.

vi. Fiber Optic Test Reporting.

Upon completion the Contractor shall issue to the Engineer all traces and loss/length print outs. These are to be submitted in a suitable binder organized by cable and strand number. A cover sheet is required for each binder indicating which cable(s) were tested, the OTDR user's name, the certified reviewer's name, the type of test performed, and the date(s) of the test. Cover sheets for final test results bearing the reviewer's signature, the date signed, and a statement indicating that the installation complies with the Specification's requirements are required. The Contractor's employee who has reviewed the traces is required to sign or initial them. A check mark is required on all traces that satisfy the Specification's requirements. For intermediate test results, the Contractor shall flag any discrepancies that may exist with a short description of the proposed corrective action (e.g. re-splice). Where test results do not satisfy the requirements as specified within the Specifications, the Contractor shall provide justification as to why the testing and/or material are not able to prove meeting the requirements as specified within the Specifications. This binder/package is to be submitted to the Engineer for fiber work acceptance and distribution. Also with this binder/package, the Contractor shall submit to the Engineer on a data compact disk or other approved electronic media the raw OTDR fiber trace files along with the OTDR documentation (manufacturer/model/serial number). The Contractor may alternately submit this binder/package as an electronic submittal (preferably in PDF format or as approved by the Engineer).

No payment for splices or terminations shall be made unless fiber optic test reports and ALDOT's OSP Database Forms have been accurately completed by the Contractor and submitted to the Engineer.

(c) Fiber Distribution Units (FDU), Connectors, and Fan-Out Kit.

The Contractor shall assemble and install all necessary material and equipment and furnish a working Fiber Distribution Unit as shown on the Plans and as specified within the Specifications. All items that are required to complete the installation and ensure a fully functional and operational system shall be supplied by the Contractor.

1. Distribution Hardware.

The following distribution equipment specifications cover installations of Fiber Distribution Units from the headend and hub, primary fiber distribution unit (PFDU) to secondary fiber distribution unit (SFDU) which are utilized within the individual cabinets and communication closets within buildings or within hub buildings.

When splicing in the field within a CommBox or aerial installation, a splice closure shall be provided as indicated on the Plans and in accordance with **Article 729.03(q)2, "*Installation of Splice Closure (Underground and Aerial)*"**.

2. Fan-Out Kit.

Fan-out kits shall be installed per fan-out kit and/or fiber optic cable manufacturer procedures and standard fiber connector installation training. Fan-out kit shall be compatible with the fiber optic cable being terminated and shall be color-coded to match the optical fiber scheme or as specified within this Specification.

3. Fiber Connectors.

Installer of fiber connectors shall have been trained to perform the installation of the type of connector being installed. Manufacturer guidelines shall be followed. Prior to testing connector, installer shall visually verify connector end is clean of foreign materials using a fiber scope. Heat cure epoxy connectors are the preferred method and shall be used unless otherwise indicated on the Plans. Mechanical Connectors shall not be allowed for permanent connections on any ALDOT project.

4. Cable Management.

The Contractor shall ensure that fiber cables are installed in the manner in which they were designed for the FDU. Cables shall be secured in the locations designed by the FDU manufacturer using zip ties while ensuring the fiber cable is not overly bound causing attenuation loss in the fiber cable. The excess end of zip ties shall be cleanly cut flush. Fiber cable shall not be stretched, kinked, or bound when run within the cable management system.

5. Splice and Termination Procedure.

The procedure for fusion splicing shall be submitted to the Engineer for approval. This submittal shall consist of:

a. OSP Database Form(s);
b. manufacturer/model of fusion splicer and date of last calibration;
c. form of splice protection; and
d. means of accessibility for splice protection and traffic control.

The Contractor shall only splice fibers at locations as shown on the Plans unless otherwise approved by the Engineer.

All splices shall be protected and stored in fiber optic splice units or integrated fiber optic splice and termination units that are housed in field cabinets, pull boxes, CommBoxes, hubs, and other buildings.

The Contractor shall document all splice and terminations on forms provided by the Engineer. No payment for splices or terminations shall be made unless forms have been accurately completed by the Contractor and accepted by the Engineer.

Fiber optic cables shall terminate in a fiber optic splice closure or fiber distribution unit where ends are protected. During installation, fiber optic cable ends must be protected per manufacturer recommended methods and as approved by the Engineer.

6. Pre-terminated Connector Assemblies.

Pre-terminated Connector Assemblies (i.e., Factory Connector Build-Outs, or pigtails) may be spliced onto a cable as an alternative to installing heat cure epoxy connectors. Pre-terminated Connector Assemblies shall be installed per manufacturer's standard operating procedures of the fiber optic cable and fiber distribution unit; and, as approved by the Engineer.

Pre-terminated Connector Assemblies (PTCA) cables shall be labeled where the buffer tube being spliced is permanently indicated on the PTCA cable jacket. This labeling is to be done prior to splicing.

7. Fiber Optic Patch Cable.

Fiber optic patch cables (a.k.a. patchcords or jumpers) shall be appropriately sized for the length of run. Excess patch cable is to be limited to no more than one slack coil of 6 inch diameter. Fiber optic patch cables and connectors shall be compatible with the fiber optic cable and equipment to which it will connect.

(d) Network Devices.

The Contractor shall assemble and install all necessary material and equipment and furnish a working Network Device as shown on the Plans and as specified within the Specifications. All items that are required to complete the installation and ensure a fully functional and operational system shall be supplied by the Contractor.

Wiring connections in poles shall be environmentally sealed using a minimum of watertight electrical connectors, mastic electrical splicing tape, and standard electrical tape. Final network device locations shall be accepted by the Engineer prior to installation.

1. Managed Ethernet Switch.

a. Installation.

Managed Ethernet Switch (MES) shall be installed as shown on the Plans and mounted using manufacturer recommended parts. Ensure that the switch is resistant to all Electromagnetic Interference (EMI). Verify that the switch is mounted securely and is fully accessible by field technicians. Wiring shall be run within wire raceways and secured using zip ties.

2. Wireless Network Device.

a. Wireless Equipment Selection and Installation.

The Contractor shall be responsible for determining field conditions of licensed and unlicensed wireless radio site including interference (noise). The Contractor shall perform wireless path loss analysis to determine appropriate radio equipment and antennas and mounting heights necessary for each site. This analysis shall be provided to the Engineer for review and acceptance. The Contractor shall be responsible for selecting equipment which meets the minimum performance

requirements shown within the Specifications with the required annual availability at the most constrained modulation (i.e., smallest dB range in modulation to obtain for that radio unit).

Prior to deploying and operating a licensed frequency, the Contractor is responsible for performing a frequency coordination, filing a public notice, and submitting an application (Form 601) with the FCC to ensure that no one else is already operating on the same frequency or a frequency that will inject interference on existing systems. If licensed radios encounter interference, it is typically resolved with the assistance of the regulatory body.

b. Antenna Installation.

Technicians performing installation work shall have a hardware certification by the microwave manufacturer on the product being installed.

Prior approval from the Engineer shall be obtained for the installation and sealing process when field drilling is required to mount an antenna on an existing cabinet and/or support structure.

Antenna mounts shall be secured to prevent movement of antennas in high wind conditions. Once the antennas are aligned, the position shall be marked with torque marking paint that shows any movement about the azimuth and elevation axis. Pictures of these marks shall be submitted as part of the as-built plan set submittal. These marks shall be made such that they do not deteriorate in the weather or sun.

c. Cable Installation.

Cable shall be routed as shown on the Plans. When the Plans do not denote a specified route, prior approval from the Engineer shall be obtained for the proposed route. Cables mounted internal to structure supports shall use a hoisting grip to properly secure each cable type at the top of the support structure. Lightning arrestors shall be installed as shown on the Plans and grounded on the support structure. Wiring connections in supports shall be environmentally sealed using a minimum of watertight electrical connectors, mastic electrical splicing tape, and standard electrical tape. A drip loop shall be provided where cable enters a support structure; the bottom of the loop shall be lower than the cable entry point. Structure entries shall be through a weatherhead, grommet or sealed using butyl rubber.

(e) Camera.

1. General.

The Contractor shall assemble and install all necessary material and equipment and furnish a working Closed-Circuit Television (CCTV) camera as shown on the Plans and as specified within the Specifications. All items that are required to complete the installation and ensure a fully functional and operational system shall be supplied and installed by the Contractor.

Wiring connections in poles shall be environmentally sealed using a minimum of watertight electrical connectors, mastic electrical splicing tape, and standard electrical tape.

The Contractor shall provide a camera installation complete with associated detection equipment, control equipment, power supplies, and any other camera-related field electronic equipment and transient voltage surge suppression as shown on the Plans and as specified within the Specifications. The Contractor shall provide an installation kit with mounting brackets, data cables, power cables, hardware and any incidentals required by the manufacturer.

The Contractor shall maintain full responsibility for the camera housing mounting to the support structure and confirm that the camera can be properly mounted on the support structure prior to installation. The Contractor shall securely mount the camera on the support structure. The camera shall be constructed and shall be adjusted to obtain optimum function of the camera.

The camera, cabinet, and other components shall be mounted at locations as shown on the Plans. The Contractor is responsible to ensure that the camera does not interfere with the operation of any other ITS electronic equipment when installed.

The Contractor shall be responsible for camera configuration and initial settings (i.e., date/time stamp, compass orientation, time server IP address, alert settings, camera ID label, SNMP settings, and initial user account login defaults). These camera settings shall be coordinated with the ALDOT Region TSM&O Engineer prior to placing camera and associated equipment in service.

a. Cabinet Equipment.

i. Controller Cabinet Installation.

The Contractor shall install the camera controller in the designated space of the ITS Cabinet. The Contractor shall install any associated camera equipment per the manufacturer's requirements and as shown on the Plans.

ii. Wiring and Connections.

Upon completion of wiring and connections, bundle all incoming cables and hold in place with nylon cable ties. Connect the front panel and chassis to the cabinet ground bus from a single point only.

Install cables and connectors so that the manufacturer's rated minimum bending radius and pulling tension are not exceeded. Take proper care to prevent abrasions to the cable jacket during installation.

b. Cables and Electrical Power Service.

The Contractor shall install the conduit for electrical cable between the service pole and the ITS Cabinet load center. Electrical Power Service shall conform to the requirements of **Sub-Article 729.03(m)** and **Article 893.13, *"Electrical Power Service and Transformer"***.

All camera data shielded cables shall be routed separate from any 120 Vac or greater power wiring or surge suppressor ground wiring. "Power-Over-Ethernet" (POE) communications cables shall be permitted where installation and cable is in accordance with NEC Chapter 8.

Cable, shield or conductor used for camera control, power supply, or grounding shall not be spliced.

c. Interface Protocol.

The Contractor shall provide the Engineer with the manufacturer's open software interface/protocols for the Camera so that it can be fully integrated into the Department's current ALGo ATMS software.

d. Manufacturer's Software.

The Contractor shall provide the manufacturer's configuration and diagnostic software along with all licenses, software installation media and documentation/manuals to the Engineer at the completion of the Burn-In. Any special camera configurations or firmware updates shall also be delivered to the Engineer with this package.

(f) Vehicle Detection Systems (VDS).

1. General.

The Contractor shall assemble and install all necessary material and equipment and furnish a working VDS as shown on the Plans and as specified within the Specifications. All items that are required to complete the installation and ensure a fully functional and operational system shall be supplied by the Contractor.

Wiring connections in poles shall be environmentally sealed using a minimum of watertight electrical connectors, mastic electrical splicing tape, and standard electrical tape.

The Contractor shall provide a VDS installation complete with associated detection equipment, control equipment, power, and communications equipment as shown on the Plans and as specified within the Specifications. The Contractor shall provide an installation kit with mounting brackets, data cables, power cables, hardware and any incidentals required by the manufacturer.

The Contractor shall maintain full responsibility for the VDS housing mounting to the support structure and confirm that the VDS can be properly mounted on the support structure prior to installation. The Contractor shall securely mount the VDS on the support structure. The VDS shall be constructed and shall be adjusted to obtain optimum function of the VDS.

The VDS, cabinet, and other components shall be mounted at locations as shown on the Plans. The Contractor is responsible to ensure that the VDS does not interfere with the operation of any other ITS electronic equipment when installed.

The Contractor shall be responsible for VDS configuration and setting up initial pre-sets using the manufacturer's software.

a. Cabinet Equipment.

i. VDS Controller Cabinet Installation.

The ITS Cabinet for remote control of the VDS from ground level shall conform to the requirements in **Sub-Article 729.03(l)** and **Article 893.12, *"ITS Cabinet"***. The ITS Cabinet shall be installed at locations as shown on the Plans unless otherwise designated and approved by the Engineer.

The Contractor shall install the VDS controller in the designated space of the ITS Cabinet. The Contractor shall install any associated VDS equipment per the manufacturer's requirements and as shown on the Plans.

ii. Wiring and Connections.

Upon completion of wiring and connections, bundle all incoming cables and hold in place with nylon cable ties. Connect the front panel and chassis to the cabinet ground bus from a single point only.

Install cables and connectors so that the manufacturer's rated minimum bending radius and pulling tension are not exceeded. Take proper care to prevent abrasions to the cable jacket during installation.

b. Cables and Electrical Power Service.

The Contractor shall install the conduit for electrical cable between the service pole and the ITS Cabinet load center. Electrical Power Service shall conform to the requirements of **Sub-Article 729.03(m)** and **Article 893.13, *"Electrical Power Service and Transformer"***.

All VDS data cables shall be routed separate from any 120 Vac or greater power wiring or surge suppressor ground wiring.

Cable, shield or conductor used for VDS control, power supply, or grounding shall not be spliced.

c. Interface Protocol.

The Contractor shall provide the Engineer with the manufacturer's open software interface/protocols for the environmental sensor.

d. Manufacturer's Software.

The Contractor shall provide the manufacturer's configuration and diagnostic software along with all licenses to the Engineer at the completion of the Burn-In.

2. Radar Vehicle Detection System (RVDS).

Structure mounted equipment shall be installed per the manufacturer's recommendations for elevation and orientation.

After installation, the RVDS shall be tested for accuracy by comparing data collected by the RVDS to manual count data under the conditions as specified within the Specifications or as approved by the Engineer to verify the RVDS is operating within the accuracy requirements as specified within the Specifications.

3. Magnetometer Vehicle Detection System (MVDS).

In ground magnetometer units shall be installed per the manufacturer's recommendations for depth, orientation, and sealant. Structure mounted equipment shall be installed per the manufacturer's recommendations for elevation and orientation.

After installation, the MVDS shall be tested for accuracy by comparing data collected by the MVDS to manual count data under the conditions as specified within the Specifications or as approved by the Engineer to verify the MVDS is operating within the accuracy requirements as specified within the Specifications.

4. Bluetooth Data Collection System (BDCS).

Structure mounted equipment shall be installed per the manufacturer's recommendations for elevation and orientation.

After installation, the BDCS shall be verified as operational by confirmed matches of discoverable and/or non-discoverable Bluetooth devices between two BDCS locations for travel time purposes.

(g) Dynamic Message Sign (DMS).

1. General.

The Contractor shall assemble and install all necessary material and equipment and furnish a working DMS as shown on the Plans and as specified within the Specifications. All items that are

required to complete the installation and ensure a fully functional and operational system shall be supplied by the Contractor.

Wiring connections in poles shall be environmentally sealed using a minimum of watertight electrical connectors, mastic electrical splicing tape, and standard electrical tape.

The Contractor shall provide a DMS installation complete with associated control equipment, 120 Vac power, and communications equipment as shown on the Plans and as specified within the Specifications. The Contractor shall provide an installation kit with mounting brackets, data cables, power cables, hardware and any incidentals required by the manufacturer.

The Contractor shall maintain full responsibility for the sign housing mounting to the support structure and confirm that the sign can be properly mounted on the sign support structure prior to installation. The Contractor shall securely mount the sign on the sign support structure. Initially, the Contractor is to set the housing at a 3 degree tilt forward toward traffic and adjust the housing under both day and night conditions to optimize the view of the sign from the roadway by a motorist and eliminate random reflections as directed by the Engineer. Alternatively, the housing may be constructed at a 3-degree tilt toward traffic, if approved by the Engineer, but shall be adjusted to obtain the same optimization of the viewing of the sign from the roadway.

The Contractor shall attach and secure all mechanical hardware for initial attachment prior to the reopening of lanes to traffic. The Contractor shall complete attachment of hardware prior to the release of crane cables. The Contractor shall also install and connect the DMS wiring and communications cables to the ground cabinet and disconnect switch in the controller cabinet only after attaching and securing the sign to the sign structure.

During the Acceptance Testing, the Engineer will evaluate the initial setting of the sign and direct the Contractor to adjust the sign tilt if necessary. The Contractor shall use nylon stop washers with mounting attachments. For all structural aspects, stainless lock washers and nuts are unacceptable; use stainless steel nuts with nylon inserts for locking.

The Contractor will lift and install the DMS housing and display in place on the overhead structure only with prior approval of, and in the presence of the Engineer. Do not lift and install the DMS housing and display until all equipment, materials, and labor are available such that the DMS can be operated with messages from the local DMS controller within 72 hours of installation on the overhead structure. The Contractor shall only program message displays on the DMS at the direction of the Engineer. Make sight alignment adjustments to the DMS housing and display as directed by the Engineer.

Securely install mounting hardware to the torque recommended by the overhead sign support manufacturer.

The DMS shall be mounted at locations shown on the Plans. The DMS shall be mounted using the manufacturer supplied mounting brackets.

The Contractor is responsible to ensure that the DMS does not interfere with the operation of any other ITS electronic equipment when installed.

The Contractor shall be responsible for DMS configuration and setting up initial pre-sets using the manufacturer's software.

a. Photosensor System.

The Contractor shall aim one sensor in the northerly direction (away from nearby lights) and scale it for a reading of up to 100 lux (horizon type). The other two sensors shall be aimed in opposite directions and perpendicular to the sign face. These two sensors shall be scaled for a reading of up to 100,000 lux. The sensors are to be mounted on the top of the housing near the right side for ease of maintenance. The aiming angle of the sensors shall be adjustable. The Contractor shall aim the photosensors and calibrate the dimming system consistent with field conditions found for each sign as a part of the installation process. This work is to be completed prior to any Acceptance Testing.

b. Cabinet Equipment.

i. Controller Cabinet Installation.

The ITS Cabinet for remote control of the DMS from ground level shall conform to the requirements in **Sub-Article 729.03(l)** and **Article 893.12, *"ITS Cabinet"***. The ITS Cabinet shall be installed at locations as indicated on the Plans unless otherwise designated and approved by the Engineer. The ITS Cabinet shall be mounted to the support pole(s) at a height of 42 inches

{107 cm} from ground level to the bottom of the cabinet housing and shall be easily accessed by maintenance personnel.

The Contractor shall install the DMS controller unit in the designated space of the ITS Cabinet. The Contractor shall install any associated DMS equipment per the manufacturer's requirements and as shown on the Plans.

ii. Wiring and Connections.

Make all connections to terminal boards or screw-type equipment terminals with insulated fork-tongue compression connectors only when using stranded cable. Make all wiring to bulkhead connectors on equipment housings with MS bayonet-type connectors. Solder connector joints for use with extra-low voltage systems, with the joint metals preheated to the flow temperature of the solder or crimped using ratchet-type positive crimp tools and a double crimp (conductor and jacket) connector.

Remove the outer jacket of data and communications cables to expose approximately 6 in. {150 mm} of the shielding or drain wire. Twist together and solder the shielding or drain wire for all cables serving a similar function with a 10 AWG minimum insulated (green jacketed) ground lead securely connected to the cabinet ground bus. Make the ground lead routing as short as possible. Cut the shield off and leave it isolated at the other end.

Upon completion of wiring and connections, bundle all incoming cables and hold in place with nylon cable ties. Connect the front panel and chassis to the cabinet ground bus from a single point only.

The controller will be powered from the power distribution assembly provided in the ITS Cabinet. Bond the shields of all extra-low voltage cables to the ground bus inside the cabinet. The shield inside the sign enclosure shall be unconnected and insulated. Route low voltage cables and extra-low voltage cables installed in the cabinet on opposite sides of the cabinet. Group similar extra- low voltage cables in the controller cabinets, between common locations, together with cable ties.

Install cables and connectors so that the manufacturer's rated minimum bending radius and pulling tension are not exceeded. Take proper care to prevent abrasions to the cable jacket during installation.

c. Cables and Electrical Power Service.

The Contractor shall install the conduit for electrical cable between the service pole and the ITS Cabinet load center. Electrical Power Service shall conform to the requirements of **Sub-Article 729.03(m)** and **Article 893.13, *"Electrical Power Service and Transformer"***.

All DMS data cables shall be routed separate from any 120 Vac or greater power wiring or surge suppressor ground wiring.

Cable, shield or conductor used for DMS control, power supply, or grounding shall not be spliced. The shield of low voltage instrumentation cables shall be grounded at one end only.

d. Use and Operations of DMS Prior to Final Acceptance.

The Department will approve or control any and all DMS displays at all times that a display is in potential public view to ensure compliance with current MUTCD. When potential public view exists, no message or graphical display of any kind or activation of any DMS display component is permitted without prior approval of the Engineer. At such time as the Engineer determines that any given DMS is ready for Department control, the Department will exercise complete and total control of that DMS display and all central and local communications with that local DMS controller. Prior to any action, coordinate with the Engineer any remaining work or any testing or maintenance that may affect that DMS display. Do not interpret such DMS display control as acceptance of the project in whole or in part. Do not construe such action as a waiver by the Engineer of any provision of this Specification. Do not consider such use part of the Burn-In Period.

e. Interface Protocol.

The Contractor shall provide the Engineer with the manufacturer's open software interface/protocols for the DMS.

f. Manufacturer's Software.

The Contractor shall provide the manufacturer's configuration and diagnostic software along with all licenses to the Engineer at the completion of the Burn-In.

2. DMS Supporting Structure.

Supporting Structure used for mounting the DMS and equipment shall conform to the requirements given in **Sections 715, 717,** and **718**.

For each DMS, the Contractor shall provide a complete Supporting Structure design which shall include all structural dimensions for the supporting structure and associated foundations.

a. DMS Housing Structural Design.

Professional Engineer calculations and a complete set of sealed DMS housing drawings shall be included within the DMS manufacturer's submittal to the Engineer. [See **Item 893.07(a)3, *"Material and Process Standards"*** and **Item 893.07(a)4, *"Sign Housing"*** for special material submittal requirements regarding: (a) Professional Engineer Certification of DMS Housing Structural Design and (b) welding inspection certification.]

A lifting mechanism shall be provided for transporting and installing the DMS and shall be a permanent, integral part of the DMS housing structural frame. Professional Engineer analysis of the DMS housing design shall include a certification of the DMS lifting mechanism.

3. Concrete Foundation.

The Contractor shall submit Concrete Foundation design for each DMS Supporting Structure in accordance with **Section 718**. The foundation design shall include all dimensions and reinforcing steel configuration.

The Contractor shall contact the Utility Companies to determine the location of underground utilities in the area where the foundations are to be located. The Contractor shall be responsible for repairing, to the satisfaction of the Utility Company, any utilities damaged by the Contractor.

4. DMS Acceptance Test.

The Contractor shall perform Acceptance Test on the DMS and ITS electronic equipment installed under this Project and have materials specified within this Specification. The Acceptance Test shall be in accordance with **Sub-Article 729.03(r), *"Testing"***.

The Visibility Inspection of the Field Test shall include the continuous display of a test message on each sign for a period of twenty 24-hour days. If any sign fails unacceptably (traveling motorist cannot recognize the test message) to complete the 20 day Burn-In due to component failure, the component shall be replaced and the 20 day Burn-In Period shall be started again from day one.

Acceptable failures are those that do not inhibit the motoring public from message recognition. Any component failures that occur within the acceptable failure shall be replaced prior to final acceptance.

The Field Test of the Acceptance Test procedure shall prove that Central and Field Controller software comply with the Specifications, and it shall demonstrate that all DMS system equipment is fully integrated and operational.

The Field Test procedure shall include the successful exercising of all diagnostic features provided with the DMS. Testing of the DMS Central Software and Computer shall include demonstrating proper data transfer to and from each remote site.

(h) Environmental Sensor.

1. General.

The Contractor shall assemble and install all necessary material and equipment and furnish a working environmental sensor as shown on the Plans and as specified within the Specifications. All items that are required to complete the installation and ensure a fully functional and operational system shall be supplied by the Contractor.

Wiring connections in poles shall be environmentally sealed using a minimum of watertight electrical connectors, mastic electrical splicing tape, and standard electrical tape.

The Contractor shall provide an Environmental Sensor installation complete with associated control equipment, 120 Vac power, and communications equipment as shown on the Plans and as specified within the Specifications. The Contractor shall provide an installation kit with mounting brackets, data cables, power cables, hardware and any incidentals required by the manufacturer.

The Contractor shall maintain full responsibility for the sensor housing mounting to the support structure and confirm that the sensor can be properly mounted on the support structure prior to installation. The Contractor shall securely mount the sensor on the support structure. The sensor shall be constructed and shall be adjusted to obtain optimum function of the sensor.

The sensor, cabinet, and other components shall be mounted at locations as shown on the Plans. The Contractor is responsible to ensure that the sensor does not interfere with the operation of any other ITS electronic equipment when installed.

The Contractor shall be responsible for environmental sensor configuration and setting up initial pre-sets using the manufacturer's software.

a. Cabinet Equipment.

i. Controller Cabinet Installation.

The ITS Cabinet for remote control of the environmental sensor from ground level shall conform to the requirements in **Sub-Article 729.03(l)** and **Article 893.12, *"ITS Cabinet"***. The ITS Cabinet shall be installed at locations as shown on the Plans unless otherwise designated and approved by the Engineer.

The Contractor shall install the environmental sensor data processing unit in the designated space of the ITS Cabinet. The Contractor shall install any associated environmental sensor equipment per the manufacturer's requirements and as shown on the Plans.

ii. Wiring and Connections.

Upon completion of wiring and connections, bundle all incoming cables and hold in place with nylon cable ties. Connect the front panel and chassis to the cabinet ground bus from a single point only.

Install cables and connectors so that the manufacturer's rated minimum bending radius and pulling tension are not exceeded. Take proper care to prevent abrasions to the cable jacket during installation.

b. Cables and Electrical Power Service.

The Contractor shall install the conduit for electrical cable between the service pole and the ITS Cabinet load center. Electrical Power Service shall conform to the requirements of **Sub-Article 729.03(m)** and **Article 893.13, *"Electrical Power Service and Transformer"***.

All environmental sensor data cables shall be routed separate from any 120 Vac or greater power wiring or surge suppressor ground wiring.

Cable, shield or conductor used for environmental sensor control, power supply, or grounding shall not be spliced.

c. Interface Protocol.

The Contractor shall provide the Engineer with the manufacturer's open software interface/protocols for the environmental sensor.

d. Manufacturer's Software.

The Contractor shall provide the manufacturer's configuration and diagnostic software along with all licenses to the Engineer at the completion of the Burn-In.

(i) Highway Advisory Radio (HAR).

1. General.

The Contractor shall assemble and install all necessary material and equipment and furnish a working HAR as shown on the Plans and as specified within the Specifications. All items that are required to complete the installation and ensure a fully functional and operational system shall be supplied by the Contractor.

Wiring connections in poles shall be environmentally sealed using a minimum of watertight electrical connectors, mastic electrical splicing tape, and standard electrical tape.

The Contractor shall provide a HAR installation complete with associated control equipment, power, and communications equipment as shown on the Plans and as specified within the Specifications. The Contractor shall provide an installation kit with mounting brackets, data cables, power cables, hardware and any incidentals required by the manufacturer.

The Contractor shall maintain full responsibility for the HAR housing and antenna mounting to the support structure and confirm that the HAR can be properly mounted on the support structure prior to installation. The Contractor shall securely mount the HAR on the support structure. The HAR shall be constructed and shall be adjusted to obtain optimum function of the HAR.

The HAR, cabinet, and other components shall be mounted at locations as shown on the Plans. The Contractor is responsible to ensure that the HAR does not interfere with the operation of any other ITS electronic equipment when installed.

The Contractor shall be responsible for HAR configuration and setting up initial pre-sets using the manufacturer's software.

a. Cabinet Equipment.

i. Controller Cabinet Installation.

The ITS Cabinet for remote control of the HAR from ground level shall conform to the requirements in **Sub-Article 729.03(l)** and **Article 893.12, *"ITS Cabinet"***. The ITS Cabinet shall be installed at locations as shown on the Plans unless otherwise designated and approved by the Engineer.

The Contractor shall install the HAR controller in the designated space of the ITS Cabinet. The Contractor shall install any associated HAR equipment per the manufacturer's requirements and as shown on the Plans.

ii. Wiring and Connections.

Upon completion of wiring and connections, bundle all incoming cables and hold in place with nylon cable ties. Connect the front panel and chassis to the cabinet ground bus from a single point only.

Install cables and connectors so that the manufacturer's rated minimum bending radius and pulling tension are not exceeded. Take proper care to prevent abrasions to the cable jacket during installation.

b. Cables and Electrical Power Service.

The Contractor shall install the conduit for electrical cable between the service pole and the ITS Cabinet load center. Electrical Power Service shall conform to the requirements of **Sub-Article 729.03(m)** and **Article 893.13, "*Electrical Power Service and Transformer*"**.

All HAR data cables shall be routed separate from any 120 Vac or greater power wiring or surge suppressor ground wiring.

Cable, shield or conductor used for HAR control, power supply, or grounding shall not be spliced.

c. HAR Antenna Grounding.

The HAR antenna grounding design and design submittal shall be either conducted by or signed off by the HAR equipment manufacturer. The Contractor's HAR submittal package shall include antenna and grounding details showing design configuration and proposed equipment and materials, supporting design calculations, recommended installation methods/procedures to be utilized, and equipment and proposed material specifications/cut-sheets.

d. Interface Protocol.

The Contractor shall provide the Engineer with the manufacturer's open software interface/protocols for the environmental sensor so that it can be fully integrated.

e. Manufacturer's Software.

The Contractor shall provide the manufacturer's configuration and diagnostic software along with all licenses to the Engineer at the completion of the Burn-In.

(j) Conduit, Conductor, Locate Tone Wire, Warning Tape, and Messenger.

Work shall be performed in accordance with the highest industry standards, meeting the requirements of the latest editions of the NEC, NESC, and NEMA.

1. Installation of Buried Duct and Conduit.

Conduit shall be installed by means of open trenching, plowing, or precision directional boring. Spare conduit shall have Pull Tape installed in the duct. Maximum spacing between supports and spacing between expansion fittings shall be as shown on the Plans or, if not shown, according to the manufacturer's recommendations.

If rocky soil conditions are encountered during precision directional bore installations, SDR-9 HDPE conduit may be required as approved by the Engineer.

Coiled non-metallic conduit shall be treated by a line tamer prior to underground (or below grade) installation.

If more than one run of underground conduit is required, install in one trench unless in conflict with NEC requirements.

Extend conduit ends 2 inches {51 mm} above concrete surfaces and 4 inches {100 mm} above crushed stones bases; and install with bushings. For metallic conduit, install metallic bushings. For non-metallic conduit, install non-metallic bushings. Where conduit connects to a panel, box, or other enclosure, use a locknut in addition to the bushing.

Where non-metallic conduits join metal conduits, connection shall be made using appropriate couplings to form a watertight raceway.

All conduits entering concrete foundations shall be provided with appropriate bushings at the ends. Conduits shall be stubbed approximately 2 inches {51 mm} above concrete and shall be provided grounding type bushings on conduit ends in the base of poles with copper bonding jumpers.

Bends and offsets shall be avoided where possible, but where necessary, shall be made with a proper pipe bender or conduit bending machine. Conduit that has been crushed or deformed due to improper bending or handling shall not be installed.

Surface damage to RMC conduit shall be repaired in accordance with the Specifications. Exposed threads shall be regalvanized.

After installation, conduits shall be tested for clearance with a 2-inch long mandrel (a.k.a., pig) having a diameter 1/4 inch smaller than the inside diameter of the conduit. Conduits not allowing passage of the mandrel shall be rejected.

After placement of conduit, all conduits shall be capped to prevent moisture or foreign matter from entering until the fiber optic cable or conductor installation is started. Upon installation of fiber optic cable and/or conductor, conduit ends shall be sealed with duct sealer. Duct sealer shall be a water-blocking, closed-cell, easily removable/re-enterable, polyurethane foam material as recommended by the cable manufacturer and approved by the Engineer. Duct sealer shall be identified for use with the fiber optic cable and conductor insulation; and should not cause deterioration of the insulation over time. For underground conduit adjacent to gasoline service stations or other installations of underground gasoline or diesel storage, piping or pumps, and which lead to a cabinet, circuit breaker panel, service or any enclosure where an arc may occur during normal operation, the Contractor shall refer to the NEC for Class 1, Hazardous Locations.

2. Installation of Hanging Duct and Conduit.

Maximum spacing between supports and spacing between expansion fittings shall be as shown on the Plans or, if not shown, according to the manufacturer's recommendations.

The conduit system shall include mechanisms such as expansion fittings or joints to ensure that the expansion and contraction stresses are normalized. Spacing or expansion fitting shall be based upon manufacturer standards for the location conditions/environment of the installation.

After placement of conduit, all conduits shall be capped to prevent moisture or foreign matter from entering until the fiber optic cable or conductor installation is started. Upon installation of fiber optic cable and/or conductor, conduit ends shall be sealed as permitted by the current NEC. If duct sealer is allowed and used, then the duct sealer shall be a water-blocking, closed-cell, easily removable/re-enterable, polyurethane foam material as recommended by the cable manufacturer and approved by the Engineer. Duct sealer shall be identified for use with the fiber optic cable and conductor insulation; and should not cause deterioration of the insulation over time.

The Contractor shall be fully responsible in the event defective conduit is installed and shall be held fully responsible for replacement (material and labor) of any conduit found to be defective due to manufacture error, improper construction, or improper installation for one year after the State's acceptance of the project.

a. Installation of RTRC.

The conduit shall be packaged for shipment at the factory. The conduit shall be assembled into manageable bundles. Each section of conduit shall be shipped with protective caps over each end of the section. Conduit that arrives at the job site without the protective cover in place over both ends will be rejected by the Engineer.

Conduit connections for RTRC shall be sealed with epoxy adhesive. Joints for RTRC shall be joined until the conduit ends are together. Once connected the joint pullout rating shall be equal to the tensile strength of the conduit. No reducing couplings shall be permitted in a conduit run.

b. Installation of RMC.

The conduit shall be packaged for shipment at the factory. The conduit shall be assembled into manageable bundles. Each section of conduit shall be shipped with protective caps over each end of the section. Conduit that arrives at the job site without the protective cover in place over both ends will be rejected by the Engineer.

3. Installation of Conductor.

On projects where a conductor(s) and/or electrical cables are to be mechanically or hand pulled, a "*Pull Tape*" as specified in **Sub-Article 893.10(d)** shall be factory or field installed within conduit for the purpose of attaching to, and the pulling of said conductor/cable. PULL ROPES NOT SPECIFICALLY DESIGNED FOR FIBER OPTIC AND ELECTRICAL CABLE INSTALLATION SHALL NOT BE USED ON ANY ALDOT PROJECT.

Conductors shall have the appropriate identification on the outer jacket. Conductors not meeting this requirement or with illegible identification are not allowed.

Wiring within pull boxes and CommBoxes shall be neatly arranged and labeled/tagged. All ends of hardwire shall be taped to exclude moisture and shall be so kept until splices are made and terminal appliances attached.

The ends of spare conductors shall be protected as permitted by the current NEC (capped method is preferred). End of fiber optic cables shall be protected from moisture by methods as shown on the Plans or as approved by the Engineer.

Splices and taps in electrical conductors shall only be made in pull boxes, CommBoxes and pole bases. They shall be made with solderless split bolt connectors. Splices and taps shall be protected and sealed in silicone gel filled enclosures to provide a waterproof connection and to ensure the required electrical insulation. Silicone gel filled enclosures shall be re-enterable; shall be ultra-violet (UV) resistant, listed for temperatures from -40˚F to 194˚F {-40˚C to 90˚C}; and shall be impact and abrasion resistant. The enclosure shall be sized as shown in the following table:

CONDUCTOR SIZE	GEL ENCLOSURE SIZE
4 AWG and smaller	#2
2 AWG	#2.5
Larger than 2 AWG	#3

Installation of conductors shall be in accordance with the NEC. Conductors shall not be pulled into a conduit until the installation of the conduit is complete. Prior to the installation of conductors, the Contractor shall ensure the conduit is free of water and debris by blowing air and pulling a foam ball, mandrel, or brush through the conduit. The ends of conduit shall be cleaned of bures and capped with a bushing to protect cables during installation.

Conductors in conduits shall be carefully pulled into place using approved methods so that the conductors will not be damaged. Powdered soapstone, talc, or other inert lubricant specifically designed for the purpose shall be used when pulling conductors through the conduit. All conductors within a single conduit shall be pulled at the same time; and, shall be handled and installed in such a manner as to prevent kinks, bends or other distortion which could damage the conductor and outer covering. When conductors are pulled through hand holes, pole shafts, etc., a pad of firm rubber or other suitable materials shall be placed between the conductors and the edges of the opening to prevent damage to the conductors.

The pulling tension on conductors shall not be exceeded. Friction reduction multiduct pulling sleeves may be used as an alternate to lubricant. The Contractor shall not exceed the NEC conduit fill capacity requirements. Fiber optic cables shall not be installed in conduits containing current carrying conductors.

4. Installation of Locate Tone Wire.

Locate Tone Wire shall be installed along the entire underground conduit run for non-conductive fiber optic cables in accordance with this Specification and as shown on the Plans. Ensure that the Locate Tone Wire enters all CommBoxes and Pull Boxes as the fiber optic cable; and, that a minimum of 10 feet {3 meters} of slack is coiled and neatly stored in each box. Locate Tone Wire shall be suited for direct burial and shall be continuous.

Locate Tone Wire system does not require to be grounded since it is a non-current carrying conductor used for locating fiber optic cable only. Locate Tone Wire shall not be installed inside ITS Cabinets.

Where fiber optic conduit is installed via trenching operation, the Locate Tone Wire is to be installed no more than 3 inches {7.62 cm} above the conduit. Where fiber optic conduit is installed via boring operation, the Locate Tone Wire is to be installed in an encasement so that the Locate Tone Wire is external to the conduit with no separation between conduit and wire. Locate Tone Wire may also be placed in the void between the inner wall of encasement and inner conduits contained within the encasement as long as no other cables are present within the void.

Locate Tone Wire may be installed inside conduit only when non-armored fiber optic cable is the only other cable within the conduit for ease of utility locating.

The Contractor shall perform the Circuit Continuity Test and Insulation Test, as defined within this Specification, on all Locate Tone Wires. The Contractor shall document and provide the test results to the Engineer upon completion of these tests. The Contractor shall replace or repair defective Locate Tone Wire at no additional cost to the Department.

5. Installation of Messenger Wire.

The Contractor shall furnish and install messenger wire, aerial lashing, down guy, mounting hardware and fittings, insulators, and all other materials necessary to provide a support for fiber optic and electrical service cables. Messenger wire shall be attached to poles at the locations as shown on the Plans. Installations shall conform with all applicable NEC, NEMA and NESC requirements, along with any special Utility Company pole attachment requirements for the pole being attached. The suspension strand shall be placed on the roadside of the pole line unless otherwise directed by the Engineer.

The installation of messenger wire shall meet all requirements of the National Electrical Safety Code (NESC) regarding clearance from electrical lines and adjacent utility lines.

The Contractor shall be responsible for locating and drilling all holes required for the attachment of the messenger wire to the poles. The Contractor shall not use any existing holes on utility poles without prior authorization of the Engineer. Re-use of existing cable attachment hardware shall not be permitted.

The Contractor shall install messenger wire in continuous segments from pole to pole except where reel splice is required. Where splices are necessary, the Contractor shall maintain absolute minimum number of splices for total length of run. Prior approval for these messenger wire splices is required from the Engineer. The Contractor shall tension the unloaded messenger wire in accordance with the recommendations of the messenger wire and fiber optic cable manufacturers, to minimize the possibility of strand fatigue failure.

The length of the messenger wire shall be adjusted to ensure the vertical sag is not greater than a two percent of the length between the support poles once loaded with fiber optic cable. Each messenger wire shall be attached to the supporting structure with separate span wire clamps.

The messenger wire shall be grounded at all pole locations where attached in accordance with NESC and the pole owner's requirements. The Contractor shall not use existing Utility Company grounds. The messenger wire shall be bonded with bonding conductors and clamps to the pole's ground conductor. For poles without an existing grounding system, the Contractor shall install grounding electrodes. The messenger wire shall be bonded at maximum intervals of 1300 feet {396 m}.

6. Installation of Guy Wire.

Guy wire (a.k.a. down guy) shall be installed where there is room on the pole to install a bolt attachment in compliance with the National Electrical Safety Code (NESC). Attach the guy assembly and the guy cable to two separate bolts with one bolt for the span and one bolt for the guy cable. Provide 8 to 12 inch {200 to 300 mm} separation between bolts or as required by the owner.

The back guy (down guy) shall be installed, wherever possible, to provide a minimum rise of 2 and run of 1.

Anchor holes should be dug to such depths that no more than approximately 6 inches {153 mm} of anchor rods should be above ground after the strain is applied by the guys. Anchors should be in line with the guys.

Install guy wire prior to installation of messenger wire and lashed fiber optic or electrical service cable. The Contractor shall determine the guy locations and shall show each location to the Engineer prior to installation of guy. Not more than 6 inches {153 mm} of rod shall remain out of the ground after the load is applied.

Down guy shall have a guy marker (a.k.a. guy guard) installed in accordance with applicable NESC, NEMA and local Utility standards.

The Contractor shall be wholly responsible for the direct interface with the Utility Company whose pole is to be shared. The Contractor shall submit the drawing representing the aerial cable installation to the said utility for that Utility Company's determination and approval of the down guys which may be required on each project. All guys and guying plans shall also adhere to the NESC. Final guying plans shall be submitted for approval to the Engineer prior to the commencement of installation.

7. Installation of Warning Tape.

For Type 1 "Open Trench" Conduit Installations, the Contractor shall place the warning tape within the same ground cut (ditch) as the conduit and locate tone wire as shown on the Plans. Once the conduit and locate tone wire are placed, the cut/ditch shall then be backfilled up to a point no more than 12 inches {305 mm} below grade and at a maximum of 6 inches {152 mm} below grade where the Contractor shall then apply on continuous, unbroken length of the warning tape between the CommBoxes. The cut/ditch shall be completely filled in and prepared to its original state or as specified by the Engineer.

For Type 5 "Directional Bore" Conduit Installations, the warning tape shall not be required unless otherwise indicated on the Plans.

(k) Grounding, Lightning Protection, Insulation, and Circuit Continuity.

1. General.

Grounding electrodes (rods) shall be installed at all service equipment, cabinets, CommBoxes, Pull Boxes, and pole foundations as shown on the Plans or as required by the Engineer and in accordance with the NEC and NESC. CommBoxes and Pull Boxes require grounding electodes only when armored fiber optic cables or electrical service conductors are being installed in said box [see **Item 729.03(q)4, *"Installation of CommBox and Pull Box"***]. Hub Building and Generator equipment shall be grounded in accordance with their respective manufacturer requirements and in accordance with the NEC and NESC. The ground resistance value shall meet the values as defined within this Specification.

All metal enclosures, metallic conduits, raceways, armored fiber optic cable, and METALLIC junction boxes containing electric wires and equipment shall be bonded together and grounded to earth through the grounding electrode system.

The ITS Cabinet grounding system shall be isolated from any other grounding system, including a support pole grounding system.

The locate tone wire system shall be isolated from any other grounding system and shall not be extended into a cabinet or building [see **Item 729.03(j)4, *"Installation of Locate Tone Wire"***].

Ground busbars shall be provided in equipment racks, enclosures, buildings, and structures as necessary.

Single grounding electrodes (rods) shall be driven vertically until the top of the electrode (rod) is at least 12 inches {305 mm} below the finished grade.

Where a grounding conductor passes through a metal conduit, a suitable grounding bushing shall be placed on each end of the conduit and connected to a ground wire.

A grounding conductor, either bare or having a green colored insulation, shall be extended from the service ground to all equipment and shall be used for grounding purposes only. The grounding conductor must be installed in one continuous length.

Exposed grounding electrode conductors shall be protected against physical damage. Unless otherwise indicated on the Plans or in these Specifications, the grounding electrode conductor shall be connected to the grounding electrode by exothermic welding, listed lugs, pressure connectors or clamps.

The ground conductor shall be isolated and insulated from any utility grounding equipment.

2. Grounding for Electrical Power Service.

For Electrical Power Service and in addition to the above general grounding requirements, the Contractor shall install grounding electrode conductor (ground wire) up the wood pole to a point adjacent to the uppermost span. This grounding electrode conductor shall be secured to the wood pole with hot-dipped galvanized wire staples on 12 inch {300 mm} centers from ground level to 8 feet {2.4 m}. Above 8 feet {2.4 m}, wire staples are to be installed on 24 inch {600 mm} centers.

Grounding electrode(s) (ground rod) shall be installed at the base of the pole and exothermically weld the grounding electrode conductor (wire) to the grounding electrode (rod).

The messenger wire shall be bonded to the grounding electrode conductor using a clamp.

3. Lightning Protection.

Lightning Protection shall be installed as shown on the Plans at all poles greater than or equal to 75 feet {22.8 m} in height and at Overhead Sign Structures.

4. Insulation Testing.

The Insulation Testing (a.k.a. Isolation Test) shall be performed for each conductor in the cable to determine insulation resistance. These tests shall be performed using the NEC as a guide. Any connected ITS devices/equipment are to be removed prior to testing to prevent damage. Any reading of less than 250,000 ohms to ground is unacceptable and shall be corrected. The Contractor shall remove the defective cable, install new cable, and the test be repeated. These insulation resistance tests shall be conducted in the presence of the Engineer.

5. Circuit Continuity Test.

The Contractor shall perform Circuit Continuity Tests. Each branch circuit shall be temporarily jumpered at its termination and the temporarily loop circuit measured for continuity to assure that no open circuits exist, that the branch circuit is according to Plan, that no high resistance connections exist and that each circuit is properly identified. Each circuit shall be marked with typed labels.

6. Ground Resistance Test.

At each grounding electrode (rod) location, a resistance to ground test shall be conducted by the Contractor in the presence of the Engineer. This test shall be conducted using a null balance earth tester with two auxiliary ground rods placed 50 ft and 100 ft {15 m and 30 m}, respectively, from the tested grounding electrode (rod). A reading of **5 ohms (Ω) or less** is satisfactory. Any reading greater than 5 ohms (Ω) will require the installation of additional grounding electrodes (rods) to be placed in a pattern as shown on the Plans and in accordance with the NEC. After adjustments in the grounding electrode (rod) configuration, the test shall be repeated (and grounding electrode configuration adjusted) until a reading of 5 ohms (Ω) or less is obtained or to the satisfaction of the Engineer.

If a ground resistance measurement of 5 ohms or less cannot be achieved with the addition of grounding electrodes totaling 80 feet in length, the Engineer may accept this 80 feet of grounding electrodes where soil conditions prevent the grounding system from achieving the 5 ohms value so long as the test results meet NEC requirement of no more than 25 ohms.

Commbox with conductive optical fiber cables or electrical service conductors shall be grounded in accordance with the NEC. A reading of **25 ohms (Ω) or less** is satisfactory. Any reading greater than 25 ohms (Ω) will require the installation of additional grounding electrodes (rods) as detailed above. These cables shall be bonded together and grounded to earth through the grounding electrode in accordance with these specifications and the NEC.

Commbox with non-conductive optical fiber cables and locate tone wire installed will not require a grounding system installed.

For aerial installations requiring a messenger wiring system, a grounding electrode shall be installed in accordance with these grounding requirements and **Item 729.03(j)5, *"Installation of Messenger Wire"***. For this **messenger wire system,** a reading of **25 ohms (Ω) or less** is satisfactory unless otherwise directed by the pole owner and approved by the Engineer. Any reading greater than the specified ohms (Ω) resistance value will require the installation of additional grounding electrodes (rods) as detailed above.

Ground resistance test should not be performed after the earth surrounding the grounding electrodes (rods) has become wet due to weather or other means. Normal soil conditions and moisture content should be observed and noted on the ground resistance test results.

Ground enhancement materials (e.g. salts or other chemical treatments) are not to be allowed as an alternative in reaching the designated soil resistivity level.

The Engineer may require additional ground resistance testing to be performed after the completion of the Acceptance Test.

(l) Intelligent Transportation System (ITS) Cabinet.

1. General.

The Contractor shall assemble and install all necessary material and equipment and furnish a working ITS Cabinet as shown on the Plans and as specified within these Specifications.

ITS Cabinets shall be installed on poles, Overhead Sign Bridge (OHSB) Structures, mounting pads, or other methods as shown on the Plans and in accordance with these Specifications. Typically, ITS Cabinets are mounted on ITS poles except for DMS installations which are mounted on the OHSB structure supporting the DMS. ITS Cabinets being utilized as Hub Cabinets (i.e. fiber distribution hub application) are to be pad mounted.

All ITS Cabinets shall be furnished with mounting plates and other necessary hardware to mount the ITS Cabinet on a pole or foundation. The ITS Cabinet should be mounted as shown on the Plans or as directed by the Engineer. All items that are required to complete the ITS Cabinet installation shall be supplied by the Contractor.

ITS Cabinet installations shall include: power and communications run to and properly terminated within the cabinet; any required work and hardware to mount and/or anchor the cabinet; any fans, thermostat, or other electronic devices as shown on the Plans; any required patch cables for equipment housed within; any DIN rails, racks, or panels required for mounting or grounding equipment whether shown on the Plans or not; and any other equipment, materials, or labor needed to provide fully operational equipment within the cabinet housing.

ITS Cabinets being utilized as fiber optic hub cabinets shall also house the following: the trunk fiber optic cable storage and major routing points of the fiber optic network; the primary fiber distribution units; any required network switch gear; electrical power equipment; and various other devices. All hub cabinets shall be furnished with mounting plates and other necessary hardware to mount the ITS Cabinet on a foundation.

2. Wiring, Conductors and Terminal Blocks.

The Contractor shall enclose all cabling and wiring entering the cabinet housing in conduit. The Contractor shall securely and neatly dress all cabling and wiring inside the cabinet, including field wiring. The Contractor shall provide sufficient slack, minimum 2 feet {600 mm}, for cabinet equipment maintenance and re-termination of the field wiring. The Contractor shall route fiber drop cables into the cabinet to provide as much physical protection as possible; secure these drop cables through-out the cabinet; and strain-relieve these drop cables within the fiber termination unit.

The Contractor shall use stranded copper for all conductors, including those in jacketed cables, except for earth ground conductors, which may be solid copper. Neatly arrange all wiring, firmly lace or bundle it, and mechanically secure the wiring without the use of adhesive fasteners. All wiring and cabling shall be routed and secured to avoid sharp edges and to avoid conflicts with other equipment or cabling. Terminate all wiring on a terminal block, strip, busbar, or device clamp or lug; do not splice any wiring. Use a minimum 12 AWG for all conductors of 120 Volts AC circuits, unless otherwise shown on the Plans.

3. Surge Protection.

Surge-Protective Devices (SPDs) are required as defined in this Specification and shown on the Plans.

Surge-Protective Devices (a.k.a. surge suppression) shall be installed to protect all copper wiring and cabling entering the cabinet housing, except for the earth ground conductor. Terminate all wiring between cabinet devices and the transient surge suppressors, except for the video signal coaxial feed, on terminal strips. Use a minimum 16 AWG grounding of each surge-protective device, or larger if recommended by the surge-protective device manufacturer. Insulated green wire and connected the ground wire directly to the ground busbar. Do not "*daisy chain*" with the grounding wires of other devices including other surge suppressors. Dress and route grounding wires separately from all other cabinet wiring. Install grounding wires with the absolute minimum length possible between the surge-

protective device and the ground busbar. Label all surge-protective devices with silk-screened lettering on the mounting panel.

Use minimum 18 AWG insulated black wiring between the surge-protective device sockets and the terminal blocks for the protected circuits, or larger if recommended by the surge-protective device manufacturer.

4. Component Installation.

All components/devices of the ITS Cabinet assembly shall be rack mounted with Phillips-head machine screws. Install screws into tapped and threaded holes in the panels. These components/devices include but are not limited to terminal blocks, busbars, panel and socket mounted surge-protective devices, circuit breakers, accessory and equipment outlets, VDS interface, video encoders, fiber distribution units and field network switches. Fasten all other cabinet components with hex-head or Phillips-head machine screws installed with nuts (with locking washer or insert) or into tapped and threaded holes. These other components include, but are not limited to: door switches, fans, lights, thermostats, thermal blocks, and door lock mechanisms. Fasten stud-mounted components to a mounting bracket providing complete access to the studs and mounting nuts. All fastener heads and nuts (when used) shall be fully accessible with a complete ITS Cabinet assembly, and any component/device shall be removable without requiring removal of other components, panels, or mounting rails. Do not use self-tapping or self-threading fasteners.

5. Electrical Power Service.

The Contractor shall provide electrical power service in accordance with these Specifications and as shown on the Plans.

6. Grounding.

The Contractor shall provide the ITS Cabinet assembly with grounding and shall be connected upon ITS Cabinet installation in accordance with these Specifications and as shown on the Plans. The Contractor shall measure the resistance to ground at each ITS Cabinet location in the presence of the Engineer. Do not splice the ground conductor between the cabinet grounding terminal and the ground rod.

7. Mounting Brackets.

Where the ITS Cabinet is pole or structure mounted, the ITS Cabinet shall be installed utilizing mounting brackets and all appurtenances necessary in accordance with the Specifications and as shown on the Plans. ITS Cabinet shall not move or flex on the structure/pole once installed and with all equipment populated. Cabinet wall reinforcement by the cabinet manufacturer may be necessary.

8. Foundation (Mounting Pad).

Where the ITS Cabinet is pad mounted, a concrete mounting pad foundation shall be installed in accordance with the Specifications and as shown on the Plans.

9. Concrete Pad (Service Platform).

Where the ITS Cabinet is pole or structure mounted, a poured in place concrete pad shall be installed below the ITS Cabinet where the Plans show it as required. This concrete service platform pad shall be installed in accordance with the Specifications and as shown on the Plans.

(m) Electrical Power Service and Transformer.

The entity (City, County, State, etc.) that will be responsible for the eventual operation and maintenance of the fiber optic and/or ITS equipment will make application for electrical service upon notification that power service will be required. The Contractor shall inform the Engineer when power service is required at least 30 calendar days prior to the need of the electrical power service. This same entity will be responsible for the cost of the service connection and the monthly service billings thereafter.

The location of the utility service point and power source shown on the Plans is approximate. The Contractor shall determine the exact location, voltage, procedure, and materials required by the Utility Company. The Contractor shall obtain the Engineer's approval of this exact power/service location prior to installation.

When the service equipment is to be installed on a utility-owned pole, the Contractor shall furnish and install riser, conduit, conductors, and other necessary material to complete the installation of the service. The position of the riser and equipment will be determined by the Utility Company.

When the Contractor is to provide a lateral drop from the power source to the service pole, the Contractor shall arrange with the serving Utility Company to complete the service connections. The Contractor shall install the riser, conduit, conductors, enclosure and accessories, disconnect switch(es), meter base and service pole.

No cable used for power supply shall be spliced.

1. Service Pole (Wood Pole).

Service Pole (Wood Pole) shall be installed below grade a minimum depth equal to one-sixth the total pole height. Refer to AASHTO "*Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*", current edition.

All final pole locations shall be marked. The Engineer shall approve each location prior to the commencement of drilling of each hole.

When service pole is installed on a slope of 2:1 or greater, the installation depth shall be increase by 1 times the diameter of the pole (depth is to be measured from the down slope side of the pole.)

The backfill shall be native material in 1 foot {300 mm} lifts to match surrounding grade. Tamp each lift to 90 percent compaction.

Existing wood poles and required wood poles used to support messenger wire or to serve as the source of power shall be grounded.

2. Guy Wire.

Guy Wire (a.k.a. down guy) shall be installed in accordance with the requirements of this Section and as shown on the details in the Special and Standard Highway Drawings, unless otherwise shown on the Plans.

3. Transformer (Step-Up/Step-Down).

The Contractor shall provide step-up/step-down Transformers in accordance with these Specifications and as shown on the Plans.

(n) Intelligent Transportation System (ITS) Pole.

1. Installation and Handling.

The Contractor shall handle and install ITS poles (especially concrete poles) in accordance with the manufacturer's standard operating procedures, the requirements of **Section 718** and **Section 891**, and the following requirements:

a. Transportation, site handling and erection shall be performed by qualified personnel with acceptable equipment and methods.

b. ITS poles shall be lifted and supported during the manufacturing, stock piling, transporting and erection operations only at the lifting or support points, or both, as shown on the shop or erection drawings.

c. Erection drawings for each ITS pole shall be provided which identify the structure number, structure length, shipping weight, center of gravity and lifting points. Each ITS pole shall be clearly marked with the corresponding information.

d. Prior to unloading concrete ITS pole, shop drawings shall be reviewed to identify proper pick-up points for unloading, storage and erection procedures. A thru-hole may be provided at the proper single point pick-up location to enable a steel bar to be inserted as a safety stop for slings during the erection process (this bar is NOT a lifting device but serves only as a safety stop to prevent the sling from sliding).

e. Each ITS pole shall be vertical installed within 1/8 inch per 10 feet {3 mm per 3 m} of height.

f. The Contractor shall be responsible for digging holes for each concrete ITS pole. Concrete ITS poles shall be placed in hole using appropriate equipment and held in vertical position until backfill has been completed in order to maintain pole position.

2. Concrete Foundation.

For each ITS Pole that requires a concrete foundation, the Contractor shall submit Concrete Foundation design in accordance with **Section 718**. The foundation design shall

The Contractor shall notify the Engineer, who shall insure that conduit and elbows are securely attached, before concrete is poured.

The Contractor shall contact the Utility Companies to determine the location of underground utilities in the area where the foundations are to be located. The Contractor shall be responsible for repairing, to the satisfaction of the Utility Company, any utilities damaged by the Contractor.

3. Auger Base Foundation.

Auger Base Foundation (screw-in helix type) shall be for vehicle detection (i.e. radar and magnetometers) installations on metal ITS poles only as shown on the Plans and defined within these Specifications. Auger Base Foundation shall be installed by being augered into place per the manufacturer's installation and standard operating procedures. If the auger base foundation cannot be installed by augering and upon the Engineer's prior approval, the auger base foundation may be installed by being encased in concrete.

If recommended by the auger base manufacturer, a pilot hole may be used to facilitate the installation of an auger base foundation. The diameter and depth of the pilot hole shall not exceed the maximum dimensions as calculated and specified by the manufacturer.

Auger Base Foundation shall also conform to the installation requirements of **Section 718** and **Section 891**, except for the concrete encasement allowance option as defined in this Section.

The Contractor shall contact the Utility Companies to determine the location of underground utilities in the area where the foundations are to be located. The Contractor shall be responsible for repairing, to the satisfaction of the Utility Company, any utilities damaged by the Contractor.

(o) Hub Building.

1. General.

Hub Building components shall include, at a minimum, the following: hub building, foundation footing, HVAC system, interior electrical distribution system, lighting, fire extinguisher, lightning protection system, interior and exterior grounding, generator with automatic transfer switch, and other items as indicated within these Specifications and shown on the Plans. This work shall include site preparation, procurement, transportation, and installation of a Hub Building with conduit connections to the size and number of conduits specified on the Plans.

Hub Building shall be placed at the designated location on and anchored to the concrete slab with slab foundation being a minimum of 1 foot above grade, said slab supplied by the Contractor as per the Specifications and as shown on the Plans. All Hub Building joints are to be sealed as recommended by the building manufacturer.

The Contractor shall provide three (3) sets of Hub Building keys to the Engineer no more than 18 hours after Hub Building installation.

The required outside surface treatment (e.g. paving, graveling, etc.) and fencing around the Hub Building shall be paid under their respective pay items and as shown on the Plans.

2. Electrical Power Service.

The Contractor shall provide Electrical Power Service in accordance with these Specifications and as shown on the Plans. This includes a Generator with Automatic Transfer Switch and Uninterruptible Power Supplies (UPSs).

3. Gas Utility Service.

The Contractor shall provide Gas Utility Service in accordance with these Specifications and as shown on the Plans.

4. Grounding.

The Contractor shall provide grounding in accordance with these Specifications and as shown on the Plans.

5. Security Fence.

A security fence shall be installed around the Hub Building as shown on the Plans. The security fence and gate for the Hub Building will be paid for using other pay item(s) as shown on the Plans.

6. Hub Building Foundation.

A concrete foundation footing shall be installed in accordance with the Specifications and as shown on the Plans.

(p) Gas Utility Service.

The location of the utility service point and gas source shown on the Plans is approximate. The Contractor shall coordinate with the local gas Utility Company to determine the exact location,

procedure, and materials required for each service point. The Contractor shall obtain the Engineer's approval of this exact service location prior to installation. Depending upon local codes, a permit may be required and is the responsibility of the Contractor.

The Contractor shall provide necessary items not provided by the local gas Utility Company to make said service connection to the Hub Building Generator and associated equipment. This typically includes the fuel line which consists of gas piping from the gas meter to the generator along with connection to the generator. The local gas Utility Company typically provides the meter set (gas meter along with a gas line pressure regulator if required) and the service line (piping from main distribution line to meter set). The gas service components are to meet or exceed applicable installation requirements of the American Gas Association (AGA), National Fuel Gas Code (NFGC), and the local gas Utility Company.

Gas Utility Service shall also conform to the requirements of **Section 646** and **Section 861**.

After Contractor completes the fuel line installation and prior to the Utility Company making connection; this gas utility service installation will be subject to inspection and approval as required by local codes.

The entity that will be responsible for the eventual operation and maintenance of the Hub Building (or other infrastructure requiring such utility as shown on the Plans) will make application for gas utility service upon notification that service will be required. The Contractor shall inform the Engineer when gas service is required at least 30 calendar days prior to the need of said service. After which, the Contractor may arrange with the serving gas Utility Company to complete the service connection. The Department's Area Office (or other entity as noted above or indicated on the Plans) will be responsible for the cost of the service connection by the Utility Company and the monthly service billings thereafter.

(q) Miscellaneous Infrastructure.

The Contractor shall assemble and install all necessary material and equipment and furnish working equipment as shown on the Plans and as specified within the Specifications. All items that are required to complete the installation and ensure a fully functional and operational system shall be supplied by the Contractor.

Wiring connections in poles shall be environmentally sealed using a minimum of watertight electrical connectors, mastic electrical splicing tape, and standard electrical tape.

1. Connector Termination Procedures.

   The procedure to be used for the termination of the **SC** connectors used and shall meet that process set out in that connector manufacturer's Standard Operating Procedure for the field installation. Fiber optic connectors shall meet the assertion loss for connectors as specified within the Specifications.

   The Contractor shall perform the final inspection of connector faces with a 200X scope.

2. Installation of Splice Closure (Underground and Aerial).

   Splice Closures are required for housing and managing outside plant fusion splices, whether installed in underground or aerial applications.

   When splicing inside a building or cabinet, a splice center shall be provided in rack or wall space utilizing fiber distribution units (FDUs) as indicated on the Plans and in accordance with **Article 729.03(c), "*Fiber Distribution Units (FDU), Connectors, and Fan-Out Kit*"**.

   Splice Closure shall be installed per manufacturer's Standard Operating Procedure, whether installed underground or aerially.

   The application and installation of an aerial splice closure shall be performed in such a manner as to allow complete splice access after closure placement. This access shall be without the removal of the closure or electrical bonds from the messenger wire. The splicing procedure and splice tray storage within the closure shall be performed in such a process as to allow for aerial re-entry and inspection of the closure.

   The Contractor shall provide aerial splice closure with manufacturer recommended mounting hardware for attaching to the messenger wire. The Contractor shall not be allowed to mount any splice closures on utility poles.

   The Contractor shall also provide and submit, for Engineer approval, the splice closure mounting hardware cut-sheets with the Material Submittal package.

3. Installation of Riser Assembly.

The Contractor shall furnish and install Riser Assembly in accordance with the Plans. The Riser Assembly shall consist of a metallic riser, backplates, mounting brackets, supports, any accessories, and required hardware as defined within the materials section and as shown on the Plans. The Riser Assembly shall be installed in conformance to the details shown on the Plans and meet all applicable NEC, NEMA and NESC requirements, along with any special Utility Company pole attachment requirements for the pole being attached.

For electrical service installations, the riser shall utilize a conduit, unless otherwise shown on the Plans.

For fiber optic installations, the riser shall utilize a U-Guard with backplate, unless otherwise shown on the Plans. The riser end attached to the wood pole shall be foam filled. The Contractor shall be responsible to calculate the minimum bend radius of the fiber optic cable and shall install the riser and fiber optic cable accordingly.

4. Installation of CommBox and Pull Box.

The Contractor shall install CommBoxes in the four steps specified in the Standard/Special Project details. A poured in place concrete collar shall also be installed around the CommBox in accordance with the Specifications when required by the Standard/Special Project Details and as shown on the Plans. This concrete collar shall be formed separately from any ITS concrete pole or structure foundations.

The Contractor shall install Pull Boxes as shown on the Plans.

The Contractor shall also install the Cable Rack for storing fiber optic cable maintenance coils and mounting splice closures within the CommBox and Pull Box as specified within this Specification and as shown on the Plans. The Contractor shall submit, for Engineer approval, the Cable Rack shop drawings/cut-sheets of the materials to be installed with the Material Submittal package.

No drilled holes shall be allowed in CommBoxes or Pull Boxes unless specified otherwise as shown on the Plans and accepted by the Engineer.

A grounding electrode (rod) shall be installed at CommBox and Pull Box locations where armored fiber sheaths for fiber optic cables and electrical service conductors are required to be grounded in accordance with the NEC and this Specification.

5. Installation of Fiber Marker Post.

Fiber Marker Post shall be installed according to the placement specified in the Standard/Special Project details. Fiber marker post shall be anchored with manufacturer's recommended anchoring system.

A "*proof check*" sample for the fiber marker post dome graphics, of quantity one, shall be produced and provided to the Engineer prior to procurement of the remaining units. The Contractor is required to obtain the Engineer's approval of the production fiber marker post including the dome cover label graphics prior to subsequent procurements by the Contractor. If the Contractor does not obtain approval prior to subsequent procurements, the Contractor assumes the risk of the fiber marker post being rejected even after installation. No payment shall be made to the Contractor if the fiber marker post is rejected.

Fiber marker post shall be placed no later than three days following the installation of the conduit that shall contain fiber optic cables. The Contractor shall be responsible for safeguarding the conduit and cables during the installation of the fiber marker posts. Any conduit or cables damaged during marker post installation shall be removed and replaced at the Contractor's expense.

6. Installation of Frequency Locate Marker.

Frequency Locate Markers shall be installed according to the placement specified in the Standard/Special Project details. Frequency Locate Markers shall be anchored with manufacturer's recommended anchoring system.

Frequency Locate Markers shall be placed no later than three days following the installation of the CommBox. The Contractor shall be responsible for safeguarding the conduit and cables during the installation of the Frequency Locate Markers. Any conduit or cables damaged during Frequency Locate Marker installation shall be removed and replaced at the Contractor's expense.

7. Installation of Surge-Protective Devices.

a. All conducting cables (i.e. communication, data, and power) entering the ITS Cabinet shall be surge protected as indicated on the Plans and in accordance with **Sub-Article 893.17(i), "*Surge Protection*"**.

b. Hub Buildings shall be surge protected as indicated on the Plans and in accordance with **Article 893.15, "*Hub Building*"** and **Sub-Article 893.17(i), "*Surge Protection*"**.

c. Electrical Power Service shall be surge protected as indicated on the Plans and in accordance with **Article 893.13, "*Electrical Power Service and Transformer*"** and **Sub-Article 893.17(i), "*Surge Protection*"**.

d. Dynamic Message Sign shall have surge protection in accordance with **Item 893.07(a)9, "*Transient Protection*"** and **Sub-Article 893.17(i), "*Surge Protection*"**.

(r) Testing.

1. Terminology.

Wherever the following terms are used in **Section 729** and **Section 893** the intent and meaning shall be interpreted as follows:

- *ITS Electronic Equipment* – Electronic equipment and/or devices paid for under **Article 729.04** and **Article 729.05**.
- *Interoperability* – The capability to operate devices from different manufacturers or different device types within the same communications system.

2. General.

Testing is a critical component of an ITS project. Not only does testing ensure the project was constructed as shown on the Plans and as specified within the Specifications, but it also validates the intent of the system. The following tests are conducted as part of each ITS project: Bench Testing, Field Testing, and Acceptance Testing.

The Contractor shall secure a test site for the Bench Test as shown on the Plans and as specified within this Specification. The test site must be submitted by the Contractor at the Pre-Construction meeting for approval by the Engineer. The Contractor shall provide the test location and facility, which shall be in the State of Alabama and within a twenty-five (25) mile radius of the project limits unless otherwise approved by the Engineer. If the Contractor fails to get test location approval prior to commencing any tests, the Contractor may be required to move testing to another site at the Contractor's expense.

There will be no direct payment to the Contractor for the cost of a suitable test site and for the setting up of the equipment for these tests. Testing should include all applicable items required to complete testing.

The Contractor shall notify the Engineer to schedule an Acceptance Test a minimum of seven (7) calendar days before each proposed test date. After successfully confirming attendance of all necessary personnel, the Engineer shall provide the approved test date to the Contractor and all attendees.

The Contractor shall perform tests in the presence of the Engineer. When problems arise during testing, the Engineer can require the Contractor to have a qualified technical representative on site during the specific testing. The Contractor shall arrange, at no additional expense to the Department, the attendance of the equipment manufacturer's qualified technical representative.

If any ITS electronic equipment requires re-test, the above minimum test information shall be provided for each re-test per each piece of equipment.

Once a test is completed, a copy of the Test Result Documentation shall be submitted to the Engineer within seven (7) calendar days following completion of test activities. Any given test session is considered incomplete until the Engineer has approved the documentation for that test session.

It shall be the Contractor's responsibility for successful completion of each test. Any equipment which fails any tests shall be subject to re-test at no additional cost to the Department.

The Engineer's approval of test procedures, Test Result Documentation, and witnessing of such tests shall not relieve the Contractor of their responsibility to provide a completely acceptable and operating ITS project.

3. Bench Test.

The Contractor shall perform a Bench Test on all ITS electronic equipment and ITS Cabinets prior to installation. The Bench Test shall be performed by the Contractor at the approved test location and witnessed by the Engineer.

The Bench Test shall consist of the following two test phases:

a. The Visual Inspection phase shall consist of visually inspecting all Intelligent Transportation System (ITS) electronic equipment, ITS Cabinets and materials to insure there is no physical damage; and that the equipment and cabinets conform to their approved material submittal cut sheets.

b. The Manufacturer's Startup and Diagnostics test phase shall consist of the Contractor performing the manufacturer's out-of-the-box startup and diagnostic test for each piece of ITS electronic equipment, using the respective manufacturer's recommended startup diagnostics, configuration, and testing. The Contractor shall submit with the Material Submittal the manufacturer's recommended startup and diagnostic test procedures for review and approval prior to conducting the Bench Test.

The Contractor shall supply all temporary wiring and cabling (e.g. CAT-5/6/6A, RS-232/422/485, DVI, VGA, Coaxial, etc.), laptop, diagnostic software, and electrical service necessary for the Bench Test.

Test Result Documentation for the Bench Test, for each item in full contract quantity, shall be submitted to the Engineer for approval. The Engineer's approval shall be in writing.

The Contractor shall deliver all manufacturers' configuration and diagnostic software to the Engineer at the completion of the Burn-In.

4. Field Test.

The Field Test shall demonstrate that the ITS electronic equipment is properly operating, configured, and transmitting data to ALDOT's Intelligent Transportation Systems software applications as shown on the Plans and as specified within the Specifications. This test is conducted in the field at each ITS device site.

The Contractor shall not begin the Field Test until all ITS electronic equipment has successfully passed the Bench Test and its Test Result Documentation has been approved by the Engineer in writing.

Before beginning any Field Test, the Contractor shall develop and submit for the Engineer's written approval a "*Functional Operations Test Procedures (FOTP)*" document. The purpose of the "FOTP" document is to: (1) identify the functional requirements to be tested; (2) define the test procedure steps required for testing these functional requirement(s); and, (3) identify the expected results for successfully passing each test procedure.

The "*FOTP*" document shall consist of the following items for each requirement to be tested, at a minimum:

- Identify the ITS equipment to be tested;
- Provide wiring diagram/sketch of the test setup configuration;
- Identify and state the functional requirement(s) for equipment;
- Identify any equipment and materials needed to perform the tests;
- List the test steps to be performed; and,
- Identify and define the expected results for successfully passing each test step (clearly identify pass/fail criteria).

The Contractor shall submit to the Engineer the "FOTP" document in its entirety such that a thirty (30) day review process may occur by the Engineer. No Field Test at any given site can begin until the "FOTP" document has been accepted by the Engineer.

The Contractor shall not begin any Field Test until all work at that location is complete.

The Contractor shall perform a Field Test for each individual device at the site.

The Field Test shall consist of the following:

a. Visual Inspection.

The Visual Inspection shall consist of the Engineer visually inspecting all ITS electronic equipment, ITS Cabinets and materials to ensure that they were not damaged while being transported from the Bench Test location to the project site and being installed.

b. Field Demonstration.

The field demonstration shall consist of the Contractor demonstrating to the satisfaction of the Engineer the following minimum requirements:

ITS electronic equipment, ITS Cabinets and associated materials have been installed as shown on the Plans;

ITS electronic equipment has been properly connected (including the patch cables, fiber drop cable, and cable termination);

Perform Continuity Test on supplied network, coaxial, DVI and VGA cabling; and,

Inspect the installation of grounding and the surge protection systems (includes performing and successfully completing the Insulation Test, Continuity Test, and Ground Resistance Test as shown on the Plans and as specified within this Specification).

c. Performing Functional Operation Test Procedures (FOTP).

The Functional Operations Test Procedures shall consist of the Contractor demonstrating to the satisfaction of the Engineer the following minimum requirements:

- Demonstrate that each piece of ITS electronic equipment is fully operational by performing the manufacturer's recommended startup and diagnostic test procedures.
- Demonstrate that each piece of ITS electronic equipment performs their respective specific functional requirements (as outlined within the following CCTV and VDU equipment requirements within this Specification; and, as detailed in their respective Specifications and on the Plans); and,
- Demonstrate that each piece of ITS electronic equipment transmits data to the ATMS software located at ALDOT's Area Traffic Management Center (TMC). [ALDOT Area TMC personnel and/or Computer Service Bureau's ATMS Support personnel will verify if the transmitted data is received properly by the ATMS software.]

The following ITS electronic equipment shall be tested for these minimum functional requirements:

i. Closed Circuit Television (CCTV) Equipment:

The Contractor shall furnish a laptop, the manufacturer's CCTV Embedded Protocol Control Software, and a 13-inch or larger color video monitor to demonstrate full operation of the CCTV camera. This demonstration of operation shall include: pan, tilt, focus, zoom, iris, position feedback, and communications address configuration. The video signal strength shall be measured at the video connector of the communications equipment.

ii. Vehicle Detection (VDU) Equipment:

The Contractor shall furnish a laptop with the manufacturer's configuration, diagnostic, and monitoring software to demonstrate full operation of the VDU equipment. VDU equipment is typically (A) Radar Vehicle Detection (RVD) and/or (B) Bluetooth Vehicle Detection (BVD) devices as setup in the project. This demonstration of operation shall respectively include: (A) true presence detection, vehicle count, occupancy, speed information, and communications address configuration; and (B) point-to-point detection of vehicles carrying devices that utilize Bluetooth technology, collection of anonymous Media Access Control (MAC) address of these Bluetooth devices, includes date/time stamps as MACs are collected, and necessary software/firmware that determines real-time and statistical travel time data (e.g. travel times, traffic speeds, etc.). The testing for the Functional Accuracy Requirements as specified in Section 739 shall be included.

The Contractor and the Engineer shall perform the "*FOTP*" tests for each device installed at the site being tested. Results shall be documented on these "*FOTP*" test report forms.

The Contractor shall supply all temporary wiring and cabling (e.g. CAT-5/6/6A, RS-232/422/485, DVI, VGA, coaxial, etc.), laptop, and diagnostic software necessary for the Field Test and performing the Functional Operations Test Procedures.

The Contractor shall generate Test Result Documentation for the Field Test which shall be broken down by project site and include all ITS electronic equipment installed at each site. The complete package of the Test Result Documentation for the Field Test shall be submitted to the Engineer for acceptance. The Engineer's acceptance shall be in writing.

5. Acceptance Test.

The Acceptance Test shall demonstrate that the ITS electronic equipment installed in the field is properly communicating, operating and configured through ALDOT's Intelligent Transportation Systems software applications.

The Contractor shall not begin the Acceptance Test until all ITS electronic equipment has successfully passed the Field Test and its Test Result Documentation has been approved by the Engineer in writing. The Acceptance Test is typically conducted at the ALDOT TMC closest to the project location. However, the Engineer may approve a different location to conduct the Acceptance Test at his/her discretion.

The Contractor shall perform an Acceptance Test for each individual site.

The Contractor shall not begin the Acceptance Test until all work at each site is complete and Field Test results accepted by the Engineer.

The Acceptance Test shall consist of performing the FOTP that were conducted as part of the Field Test.

The Contractor shall generate Test Result Documentation for the Acceptance Test. The Acceptance Test shall be submitted to the Engineer for acceptance. The Engineer's acceptance shall be in writing.

(s) Burn-In.

The Contractor shall perform Burn-In on the ITS electronic equipment, ITS Cabinets and materials to ensure their proper operation, interoperability and service for an extended time frame within actual field conditions and without any failures or maintenance problems.

The Contractor shall not begin the Burn-In until the Acceptance Test has been successfully completed for all sites and approved by the Engineer in writing.

After confirming all sites have successfully completed the Acceptance Test, the Engineer shall send written notice to the Contractor and all necessary personnel of the authorized Burn-In start date.

The Burn-In Period shall be thirty (30) consecutive calendar days without system failure. During the Burn-In Period, the Contractor shall expeditiously perform any necessary adjustment and replace any malfunctioning parts of the equipment required to place the system in an acceptable operational condition to the satisfaction of the Engineer. No extra compensation will be allowed for any work so required, such being considered incidental to furnishing and installing a complete operational system.

During the Burn-In Period, time charges shall be suspended if all other work has been completed and accepted pending the results of the Burn-In.

The Contractor shall deliver the As-Built Drawing package and all the ITS device manufacturers' Embedded Protocol Control software packages to the Engineer at the completion of the Burn-In.

The Burn-In Period is intended to be concurrent for all sites within the project. However, the Engineer may elect due to a state of emergency to allow multiple concurrent Burn-In periods to occur based on a breakdown of the project at his/her discretion (e.g., DMS sites, Camera sites, individual sites, etc.).

An equipment failure during the Burn-In Period is defined as a condition where a component stops functioning. A system failure is defined as a condition under which the system is unable to function as a whole or in significant part to provide the services as designated. While a single component failure may not constitute a system failure, chronic failure of that component or component type may be sufficient to be considered a system failure as determined by the Engineer. What constitutes a chronic failure shall be agreed upon in writing by the Contractor and the Engineer prior to beginning the Burn-In.

ITS electronic equipment which has repeated failures (repeated failures are defined as more than two in a thirty-day period) during the Burn-In Period shall be replaced by the Contractor at no cost to the Department. Field Test must be conducted for the new equipment and the Engineer's acceptance shall be obtained for said testing. Upon satisfactory completion of the testing, the Engineer will provide written authorization to commence with a thirty (30) day Burn-In Period for the new equipment.

Final acceptance shall mean successful completion of Burn-In to the satisfaction of the Engineer.

If any equipment or device fails to complete the thirty (30) day Burn-In Period, the Burn-In Period shall be suspended and time charges resumed. The Burn-In Period will not be restarted except when the following has been met:

- Repairs to the malfunctioning equipment/device have been satisfactory completed; and,
- The repaired equipment/device is to be re-tested and proven to be properly functioning.

Only upon the Engineer's acceptance of the repaired equipment/device, will the Contractor be allowed to resume the Burn-In Period.

General communication outage or failure due to hardware is considered a system failure in any case. Communication failure due to a minor component may not be a system failure. Specifically exempted as system failures are failures caused by accident, natural disasters, or other external forces. The Engineer will advise the Contractor in writing when it considers that a system failure has occurred, or a chronic failure exists.

Each system failure during this Burn-In Period shall require restarting the clock plus an additional two (2) calendar days of successful operation prior to being eligible for final acceptance (i.e., if there are two system failures during the initial 30 day period, the period would be increased by 4 days). Successful completion of the Burn-In Period shall occur at the end of thirty (30) complete calendar days of operation without a system failure ascribable to hardware, software, or communications components.

The Contractor shall generate Test Result Documentation for the Burn-In which shall include at a minimum:

- Documentation for any ITS electronic equipment failures, system failures or communications failures;
- Document corrective actions taken by the Contractor for equipment repairs;
- Any re-test documentation for the repaired or replacement equipment;
- All manufacturers' ITS electronic equipment protocol control software; and,
- All manufacturers' configuration and diagnostic software along with licenses transferred to the Department.

This Test Result Documentation shall also consist of the minimum applicable information as specified within Acceptance Test of the Specification. Once the Burn-In Period is successfully completed, the Contractor shall submit the complete package of the Test Result Documentation for Burn-In to the Engineer for acceptance. The Engineer's acceptance shall be in writing, which acknowledges receipt of the Test Result Documentation along with verification that Burn-In was successfully completed.

If equipment or device failures occur, the Engineer may request for the Contractor to submit advance copies of the Burn-In Test Result Documentation so as to gain insight to the equipment problems and any corrective actions taken to date.

(t) Training.

The Contractor shall provide installation, operations and maintenance training for up to ten (10) people. Training shall be performed by product manufacturer(s) for the ITS electronic equipment installed on the Project; and shall be performed both in the field and in the office (or classroom). Training shall include all applicable items required to complete training.

The Contractor shall notify the Engineer to schedule training a minimum of seven (7) calendar days before the proposed training date. After successfully confirming attendance of all necessary personnel, the Engineer shall provide the accepted training date to the Contractor and all attendees. The Contractor shall be responsible for coordinating accepted training date with the product manufacturer instructor(s), along with any field and in-office preparations for completing this training. The Contractor shall take into consideration any time necessary for product manufacturer's instructor(s) travel (including lead times for booking flights and/or rental cars, time for actual commutes, and time for any field or classroom setup).

The Contractor shall include in the cost of training all supplies, equipment, materials, user manuals, handouts, travel, and subsistence necessary to conduct the training. A training notebook shall be provided to each trainee in a labeled 3-ring binder.

The Contractor shall submit the proposed training package to the Engineer for acceptance. The training package shall include detailed course curriculum(s), detailed daily training schedule, draft manuals, handouts, and resumes of all instructors. This training package shall be submitted a minimum of thirty (30) calendar days prior to scheduling training. The Engineer shall review the proposed training materials and reserves the right to request modifications to the training program and materials as appropriate. The Engineer's acceptance of the training package shall be in writing.

Training shall not last for more than eight (8) hours of any given day (i.e., twenty-four (24) hours of training would be conducted over at least a three (3) day period). Training shall be a mixture of formal classroom and hands-on training, and at least half of the training shall be hands-on. Training shall be conducted at a facility approved by the Engineer and shall be completed within sixty (60) days after completion of Burn-In. Upon the request of the Contractor, the Engineer may approve training to be conducted prior to completion of Burn-In.

The training shall be for the ITS electronic equipment as shown on the Plans or as specified within the Specifications; and, for any modifications or enhancements made by the Contractor to ALDOT's Intelligent Transportation Systems software applications or overall ITS system.

Training material shall serve not only as training course guidance, but also as a quick reference guide for future use by the attendee. A copy of all training material, in reproducible form, shall be delivered to the Engineer after training is complete.

(u) Warranty.

The Contractor shall warrant and guarantee the satisfactory in-service operation of all ITS equipment and all related apparatus, specified or implied within the Specifications and as shown on the Plans, for a warranty period of one (1) year following the completion of partial acceptance for maintenance. The Contractor's warranty shall be a written guarantee that the ITS equipment will be fully functional and will remain free of defects in material and workmanship during said warranty period.

Upon successful completion of a required Burn-In Period, the Contractor may request partial acceptance for maintenance, as addressed by **Sub-Article 105.15(b)**, of the portion or component of the work covered by the Burn-In. The Engineer will review the request and will issue partial acceptance for maintenance if the installation has been acceptably completed. The warranty period will then start for that portion or component of the work.

During the warranty period, the Contractor shall repair with new materials, or replace at no charge, any device, product, or other material containing a warranty defect. During the support period, the Contractor shall enter a precise description of any necessary repair work performed into a logbook. All materials returned from warranty repairs shall be made through the distributor or manufacturer at no additional charge. Warranty repairs and replacements shall be completed within two weeks from date of return to the distributor or manufacturer.

Before final payment is made, the Contractor shall supply ALDOT's Construction Bureau a letter setting forth the dates of the guarantees giving a telephone number, an address, and a person to contact for any required warranty service.

The Contractor shall transfer any available manufacturer's warranties or guarantees to the Department. These warranties and guarantees shall be continuous throughout their duration and state that they are subject to such transfer.

The Department will not make the final payment for work under this Section until the warranties, guaranties and contact information are furnished to the Engineer.

729.04 Method of Measurement.

The Intelligent Transportation Systems shall be measured for payment by the appropriate items complete, in place, acceptably installed, tested and operational in accordance with the following:

ITEM 729-A: Fiber Optic Cable with number of fibers indicated shall be measured per linear foot.
ITEM 729-B: Fiber Distribution Unit, Fan-Out Kit, and Fiber Optic Patch Cable shall be measured by each unit installed.

ITEM 729-C: Network Device shall be measured by each unit installed.
ITEM 729-D: Camera shall be measured by each unit installed.
ITEM 729-E: Vehicle Detection Systems shall be measured per each device installed.
ITEM 729-F: Dynamic Message Sign shall be measured by each unit installed.
ITEM 729-G: Environmental Sensor shall be measured by each unit installed.
ITEM 729-H: Highway Advisory Radio shall be measured by each unit installed.
ITEM 729-I: Conduit, Conductor, Locate Tone Wire, Messenger, and Warning Tape shall be measured per linear foot.
ITEM 729-J: ITS Cabinet shall be measured by each unit installed.
ITEM 729-K: Electrical Power Service and Transformer shall be measured per each site/unit installed.
ITEM 729-L: Pole shall be measured by each unit installed.
ITEM 729-M: Building shall be measured per lump sum.
ITEM 729-N: Miscellaneous Infrastructure shall be measured by each unit installed.

729.05 Basis of Payment.

Unless otherwise indicated below, all payments shall be made in increments of:

1. Up to 70% of the contract unit price upon successful completion of the BENCH TEST and installation of item(s). [Partial payments may be made in accordance with **Article 109.07** up to this percentage.];
2. Additional 15% of the contract unit price upon completion of the FIELD TEST; and,
3. Final 15% of the contract unit price upon completion of the ACCEPTANCE TEST (BURN-IN).

(a) Unit Price Coverage.

ITEM 729-A. FIBER OPTIC CABLE, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following: fiber optic cable with the number of fibers indicated; attached to messenger wire and pulled through conduit when required; all required connections; fiber optic cable tags and labeling; aerial slack brackets; manufacturer and Contractor warranties; and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work. (*Please Note*: Conduit, Messenger Wire, Fiber Marker Post, and Fusion Splicing are separate pay items.)

ITEM 729-B. FIBER DISTRIBUTION UNIT, FAN-OUT KIT, FIBER OPTIC PATCH CABLE, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following:

a. Fiber Distribution Unit: including housing, panels, connectors, connector barrels, zip ties, clamps, cable trays, cable management organization, and labels; all adapters/couplings, for the number of fibers indicated, all required termination splicing; mounting brackets and hardware;
b. Fan-Out Kit: fan-out kit with adapters/couplings, for the number of fibers indicated;
c. Fiber Optic Patch Cable: fiber optic patch cable of functional length required to connect the associated equipment and FDUs; connectors, connector barrels, and associated hardware;
d. manufacturer and Contractor warranties;
e. and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

Fan-Out Kit and Fiber Optic Patch Cable will be paid at 100% of the contract bid price upon completion of the installation of these items.

ITEM 729-C. NETWORK DEVICE, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following:

a. Network device with all necessary electrical components, including but not limited to wiring, cabling, harnesses, and indicators;
b. Wireless Licensing (including wireless path loss analysis and testing, frequency coordination, FCC application process, and associated costs/fees);

c. Network hook-up, fiber optic transceivers field and head-end, wireless communication devices (antenna, dishes, remote and head-end), communication modules with data cables (CAT 5E/6/6A patch cables, antenna cables and mounts);
d. Equipment mounts;
e. Power hook-up; power supplies with power cables;
f. Surge protection for communication/data and power; grounding system;
g. Manufacturer's operational software package(s) and firmware;
h. Initial configuration, Acceptance Testing with Burn-In, complete device documentation, manufacturer and Contractor warranties and support;
i. and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

ITEM 729-D. CAMERA, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following:

a. Camera assembly complete with all components including, but not limited to: camera, lens, pan/tilt drive, control electronics and environmental enclosure, cables (power, video and control), housing assembly and mounting brackets;
b. camera/video drivers, control and diagnostics software, initial configuration; complete camera documentation/manuals;
c. Network connection and configuration;
d. Surge protection for communication/data and power;
e. Power supplies with cabling and connection;
f. Grounding system; air terminals and lightning protection system;
g. Testing (including all test report/packages, electronic files and deliverables), Training (including all instructors, travel, classroom and field materials, electronic files and deliverables), and Acceptance Testing with Burn-In;
h. Manufacturer and Contractor warranties and support;
i. and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

ITEM 729-E. VEHICLE DETECTION SYSTEMS, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following:

a. Vehicle Detection Systems complete with all components including, but not limited to: vehicle detection unit(s) (e.g. sensors, repeaters, access points, antenna), control and interface equipment (e.g. detection system processor, communication interface panel, cabinet interface unit), cables (power, data and control), housing assembly, and mounting brackets (with pole extensions if required);
b. Vehicle Detection device/equipment drivers, control and diagnostics software, initial and post configuration (e.g. software setup and programming, adjusting detection zones, adjustment for repeaters and access points); license(s); complete Vehicle Detection Systems documentation/manuals;
c. Network connection and configuration;
d. Surge protection for communication/data and power;
e. Power supplies with cabling and connection;
f. Grounding system; air terminals and lightning protection system (if required);
g. Testing (including all test report/packages, electronic files and deliverables), Training (including all instructors, travel, classroom and field materials, electronic files and deliverables), and Acceptance Testing with Burn-In;
h. Manufacturer and Contractor warranties and support;
i. and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

ITEM 729-F. DYNAMIC MESSAGE SIGN, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following:

a. All electrical, electronic, or electromagnetic components use in any DMS assembly, including but not limited to capacitors, potentiometers, resistors, semiconductor devices, transformers, inductors, circuit breakers, switches, terminal blocks, wiring, cabling, harnesses, indicators, electromechanical shutter units, light emitting diodes and modules, lamps, driver boards, sign control logic boards, opto-isolation cards, photosensors, sign electronics power supply, pin and socket connectors, PCB connectors, wire connectors, PCB assemblies, fans, filters, and warning beacons;
b. All DMS housing components including, but not limited to: the walk-in housing assembly and mounting hardware, DMS platform and housing door, and maintenance safety eyebolts;
c. DMS controller and remote controller, if any;
d. Network connection and configuration;
e. Power supplies with cabling and connection;
f. Surge protection for communication/data and power;
g. Grounding system; air terminals and lightning protection system;
h. Software/driver interfaces, control and diagnostics software, initial configuration; complete DMS documentation;
i. Testing (including all test report/packages, electronic files and deliverables), Training (including all instructors, travel, classroom and field materials, electronic files and deliverables), and Acceptance Testing with Burn-In;
j. Manufacturer and Contractor warranties and support;
k. and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

ITEM 729-G. ENVIRONMENTAL SENSOR, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following:

a. Environmental Sensor system including, but not limited to: air temperature sensor, relative humidity sensor, visibility sensor, precipitation rate sensor, barometric pressure sensor, wind speed and direction sensor, pavement precipitation depth sensor, and either an in-road or remote road pavement sensor, as shown on the Plans;
b. Environmental Sensor data processing unit and remote controller, if any;
c. All Environmental Sensor housing components including, but not limited to: the housing assembly, and mounting brackets (with pole extensions if required) and hardware;
d. Environmental Sensor device/equipment drivers, control and diagnostics software, initial and post configuration (e.g. software setup and programming, adjusting sensors); license(s); complete Environmental Sensor(s) documentation/manuals;
e. All wiring, cabling, harnesses and connections; Network connection and configuration;
f. Surge protection for communication/data and power;
g. Power supplies with cabling and connection;
h. Grounding system; air terminals and lightning protection system (if required);
i. Testing (including all test report/packages, electronic files and deliverables), Training (including all instructors, travel, classroom and field materials, electronic files and deliverables), and Acceptance Testing with Burn-In;
j. Manufacturer and Contractor warranties and support;
k. and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

ITEM 729-H. HIGHWAY ADVISORY RADIO, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following:

a. Highway Advisory Radio complete with all components including, but not limited to: radio transmitter, digital recorder/player, GPS synchronizer, HAR enclosure/cabinet, antenna subsystem, and mounting hardware;
b. HAR local and remote controller, if any;
c. Highway Advisory Radio device drivers/interfaces, HAR system software (including control and diagnostics software), initial configuration; FCC license(s); complete HAR documentation/manuals;
d. All wiring, cabling, harnesses and connections; Network connection and configuration;
e. Surge protection for communication/data and power;
f. Power supplies with cabling and connection;
g. Grounding system; air terminals and lightning protection system (if required);
h. Testing (including all test report/packages, electronic files and deliverables), Training (including all instructors, travel, classroom and field materials, electronic files and deliverables), and Acceptance Testing with Burn-In;
i. Manufacturer and Contractor warranties and support;
j. and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

ITEM 729-I. CONDUIT, CONDUCTOR, LOCATE TONE WIRE, MESSENGER, and WARNING TAPE, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following:

a. Conduit: including pull tape, conduit hangers, brackets, coupling, conduit lubricant, accessories, supports, attachment hardware, hardware, fittings, trenching, placing, joining, attaching to structure, backfilling, seeding and mulching of disturbed areas, disposal of debris;
b. Conductor or Locate Tone Wire: including hardware, fittings, trenching, placing, joining, attaching to structure, backfilling, seeding and mulching of disturbed areas, disposal of debris;
c. Messenger: messenger wire, lashing, down guy, mounting brackets, supports, accessories, insulators, hardware and fittings, couplings, grounding electrode system;
d. Warning Tape: including print proofs, tape splicing components, trenching, placing, backfilling, seeding and mulching of disturbed areas, disposal of debris;
e. Friction Reduction Multiduct Sleeve: sleeve material and pull tape;
f. Manufacturer and Contractor warranties;
g. and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

ITEM 729-I will be paid at 100% of the contract bid price upon installation.

ITEM 729-J. ITS CABINET, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following:

a. Cabinet complete with documentation, base mount foundation, pole mount attachment hardware, incidental hardware;
b. Fully mounted, either pole, base, or pedestal, as shown on the Plans with all required conduits.
c. Electrical wiring, transformers, breakers, fans, switches, interior lighting, terminal blocks, receptacles, panel board, surge protection, cable racks, equipment bays, other devices as indicated, and all associated incidental equipment inside the cabinet;
d. Grounding electrode system;
e. Manufacturer and Contractor warranties and support;
f. and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

ITEM 729-K. ELECTRICAL POWER SERVICE and TRANSFORMER, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following:

a. Electrical Power Service: including enclosure, circuit breaker(s), disconnect switch(es), transient/surge protection, weather head, vertical conduit(s) and riser; meter base installation (as required by the utility);
b. Transformer: including enclosure, disconnect switch(es), transient/surge protection, step-up/step-down transformer(s), vertical conduit(s) and riser;
c. All wiring from utility service to the meter base and connections (*Please Note*: Lateral/horizontal conductors, after the service disconnect/meter base, are separate pay items.);
d. Wood pole(s), guy wire, excavating, backfilling, attachment hardware, grounding system, and attachment to local utility;
e. Manufacturer and Contractor warranties;
f. and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

ITEM 729-L. POLE, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing and installing, complete in place, as shown on the Plans, with the following:

a. Complete Pole assembly with all components including, but not limited to: pole, tenon (if required), foundation (if required, with reinforcing steel, rebar, anchor bolts, conduits, auger and base plate), design calculations, weather head(s), vertical conduit and riser;
b. Guy wire (if required),
c. Drilling, excavation and backfill, attachment hardware;
d. Grounding system; air terminals and lightning protection system (if required);
e. Manufacturer and Contractor warranties;
f. and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

ITEM 729-L will be paid at 100% of the contract bid price upon completion of the installation of the pole.

ITEM 729-M. BUILDING, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following:

a. Hub Building complete with all interior lighting, receptacles, switches, panel board, wiring/conductors/conduits, surge protection, grounding system, security system, cable racks, generator (with concrete pad), automatic transfer switch, and other devices as indicated;
b. Installed complete on a foundation with all utilities connected and operational, incidental hardware, and gas source for the generator, at no separate cost to the Department;
c. Manufacturer and Contractor warranties and support;
d. and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

ITEM 729-N. MISCELLANEOUS INFRASTRUCTURE, measured as noted above, will be paid for at the contract bid price, which shall be full compensation for furnishing, installing, and testing, complete in place, as shown on the Plans, with the following:

a. Fusion Splicing: fusion splices, fusion heat shrink sleeves and incidentals, testing, and documentation (All splices and terminations shall be accurately and fully documented on forms supplied by the Department. No payment for splices or terminations shall be made unless forms have been accurately completed by the Contractor and approved by the Engineer.);
b. Splice Closure: splice closure housing with seals, splice organizer, splice trays, mounting brackets, hardware, and accessories;

c. Riser Assembly: riser, backplate, conduit, couplings, weatherhead, standoffs, mounting brackets, supports, hardware, and accessories;
d. CommBox: communication box with cover, cable rack system, attachment hardware, base material, and concrete collar; grounding electrode system (where required); excavation, backfilling, seeding and mulching of disturbed areas; disposal of debris;
e. Pull Box: pull box with cover, cable rack system, cable management, attachment hardware, supports, and all necessary accessories; grounding electrode system (where required);
f. Fiber Marker Post: post, dome with graphics label and sleeve, and anchor;
g. Frequency Locate Marker: locate marker unit and labeling;
h. Uninterrupted Power Supply: control/monitoring unit, batteries, transient/surge protection, wiring, network card, mounting, and incidental hardware and software;
i. Manufacturer and Contractor warranties; and for all materials, labor, equipment, tools, transportation, and incidentals necessary to complete this item of work.

Fusion Splicing, Splice Closure, Riser Assembly, CommBox, Pull Box, Fiber Marker Post and Frequency Locate Marker will be paid at 100% of the contract bid price upon completion of the installation of these items.

(b) Payment will be made under Item No.:

729-A Fiber Optic (1) Cable, ____ - per linear foot
729-B Fiber Distribution Unit, (2) - per each
Fan-Out Kit – per each
FO Patch Cable, (3) - per each
729-C Network Device, (4) - per each
729-D Camera, (5) - per each
729-E Vehicle Detection System (6) - per each
729-F Dynamic Message Sign, (7) (8) - per each
729-G Environmental Sensor, ____ - per each
729-H Highway Advisory Radio, (9) - per each
729-I Conduit, (10) - per linear foot
Conductor, (11) - per linear foot
Locate Tone Wire - per linear foot
Messenger - per linear foot
Warning Tape - per linear foot
729-J ITS Cabinet, Type ____ - per each
729-K Electrical Power Service (12) - per each
Transformer (13) – per each
729-L Pole, (14) - per each
729-M Building, (15) - per lump sum
729-N Miscellaneous Infrastructure, ____ - per each

(1) Specify Cable Type [Trunk, Drop, or Armored]
(2) Specify Fiber Distribution Unit Type [Primary or Secondary]
(3) Specify FO Patch Cable Type and Length
(4) Specify Network Device Type
(5) Specify Camera Type [Fixed, Positioner, or Dome]
(6) Specify Detection Type [Radar, Magnetometer, or Bluetooth]
(7) Specify Dynamic Message Sign Type [Walk-In, Front Access, or Dedicated]
(8) Specify Dynamic Message Sign Size
(9) Specify Highway Advisory Radio Type [Permanent or Portable]
(10) Specify Conduit Type [Exposed, Underground, Rigid Metallic, Reinforced Thermosetting Resin, or Friction Reduction Multiduct Sleeves] and Size [1 1/2", …, 2 x 2 Inch]
(11) Specify Conductor Size [8 AWG, 6 AWG, 4 AWG, 2 AWG, 1 AWG, 1/0 AWG, 2/0 AWG, 3/0 AWG, 4/0 AWG, 250 KCMIL, 400 KCMIL, or 500 KCMIL]
(12) Specify site location
(13) Specify Transformer Type and/or Size

(14) Specify Pole Type [Concrete, Steel or Fiberglass]
(15) Specify Building Type and/or Site location

SECTION 893
INTELLIGENT TRANSPORTATION SYSTEMS MATERIALS

893.01 General.

The following are the requirements for Intelligent Transportation Systems (ITS). These requirements may be supplemented or amended by the requirements given elsewhere in the proposal, on the Plans, and on the details in the Special and Standard Highway Drawings.

Requirements as specified within these Specifications shall comply with the latest applicable editions of the National Electrical Code (NEC) (a.k.a. NFPA 70), the American Society of Testing and Materials (ASTM), the American National Standards Institute (ANSI), National Electrical Manufacturers Association (NEMA), National Fire Protection Association (NFPA), National Electrical Safety Code (NESC) (a.k.a. ANSI/IEEE C2), the Underwriter's Laboratory Incorporated (UL), International Organization for Standardization (ISO), Telecommunications Industry Association (TIA), the International Telecommunications Union (ITU), Institute of Electrical and Electronics Engineers (IEEE), Electronic Industries Alliance (EIA), the National Transportation Communications for ITS Protocol (NTCIP), and the applicable standards, specifications, and regulations of ALDOT. In case of conflict with cited Standard Publications and the Specifications, the requirements of the Specifications shall govern.

(a) Compatibility.

All ITS devices and equipment shall be fully compatible and integrated with the current version of: "*ALDOT's Intelligent Transportation Systems software applications*" (also known as ALDOT's Advanced Transportation Management System or "*ALDOT ATMS*"); ALDOT's ITS communications network; and, ALDOT's communication network management system. All items that are required to complete the installation and ensure a fully functional and operational system shall be supplied by the Contractor. Items required but not listed shall be at no direct pay. All components supplied by the Contractor are the responsibility of the Contractor.

893.02 Fiber Optic Cable.

(a) General.

1. Manufacturer Standards and Requirements.
   Each fiber optic cable shall meet all the following criteria:
   a. Manufacturer shall be Certified in accordance with International Organization for Standardization ISO 9001.
   b. Each cable shall meet the requirements of ANSI/Insulated Cable Engineers Association (ANSI/ICEA S-87-640) "Standard for Optical Fiber Outside Plant Communications Cable" (a.k.a. TIA-472D000) and United States Department of Agriculture (USDA) Rural Utilities Service (RUS) 7 Code of Federal Regulations (CFR) 1755.900.
   c. Fiber optic cable shall be factory tested and documented to pass and/or adhere to, and in accordance with, the following tests:

Telcordia GR-20	"*Generic Requirements for Optical Fiber and Optical Fiber Cable*"
ASTM-D1248, Type II, Class C, Category 4, Grade 4	"*Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable*"
ASTM-D1603	"*Standard Test Method for Carbon Black in Olefin Plastics*"
ASTM-D3895	"*Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry*"

ASTM-D4565	"*Standard Test Methods for Physical and Environmental Performance Properties of Insulations and Jackets for Telecommunications Wire and Cable*".

d. Fiber optic cable shall also be factory tested and documented to pass and/or adhere to, and in accordance with the most current ANSI/TIA/EIA-455 *"General Requirements for Standard Test Procedure for Optical Fibers, Cables, Transducers, Sensors, Connecting and Terminating Devices, and other Fiber Optic Components"*. The Fiber Optic Test Procedures (FOTPs) addenda, as they are applicable to the required fiber optic cable, are as follows:

ANSI/TIA/EIA-455-3	"*FOTP-3 Procedure to Measure Temperature Cycling Effects on Optical Fiber Units, Optical Fiber, and Other Passive Fiber Components*"
ANSI/TIA/EIA-455-25	"*FOTP-25 Impact Testing of Optical Fiber Cables*"
ANSI/TIA/EIA-455-28	"*FOTP-28 Measuring Dynamic Strength and Fatigue Parameters of Optical Fibers by Tension*"
ANSI/TIA/EIA-455-31	"*FOTP-31 Proof Testing Optical Fibers by Tension*"
ANSI/TIA/EIA-455-33	"*FOTP-33 Optical Fiber Cable Tensile Loading and Bending Test*"
ANSI/TIA/EIA-455-37	"*FOTP-37 Low or High Temperature Bend Test for Fiber Optic Cable*"
ANSI/TIA/EIA-455-41	"*FOTP-41 Compression Loading Resistance of Optical Fiber Cables*"
ANSI/TIA/EIA-455-62	"*FOTP-62 Optical Fibres - Part 1-47: Measurement Methods and Test Procedures - Macrobending Loss*"
ANSI/TIA/EIA-455-78	"*FOTP-78 Optical Fibres - Part 1-40: Measurement Methods and Test Procedures - Attenuation*"
ANSI/TIA/EIA-455-80	"*FOTP-80 Optical Fibres - Part 1-44: Measurement Methods and Test Procedures - Cut-Off Wavelength*"
ANSI/TIA/EIA-455-81	"*FOTP-81 Compound Flow (Drip) Test for Filled Fiber Optic Cable*"
ANSI/TIA/EIA-455-82	"*FOTP-82 Fluid Penetration Test for Fluid-Blocked Fiber Optic Cable*"
ANSI/TIA/EIA-455-104	"*FOTP-104 Fiber Optic Cable Cyclic Flexing Test*"
ANSI/TIA/EIA-455-113	"*FOTP-113 Polarization-Mode Dispersion Measurement for Single-Mode Optical Fibers by the Fixed Analyzer Method*"
ANSI/TIA/EIA-455-175	"*FOTP-175 Optical Fibres - Part 1-42: Measurement Methods and Test Procedures - Chromatic Dispersion*"
ANSI/TIA/EIA-455-176	"*FOTP-176 Optical Fibres - Part 1-20: Measurement Methods and Test Procedures - Fibre Geometry*"
ANSI/TIA/EIA-455-181	"*FOTP-181 Lightning Damage Susceptibility Test for Fiber Optic Cables with Metallic Components*"
ANSI/TIA/EIA-455-191	"*FOTP-191 Optical Fibres - Part 1-45: Measurement Methods and Test Procedures - Mode Field Diameter*"

These industry standards listed above shall be of the most current active version. If a standard is withdrawn by the authorizing organization, then the superseding standard(s) shall apply.

All fiber optic cable supplied and utilized on this project shall be from a single (one) United States (U.S.) resident manufacturer who can demonstrate that said manufacturer is regularly, and for a minimum of five (5) previous years (continuous), engaged in the production of each, every and all specified fiber optic cable(s) herein and shall warrant that said cable(s) shall be produced

utilizing the manufacturing processes for said cable(s) noted within this Specification. All fiber optic cable(s) supplied and utilized shall be manufactured from U.S. made components only, with the exception of aramid yarn.

In the event that U.S. resident manufactured fiber optic cable is readily unavailable due to excessive lead time, as specified by the Construction Engineer, for production, the Contractor may submit, with or prior to the material submittals, a Non-U.S. based cable manufacturer cable meeting requirements to the Engineer for consideration of acceptance. The Contractor shall submit to the Engineer letters from U.S. based manufacturers documenting the excessive lead time.

2. Fiber Optic Characteristics.

Each optical fiber shall be glass and consist of a doped silica core surrounded by concentric silica cladding. All fibers shall be sufficiently free of surface imperfections and inclusions to meet the optical, mechanical and environmental requirements as specified within the Specifications.

The coating shall be dual layered, ultraviolet (UV) cured acrylate. The coating shall be mechanically or chemically strippable without damaging the fiber.

The required optical fiber grade shall reflect the maximum individual fiber attenuation, to guarantee the required performance of every fiber in the cable.

Only single-mode all-dielectric fiber optic cables shall be used unless otherwise specified on the Plans.

Optical fiber shall also meet the following criteria:

PARAMETERS	**SINGLE-MODE VALUES**
Standards	International Telecommunication Union (ITU)-T G.652.D International Electrotechnical Commission (IEC) 60793-2-50 Type B.1.3 Dispersion unshifted single-mode TIA 492-CAAB
Type	Step Index
Core Diameter	8.3 µm (Nominal)
Proof Tensile Test	100 kpsi {0.69 GN/m² or 0.69 GPa}
Operating Temperature Range	-22˚F to 158˚F {-30˚C to 70˚C}
OPTICAL SPECIFICATIONS	
Attenuation (Maximum): @ 1310 nm-1625 nm (SM) @ 1550 nm (SM)	 ≤ 0.4 dB/km ≤ 0.3 dB/km
Cut-Off Wavelength (λ_{cc})	$\lambda_{cc} \leq 1260$ nm
Mode Field Diameter (MFD): Nominal range @ 1310 nm	 (8.6 µm – 9.5 µm) ± 0.6 µm
Dispersion (Maximum): @ 1285 nm – 1330 nm @ 1550 nm	 ≤ 3.3 ps/(nm•km) ≤ 18 ps/(nm•km)
Chromatic Dispersion, Zero Dispersion (λ_o)	1300 nm ≤ λ_o ≤ 1324 nm
Wavelength Zero Dispersion Slope (S_o)	$S_o \leq 0.092$ ps/(nm²•km)
GLASS GEOMETRY	
Cladding Diameter	125.0 µm ± 1.0 µm
Core to Cladding Offset	≤ 0.8 µm
Cladding Non-Circularity	≤ 1.0%
COATING GEOMETRY	
Coating Diameter (OSP)	250 µm ± 15 µm

3. Cable Markings.

Cable markings shall be indent printing with white characters on the outer jacket. The characters shall be approximately 3 mm in height and spaced to produce good legibility. The cable shall be sequentially marked at 3 feet {0.91 m} intervals maximum. The length marks will not run through zero on any length of cable. The length markings are to be in feet. The maximum variance between the actual cable length and marked cable length is ± 1%.

Each length of cable shall be marked with the following legend:

"(Mfg. name) OPTICAL CABLE (Cable Description) (Mfg. month and year) (telecommunications headset symbol) ALDOT XXXF"

where "XXX" denotes the number of fibers within the cable.

Note: Special marking of "ALDOT XXXF" is not required if the individual reel cable length is less than 6,300 feet {1,920 meters}.

No re-marking of cables is allowed without prior approval by the Engineer.

4. Color Coding.

Buffer tubes and individual optical fibers within those buffer tubes shall adhere to ANSI/TIA/EIA-598-C "*Optical Fiber Cable Color Coding*" as follows:

1 = Blue (BL)	2 = Orange (OR)	3 = Green (GR)	4 = Brown (BR)	5 = Slate (SL)	6 = White (WH)
7 = Red (RD)	8 = Black (BK)	9 = Yellow (YL)	10 = Violet (VI)	11 = Rose (RS)	12 = Aqua (AQ)

where legend for above is: "fiber/tube number = color code (abbreviation)".

For cables containing more than 12 buffer tubes, use the color code shown above for tubes 1 through 12, and use stripes or tracers in conjunction with the standard color code for tubes 13 through 24.

The colors shall be stable during temperature cycling and not subject to fading or smearing onto each other or into the gel-filling/water blocking material. Ensure colors do not cause fibers to stick together.

5. Outside Plant (OSP) Manufacturing.

All optical fiber cables shall be outside plant cable and loose tube. Fiber cable shall contain the fiber count as shown on the Plans with 6 or 12 fibers per buffer tube as allowed for cable type (trunk, drop, etc.).

A layer of aramid yarns, along with at least one ripcord, shall be applied over the buffer tube bundle, producing the cable core.

The cable core interstices and buffer tubes interstices shall be protected from water intrusion by water blocking material. Water blocking material shall be gel or dry; and, be designed to prevent the ingress of water. Water blocking material shall be non-hygroscopic, non-nutritive to fungus, electrically non-conductive, and homogeneous. Water blocking material shall also be free from dirt and foreign matter and readily removable with conventional non-toxic solvents.

Cable jacket shall be a circular extrusion medium density polyethylene (MDPE) of 1.3 mm minimum thickness with no bubbles or blisters and shall be suited for conduit, duct, direct burial and aerial lashing. Jacketing material shall be directly applied over the central tensile strength members and water blocking material.

The buffer tubes shall have a 2.5 mm outer diameter. Each tube shall have water blocking material as specified above. Buffer tubes shall be wrapped around the central strength member in reverse oscillation manner (a.k.a. S-Z spanning) so that the cable may be broken into and fibers selectively broken out without having to cut the entire cable.

6. Quality Assurance and Packing.

The cable shall be packaged wound on spools or reels. Each package shall contain only one continuous length of cable. The packaging shall be as to prevent damage to the cable during shipping and handling.

When the cable length creates a reel weight exceeding 800 lbs. {362.87 kg}, the manufacturer shall be required to supply the cable on a large wooden reel and the reel shall be lagged with wooden staves. The cable shall be covered with a thermal wrap. The outer end of the cable shall be securely

fastened to the reel head so as to prevent the cable from becoming loose in transit. The inner end of the cable shall project a minimum of 10 feet {3.0 m} into a slot in the side of the reel or into housing on the inner slot of the drum, in such a manner to make it available for testing. An arbor hole of 1.5 inch {3.8 cm} minimum is required.

Test tails shall be at least 6.5 feet {2.0 m} and accessible from the outside of the reel. The inner end shall be fastened so as to prevent the cable from becoming loose during shipping and installation. End seals shall be applied to each end of the cable to prevent moisture from entering the cable. Reels shall be permanently marked with an identification number that can be used by the manufacturer to trace the manufacturing history of the cable and the fiber.

Each reel shall be plainly marked to indicate the direction in which it should be rolled to prevent loosening of the cable on the reel.

Documentation shall accompany each reel. The documentation shall indicate the attenuation of each cable fiber in dB/km. The attenuation shall be measured at 1310 nm and 1550 nm for single-mode.

Each reel shall have stenciled on the reel or a weatherproof reel tag firmly attached identifying (at a minimum) the following:

- Name of Cable Manufacturer and Address
- Type Fiber Optic Cable
- Number of Fibers
- Length of Cable (ft/m)
- Reel Number
- Direction of Rotation
- “DO NOT LAY REEL ON SIDE”

A cable reel data sheet (a.k.a. manufacturer’s certified test report) shall accompany each cable reel. The following information (at a minimum) shall be included:

- Name of Cable Manufacturer and Address
- Cable Number
- Reel Number
- Year of Manufacture
- Factory Order Number
- Customer Purchase Order Number
- Type Fiber Optic Cable
- Number of Fibers
- Measured Attenuation of Each Fiber (for lengths > 1000 m)
- Ordered Length (ft/m)
- Actual Shipped Length (ft/m)

This cable reel tag and data sheet are to be delivered to the Engineer as defined in the Construction Section of this Specification.

(b) Trunk Cable.

All optical fiber trunk cables shall be outdoor rated cable (non-plenum) and loose tube. Trunk cable shall contain the fiber count with 12 fibers per buffer tube as shown on the Plans.

Trunk fiber cable shall have a maximum pulling tension rating of 600 lbf {2700 N} or as recommended by the manufacturer. Trunk cable must be able to withstand a minimum bending radius of 10 times the cable diameter under no load and 20 times the cable diameter under load without affecting the performance characteristics of the cable. Maximum pulling tension shall be 600 lbf {2700 N} during installation (short-term) and 180 lbf {810 N} long-term installed or as recommended by manufacturer.

(c) Drop Cable.

All optical fiber drop cables shall be outdoor rated cable (non-plenum) and loose tube. Fiber drop cable shall contain the fiber count of 6 or 12 fibers per buffer tube as shown on the Plans.

In addition to the GENERAL requirements previously listed, each drop cable shall also meet the requirements of ANSI/ICEA S-110-717, *"Standard for Optical Fiber Drop Cable"* (a.k.a. ANSI/TIA-472F000).

Drop cable shall be sheathed with flame retardant polyvinyl chloride (PVC) and shall be an all-dielectric manufacturing. The nominal jacket thickness shall be 1.4 mm and shall be applied directly over the tensile strength member(s). The PVC jacket shall contain carbon black to provide ultra-violet (UV) protection and shall not promote the growth of fungus. The cable shall meet the requirements of the NEC Section 770 for Non-Plenum Applications – Applicable Flame Tests: ANSI/UL 1666 and shall be rated OFNR (optical fiber nonconductive riser).

Drop cable with 12 fibers or less shall be a single buffer tube with a maximum pulling tension rating of 300 lbf {1350 N} during installation (short-term) and 90 lbf {400 N} long-term installed or as recommended by manufacturer. Drop cable with more than 12 fibers shall have multiple buffer tubes of 12 with a maximum pulling tension of 600 lbf {2700 N} during installation (short-term) and 180 lbf {810 N} long-term installed. The buffer tubes shall have a 2.5 mm outer diameter. Each tube shall be dry with either water blocking yarn, powder, or liner. Buffer tubes shall be wrapped around the central strength member in a reverse oscillation manner (a.k.a. S-Z spanning) so that the cable may be broken into and fibers selectively broken out without having to cut the entire cable.

(d) Armored Cable.

All optical fiber armored cables shall be outdoor rated cable (non-plenum) and loose tube. Armored cable shall contain the fiber count with 12 fibers per buffer tube as shown on the Plans. Armored cable shall also contain a corrugated steel tape armor located between two MDPE jackets (i.e., double-jacketed).

Armored fiber cable shall have a maximum pulling tension rating of 600 lbf {2700 N} or as recommended by manufacturer. Armored cable must be able to withstand a minimum bending radius of 10 times the cable diameter under no load and 20 times cable diameter under load without affecting the performance characteristics of the cable. Maximum pulling tension shall be 600 lbf {2700 N} during installation (short-term) and 180 lbf {810 N} long-term installed or as recommended by manufacturer.

Armored fiber optic cable with messenger wire manufactured within the cable shall NOT be allowed for aerial cable. Similarly, no metallic central strength member serving as a messenger wire shall be allowed for aerial cable. Aerial fiber optic cable may be armored or not armored.

(e) Aerial Slack Bracket.

Aerial Slack Bracket (a.k.a. snowshoes) shall be used for the management of aerial fiber optic cable slack storage loops (a.k.a. maintenance coils). The aerial slack bracket shall protect the minimum bending radius of the fiber optic cable.

The aerial slack bracket shall be nonconductive, polymer based, ultra-violet (UV) treated plastic, rated twenty-years in the outdoor environment. Stainless steel hardware shall be used for attaching this aerial slack bracket to the messenger wire. Predrilled holes shall be included along the bracket for securing the fiber optic cable to the bracket.

(f) Fiber Optic Tag.

1. General.

   All fiber optic cabling shall be labeled with a unique identification in a permanent and consistent manner that is approved by the Engineer prior to installing fiber cable. The Engineer shall provide the Contractor with the identifications to be used.

   All fiber cable tags shall be of a material designed for long term permanent labeling of fiber optic cables and shall be marked with permanent ink on non-metal types or embossed lettering on metal tags. Metal tags shall be manufactured of stainless steel. Non-metallic tags shall be nonconductive, polymer based, ultra-violet (UV) resistant, rated twenty-years in the outdoor environment, and durable to extreme weather conditions. Cable tag and label materials shall be approved by the Engineer.

2. Aerial Fiber Cable Labeling.

   Aerial fiber optic cable tag shall be nonconductive, polymer based, ultra-violet (UV) resistant, rated twenty-years in the outdoor environment, and durable to extreme weather conditions.

   Aerially-mounted fiber optic cable shall be marked with a yellow retroreflective tag with black print containing the graphic system as shown on the Plans. The tags shall make the cable identifiable

as ALDOT fiber when viewed from ground level. The black on yellow graphic system shall not fade, peel or chip.

See corresponding Construction Section for fiber optic cable label "*proof check*" sample and approval requirements.

893.03 Fiber Distribution Units (FDU), Connectors, and Fan-Out Kit.

(a) General.

1. Distribution Hardware.

The following material specifications covers Fiber Distribution hardware requirements from the headend and hub, primary fiber distribution unit (PFDU) to secondary fiber distribution unit (SFDU) which are utilized within the individual cabinets and communication closets within buildings or within hub buildings.

2. Fiber Optic Connectors.

Fiber Optic Connectors shall be Type LC for all new network installations. The use of Type ST, SC, or FC connectors are only allowable for connections to existing equipment or as specified in the Plans or in these Specifications. Fiber optic connectors shall meet the requirements of TIA/EIA-604, "*Fiber Optic Cable Intermateability Standards (FOCIS)*" along with the associated test document addendum FOCUS-3. Fiber optic connectors shall be Telcordia GR-326 certified and must meet applicable TIA/EIA-4750000, IEC 61754, and JIS C5973 standards. Ensure that ST and FC connectors include a metallic body.

Connector and adapter plug bodies for single-mode fiber optic cable shall be blue in accordance with color coding requirements of TIA/EIA-568-C.3 "*Optical Fiber Cabling Components Standard*".

Fiber optic connectors shall not exceed 0.25 dB insertion loss per connector across a single fiber regardless of whether field or factory, mechanical or heat cure epoxy terminated.

(b) Primary Fiber Distribution Unit (PFDU).

Primary Fiber Distribution Unit (PFDU) shall be utilized within the primary hub and headend facility that is in support of the hub distribution system and the primary network. This point in the system allows the distribution of signals directly to the network electronics via a jumper/patchcord cable management system.

1. The PFDU is characterized as modular, powder coated aluminum.
2. The termination method for PFDU shall be field termination of inbound fiber cable and patchcord method of connectivity to other outbound cables and network electronics. PFDU may also use pre-terminated factory connector build-outs (Pre-terminated Connector Assemblies) with adapter ports preinstalled as an alternative method.
3. The PFDU shall be mountable within a 19 inch {482.6 mm} EIA-310 rack or bay and have a typical dimension of approximately 8 inches {203.2 mm} high (i.e., 4-U), by 19 inches {482.6 mm} wide by 18 inches {457.2 mm} deep.
4. The PFDU hardware shall be easily adaptable for bay routing of patchcords and cable.
5. Each PFDU maximum connector capacity shall be 72 or 144 fibers, 12 adapter panels.
6. The maximum number of adapters per build-out shall be twelve.
7. PFDU may include factory connector build-outs with adapter ports preinstalled.
8. PFDU shall manage splice trays capable of handling the PFDU maximum capacity of fiber splices.

(c) Secondary Fiber Distribution Unit (SFDU).

Secondary Fiber Distribution Unit (SFDU) shall be wall mounted or 1U as required by cabinet for device to be installed. Mounting shall use brackets and/or backer plates; no exterior wall penetrations shall be allowed. SFDU shall be small enough to fit in limited area or wall space.

1. SFDU is characterized as modular, powder coated aluminum.
2. SFDU may include pre-terminated factory connector build-outs (Pre-terminated Connector Assemblies) with adapter ports preinstalled.
3. SFDU shall be modular with separate splicing, connector, and jumper managements.
4. SFDU panels shall come in 12 or 24 fiber capacity, project specific.
5. SFDU shall manage splice trays capable of handling 24 fiber splices, minimum.
6. The maximum number of adapters per build-out shall be twelve.

(d) Fan-Out Kit.

Fan-Out Kits shall be used on all loose tube and central core fiber optic cable at each terminal end when cable end is to be terminated. The fan-out kit can be an individual buffer tube kit, a multiple buffer tube kit, or spider design kit. All fan-out kits shall have a minimum of 24 inch {61 cm} of tubing, measured from cable end to the back of the connector body, covering each fiber when installation is complete. Fan-out kits shall be rated for outdoor use within a temperature range of -22°F to 158°F {-30°C to 70°C}.

Only one type of fan-out kit may be used on any one project.

(e) Heat Cure Epoxy Connectors.

Heat Cure Epoxy Connectors shall be ceramic ferrule, nickel plated zinc connector body (composite connector body for corrosive atmospheres), 125µm diameter fiber, with the fiber permanently secured within the ferrule with epoxy (heat epoxy cured or air dried) as specified by the connector and/or the epoxy manufacturer. The operating temperature shall be between -40°F to 167°F {-40°C to 75°C}.

(f) Mechanical Connectors.

Mechanical Connectors shall be high-precision ceramic ferrule connectors with guaranteed insertion loss 0.2 dB typical/0.5 dB maximum per connector pair for single-mode. Cleaver, mating tool and mechanical connector shall be of the same manufacturer and specified to be compatible. Mating tool to install the mechanical connector shall be handheld operated and provide immediate verification that proper mating of the mechanical connector was successful or unsuccessful. Cleaver shall include dual stage clamping which holds the fiber (1st stage) before cleaving (2nd stage). Cleaver shall use a diamond blade for high-precision. Mechanical connectors shall not require epoxy or post installation polishing.

(g) Pre-terminated Connector Assemblies.

Pre-terminated Connector Assemblies (i.e., Factory Connector Build-Outs, or pigtails) consist of fiber optic cables with factory-installed connectors on one end of the cable and an un-terminated optical fiber on the other. Pre-terminated Connector Assemblies shall meet the optical fiber and cable requirements within this Specification. The connectors on the factory connector build-out shall be heat cured epoxy connectors meeting specified requirements. Pre-terminated Connector Assemblies shall be installed with fusion splices; and, shall be equivalent in length of the fan-out field termination approach. Splices shall be housed in the appropriate fiber distribution equipment and installed using heat shrink protectors. Fusion splice shall meet specified requirements for maximum attenuation loss.

Pre-terminated Connector Assemblies' optical fiber shall match the mode field diameter (MFD) of the fiber optic cable to which it will be spliced. MFD must be matched to minimize dB losses between optical fibers.

(h) Patch Cable.

Fiber optic Patch Cable assembly (a.k.a. patchcords or jumpers) shall be all-dielectric, single-mode fiber design with the appropriate termination as required herein and as shown on the Plans. The fiber optic cable and optical fiber shall meet the General requirements of **Sub-Article 893.02(a)**. Patch cable shall be yellow in color (single-mode) and shall incorporate tight buffered fiber, aramid yarn strength member and an outer jacket. Fiber patch cables shall be pre-connectorized; and shall meet the connector requirements herein and as shown on the Plans.

All single-mode duplex patch cables, zip cord or round, shall have connector boots of two (2) colors: white or off-white for one leg of the duplex cord (non-printed zip leg) and blue for the opposite leg (printed zip leg) of the duplex cord in accordance with TIA/EIA-568.3-D "*Optical Fiber Cabling Components Standard*".

All connectors used shall have an operating temperature range of -22°F to 158°F {-30°C to 70°C}. Each connector is to have a minimum of a 1.0 inch {25 mm} strain relief boot and shall match the patch panel and/or fiber equipment being connected without adaptors.

Each assembly shall be fully tested per the Fiber Optic Association (FOA) Standard FOA-2 to verify that the patch cable does not exceed the acceptable loss of the connector and fiber cable. Each assembly shall be individually packaged within a plastic bag that shall have the submitted manufacturer's part number marked clearly on the outside of bag. Each patch cable shall be labeled as directed by the Engineer.

893.04 Network Devices.

(a) General.

The following Network Device material specifications covers equipment requirements for ethernet network elements (links, nodes, switches, etc.) which will provide the ITS communications network from the Regional/Area Traffic Management Center to the ITS field components and other stakeholders. These Network Devices will typically reside within the individual cabinets and communication closets within buildings or within hub buildings.

Network Devices and components shall be provided and installed at all locations as shown on the Plans. Furnished materials and equipment shall be new, free from defects, and manufactured using the highest quality, commercially available components and techniques to assure high reliability and minimum maintenance. Hardware and fittings shall be galvanized, stainless steel or other non-corrosive metal.

1. Managed Ethernet Switch (MES).

The Managed Ethernet Switch (MES) shall be equipped to operate at Fast Ethernet (10/100 Mbps) data rates for local devices and gigabit (1000 Mbps) Ethernet rates for all uplink ports. MES shall be metal housing construction and have diagnostic light emitting diodes (LED), including link, TX, RX, and power LEDs. The Contractor shall provide items such as cables, connectors, software, modules, Small Form Pluggable (SFP) optics, etc. which are necessary for a complete and operational system. MES shall have an operating temperature range of -22˚F to 158˚F {-30˚C to 70˚C} and an operating ambient humidity of 5% - 95% (non-condensing), without fans. Materials furnished, assembled, fabricated, and/or installed under this item shall be compliant with the Institute of Electrical and Electronics Engineers (IEEE) 802.3 Ethernet standards, shall be manufactured to ISO 9001 Quality Assurance specifications, and shall be Engineer reviewed and accepted. MES shall comply with the EIA/TIA Ethernet data communication requirements using single-mode fiber optic transmission medium and Category 6 copper transmission medium. The MES shall have a minimum Mean Time Between Failures (MTBF) of 10 years, or 87,600 hours, as calculated using the Bellcore/Telcordia SR-332 *"Reliability Prediction Procedure for Electronic Equipment"* handbook/standard.

Equipment shall be new and corrosion resistant. Power supply shall accept 120 Vac or as defined within the specific MES Layer power requirements. All MES shall have fully integrated power supply internal to the switch with a universal high-voltage range of 88-830 Vdc or 85-264 Vac. The MES shall have terminal blocks for reliable maintenance free connections. MES shall be UL 60950 safety approved with operating temperature tested at 185˚F {85˚C} for 16 hours. MES shall have the following minimum features:

DESCRIPTION	SPECIFICATION
Ethernet Connectivity	100 Mbps
Ingress Protection	IP30
Switching Method	Store & Forward
Priority Queues	4
Simultaneous Virtual Local Area Networks (VLAN)	255
Port Rate Limiting	128 kbps - 8 Mbps
No head of line blocking	Yes

MES shall comply with all applicable IEEE network standards for Ethernet communications, including but not limited to:

802.3-10 BaseT	802.1d - Spanning Tree Protocol
802.3u-100 BaseTX, 100 BaseFX	802.1p - Class of Service
802.3x-Flow Control	802.1Q - VLAN Tagging
802.3z-1000 BaseLX	802.1w - Rapid Spanning Tree Protocol
802.3ab-1000 BaseTX	802.1x - Port Based Network Access Control
802.3ad-Link Aggregation	802.1Q - Multiple Spanning Tree Protocol (MSTP)

802.1d-Media Access Control (MAC) Bridges	802.3ae-2002* – 10 Gigabit Ethernet (10GBase) *(* where indicated by network device Type)*

MES shall support Layer 2 management features and some higher-level multicast data transmission and routing features. These features shall include, but not be limited to:

Hyper Text Transfer Protocol Secure (HTTPS) graphical web-based, SSL (128-bit encryption)	Secure Shell (SSH)
Simple Network Management Protocol (SNMP) v1, v2c, v3 (56-bit encryption)	Role Based Access Control
SSH/Secure File Transfer Protocol (SFTP) (128-bit encryption)	Remote Monitoring (RMON)
Command Line Interface (CLI)	Remote Syslog
Rivest-Shamir-Adleman (RSA) Key Management (1024 bit key)	Rich set of diagnostics with logging and alarms
RADIUS client, Point to Point Protocol (PPP)	

The ports for the MES shall meet or exceed the following specifications:

SFP Pluggable Optics	Long haul optics allow Gigabit distances up to 43.5 mi {70 km}
Two transmit and receive ports	Bi-directional single strand fiber support

All MES shall pass or exceed the following approvals:

Hazardous Locations: Class 1, Division 2	Emissions: Federal Communications Commission (FCC) Part 15 (Class A), EN55022 (CISPR22 Class A)
ISO: Designed and manufactured using an ISO 9001 certified quality program	Safety: UL 60950
European Conformity (CE) Marking	Laser Eye Safety (US Food and Drug Administration (FDA)/Center for Disease and Radiological Health (CDRH)): Complies with 21 Code of Federal Regulation (CFR) Ch.1, Subchapter J, Part 1040

MES shall be in compliance with the following standards, to reduce potential interference with/by other devices when in close proximity:

IEC 61000-6-2 Industrial (Generic)	IEEE 1613 Electric Utility Substations
IEC 61800-3 Industrial (Variable Speed Drive Systems)	NEMA TS2 Traffic Control Equipment
IEC 61850-3 Electric Utility Substations	Failsafe Output Relay: for critical failure or error alarming

MES shall have the following features, to ensure only technicians authorized by ALDOT can operate the switch:

Multi-level user passwords	VLAN (802.1Q) to segregate and secure network traffic
SSH/SSL: 128 bits	RADIUS centralized password management
Enable/disable ports, MAC based port security	SNMP v3 authentication and 56-bit encryption
Port based network access control (802.1x)	

MES shall have the following protocols:

Authentication	Dynamic Host Configuration Protocol (DHCP) Agent (Option 82 Capable)

2. Optical Ports.

Optical fiber (link) ports shall operate at 1310 or 1550 nanometers in single-mode. The optical ports are to be Type ST, SC, LC, or FC only, as shown on the Plans. Mechanical transfer registered jack (MTRJ) type connectors shall not be allowed. Each optical port shall support: paired fiber communications (i.e., one fiber will transmit (TX) data and one fiber will receive (RX) data); or, bi-directional TX and RX over one fiber. The optical ports shall have an optical power budget of at least 15 dB for 10K optics. MES shall have a minimum of two optical SFP transceiver ports.

3. Copper Ports.

Copper ports shall use 8P8C (a.k.a. type RJ45 "unkeyed") modular jacks and shall auto-negotiate speed (i.e., 10/100/1000 Base at a minimum) and duplex (i.e., full or half). These 10/100/1000 BaseTX ports shall meet the requirements detailed in this Section and shall be compliant with the IEEE 802.3 standard pin outs.

4. CAT Network Cable.

Category 5E unshielded twisted pair/shielded twisted pair network cables shall be compliant with the TIA/EIA-568-A standard. Category 6 or Category 6A unshielded twisted pair/shielded twisted pair network cables shall be compliant with the TIA/EIA-568-C.2 standard. When installed outdoors, the above category (CAT) cables shall be outdoor rated. Color(s) of CAT cable jackets shall be as approved by the ALDOT Region Transportation System Management and Operations (TSM&O) Engineer.

(b) Wired Network Devices.

1. Type A - Core Managed Ethernet Switch (CMES).

Core Managed Ethernet Switches (CMES) are typically installed in the Department Traffic Management Center (TMC), office buildings, or hub cabinets/buildings to support the wide area network (WAN). CMES shall be **Layer 3 (Core)**, with capabilities including but not limited to: architecture standardization, open connectivity (i.e., interoperability), bandwidth management, rate limiting, security filtering, and general integration management of an advanced Ethernet switching architecture. CMES shall have the following minimum features:

DESCRIPTION	SPECIFICATION
Mounting	Rack or Panel mountable
Switching Latency	≤ 10.5 µs
Switching Bandwidth	≥ 88 Gbps
MAC addresses	≥ 98304
MAC address table size	≥ 64 kbytes
Frame buffer memory	≥ 2 Mbit
Network Management	NETCONF
Power Supply	Power supply shall be modular and hot swappable Fully integrated, dual-redundant power supplies
Ethernet Ports	Fiber Optical (SFP) Gigabit Ethernet Ports minimum: 2 each – 10GBase, 18 each – 1000 BaseTX Copper/RJ45 Fast Ethernet Ports (10/100/1000 BaseTX) minimum: 16 each
Optical SFP Transceivers	Provide SFP transceiver modules (Type LC) with quantity minimums as follows (unless otherwise shown on the Plans): b. ten (10) each that transmit at distances of 10 km, and b. ten (10) each that transmit at distances of 40 km
Serial Ports	Fully compliant EIA/TIA RS-485, RS-422, RS-232 serial ports Distributed Network Protocol (DNP) MODBUS Raw socket mode allows conversion of any serial protocol
Layer 3 Protocols	Multilink PPP RFC 1990 GOOSE messaging support IP Routing: OSPF, BGP, RIPv1, RIPv2, VRRP Traffic Control, Network Time Protocol (NTP) Server, Internet Protocol (IP) Multicast Routing WAN

2. Type B - Aggregation Managed Ethernet Switch (AMES).

Aggregation Managed Ethernet Switch (AMES) are typically installed in hub cabinets to support the communications WAN. AMES shall have **Layer 2 and/or Layer 3** capabilities (aggregate switch/router) as defined within this Specification. AMES shall also include but not be limited to: architecture standardization, open connectivity (i.e., interoperability), bandwidth management, rate limiting, security filtering, and general integration management of an advanced Ethernet switching architecture. AMES shall have the following minimum features:

DESCRIPTION	SPECIFICATION
Mounting	Rack Mountable
Switching Latency	≤ 8 µs
Switching Bandwidth	≥ 10 Gbps
MAC address table size	≥ 64 kbytes
Frame buffer memory	≥ 1 Mbit
Network Management	NETCONF
Power Supply	Power supply shall be modular and hot swappable Fully integrated, dual-redundant (optional) power supplies
Ethernet Ports	Fiber Optical (SFP) Gigabit Ethernet Ports (1000 BaseX) minimum: 6 each Copper/RJ45 Fast Ethernet Ports (10/100/1000 BaseTX) minimum: 6 each
Optical SFP Transceivers	Provide SFP transceiver modules (Type LC) with quantity minimums as follows(unless otherwise shown on the Plans): a. six (6) each that transmit at distances of 10 km, and b. two (2) each that transmit at distances of 40 km
Serial Ports	Fully compliant EIA/TIA RS-485, RS-422, RS-232 serial ports DNP MODBUS Raw socket mode allows conversion of any serial protocol
Layer 3 Protocols	Multilink PPP RFC 1990 GOOSE messaging support IP Routing: OSPF, BGP, RIPv1, RIPv2, VRRP Traffic Control, NTP Server, IP Multicast Routing WAN
WAN Port Options	T1/E1 (channelized/unchannelized) E1 75 ohms (Ω) via BNC Cellular (LTE or better) DDS

3. Type C - Field Managed Ethernet Switch (FMES).

Field Managed Ethernet Switch (FMES) are typically installed in the ITS Cabinets to support the ITS field equipment (e.g. cameras, VDS, and DMS). FEMS shall be **Layer 2** capable. FMES shall have the following minimum features:

DESCRIPTION	SPECIFICATION
Mounting	DIN Rail or Panel mountable
Switching Latency	≤ 8 µs
Switching Bandwidth	≥ 5.6 Gbps
MAC address table size	≥ 32 kbytes
Frame buffer memory	≥ 1 Mbit
Electromagnetic Interference (EMI) Immunity and Environmental Compliance	BS EN 50121-4 "*Railway Applications – Electromagnetic Compatibility – Part 4: Emission and Immunity of the Signaling and Telecommunications Apparatus*"
Management Tools	Telnet (not for remote control), Command Line Interface (CLI) management interfaces

Ethernet Ports	Fiber Optical (SFP) Gigabit Ethernet Ports (1000 BaseX) minimum: 2 each Copper/RJ45 Fast Ethernet Ports (10/100/1000 BaseTX) minimum: 8 each
Optical SFP Transceivers	Provide SFP transceiver modules (Type LC) with quantity minimums as follows (unless otherwise shown on the Plans): a. two (2) each that transmit data at distances of 10 km

(c) Wireless Network Devices.

1. Wireless Managed Ethernet Switch (WMES).

Wireless Managed Ethernet Switch is network switch that is to be installed in field level device cabinets to support the communications network at remote areas where physically hardwired communications infrastructure is not available. The WMES shall provide wireless 802.11g 2.4 GHz connectivity at minimum transmission rates of 54 Mbps from the remote ITS device installation location to the ITS network trunk interconnection point. WMES shall be **Layer 2** capable. WMES shall include the following minimum features:

DESCRIPTION	SPECIFICATION
Mounting	DIN Rail or Panel mountable
Switching Latency	≤ 8 µs
Switching Bandwidth	≥ 1.8 Gbps
MAC address table size	≥ 16 kbytes
Frame buffer memory	≥ 1 Mbit
Electromagnetic Interference (EMI) Immunity and Environmental Compliance	BS EN 50121-4 "*Railway Applications – Electromagnetic Compatibility – Part 4: Emission and Immunity of the Signaling and Telecommunications Apparatus*"
Management Tools	Telnet (not for remote control), CLI management interfaces
Warranty	2 years
Ethernet Ports	Copper/RJ45 Fast Ethernet Ports (10/100 BaseTX) minimum: 8 each

2. Licensed Wireless Network Device.

The Licensed Wireless Network Device and components shall be a microwave system utilizing a Federal Communications Commission (FCC) approved 6 to 40 GHz broadband communication package to be used for the backbone communications unless otherwise shown on the Plans. The microwave shall be a split system consisting of an Indoor Unit (IDU) modem and an Outdoor Unit (ODU) radio that is mounted directly to the antenna. The IDU shall be installed within an environmentally controlled environment (cabinet or inside a building).

The microwave and all appurtenances shall be FCC approved under FCC Part 101 and shall have an equipment authorization as part of Article 15. The Contractor shall obtain the license in ALDOT's name and bear all cost associated with the license as part of payment for the licensed wireless link. (See additional Contractor responsibilities within the respective Construction Section of this Specification.)

The wireless transceiver assembly shall operate as point-to-point or point-to-multipoint and at the frequency/frequencies as shown on the Plans. The equipment used shall be designed to protect personnel from exposure to high voltages during equipment operation, adjustments, and maintenance. Radios used for a link(s) shall be of the same brand to accommodate the sharing of the IDU for sparring.

The licensed wireless equipment shall meet the following minimum requirements:

DESCRIPTION	SPECIFICATION
Power and Connectors	120 Vac or 48 Vdc
I/O Interface	4 each - GigE ports (2 each - 10/100/1000 BaseT and 2 each - SFP Optical 1000 BaseX, minimum)
Radio: Annual Availability Frequency Range	 99.999% FCC approved licensed frequency for the project application
Radio Modulation	Hitless and jitterless adaptive modulation with conservative and aggressive configurations
Data Throughput Performance	1000 Mbps or greater true usable throughput as tested by bandwidth speed test unless specified otherwise on the Plans; 1000 Mbps performance shall be under all environmental conditions, times of day, and interference and not be subject to fluctuation below minimum performance standards
Encryption	Hardware based Advanced Encryption Standard (AES) encryption
Operating Temperature: IDU ODU	 23˚F to 131˚F {-5˚C to 55˚C} -27˚F to 131˚F {-33˚C to 55˚C}
Microwave Antenna	High performance antenna with radome at the sizes indicated on the Plans, includes a seven-year manufacturer warranty
Cabling	LMR400 or equivalent or 0.5 in. Heliax Cable

Antenna mounts shall prevent movement in high winds. Mounts shall be accepted by the Engineer prior to ordering.

3. Unlicensed Wireless Network Device.

Unlicensed Wireless Network Device and components shall be a license-exempt Ethernet microwave system which utilizes 2.4 GHz or 5 GHz frequencies. These unlicensed frequencies have no regulating body and will receive no help from authorities regarding interference. Unlicensed Wireless Network Device and components shall be installed at the frequency specified on the Plans and as accepted by the Engineer.

The wireless unlicensed Ethernet radio system shall meet the following minimum requirements:

a. 2.4 GHz and 5 GHz radios supplied shall meet FCC Part 15.247 and Industry Canada (IC) RS-210. Equipment shall operate within the ranges as specified in FCC Part 15.247.
b. Radio shall provide data rates of 300 Mbps along with the highest industry-established security features available. The radio shall be compatible with high bandwidth, long range industrial application.
c. Radios shall be point-to-point or point-to-multipoint based on Plan details.
d. Time-division multiple access (TDMA) may be allowed for wireless communications based on project bandwidth requirements and acceptance by the Engineer.
e. Radios shall be dual chain (e.g., 2x2 MIMO) or greater.
f. One each 8P8C (a.k.a. type RJ45 “unkeyed”) modular jack port required operating at 10/100/1000 Ethernet.
g. The radios shall also have security equal to the following encryptions: WPA, WPA2 [including AES, Cryptography (CCMP), and MAC/RADIUS Authentication]. WEP, and Temporal Key Integrity Protocol (TKIP) shall not be allowed.

h. Adaptive modulation: RF link is monitored to automatically adjust the data rate to optimize the maximum link performance.
i. Radios shall support these networking features: Rapid Spanning Tree Protocol (RSTP), DHCP, NTP, SNMP, VLAN, Routing, and Quality of Service (QOS) (802.11e/Wi-Fi Multimedia (WMM)), and Multicasting.
j. Radios shall provide embedded web-based configuration and diagnostic menus and a complete software toolset to assist in design, configuring, monitoring and optimizing the wireless network.
k. Radios may be powered by Powered over Ethernet (PoE) Injector (IEEE 802.3). Surge Protection shall be required when PoE is used.
l. Real time link monitoring.
m. Configuration Manager: HTTP Secured (HTPS), SNMP, and IP auto discovery; Noise level graph; LAN statics; WLAN statics; Error report; Uptime.
n. Limited warranty period for defects in materials or workmanship under normal use and service for a period of two (2) years from the date of installation.

4. Cellular Modem.

The Cellular Modem system shall consist of these major components: cellular modem and antenna.

The cellular modem shall be a gateway type interface and include as a minimum the following:

DESCRIPTION	SPECIFICATION
LTE Frequency Bands	1900 MHz (Band 2); Advanced Wireless Services (AWS), 1700 MHz (Band 4); 850 MHz (Band 5); 700 MHz (Band 13); 700 MHz (Band 17); 1900 MHz (Band 25)
Power and Connectors	9-36 Vdc using 120 Vac or 12 Vdc power supply
VPN	IPsec, Generic Routing Encapsulation (GRE) tunneling, and SSL VPN client Up to 5 concurrent tunnels Port Filtering
Network and Routing	Port Forwarding Network Address Translation (NAT) Dynamic DNS
Security	LDAP, RADIUS and TACACS+ DMZ MAC Address Filtering Inbound and outbound port filtering
Host Interfaces	(2 each) 10/100 Base-T 8P8C (a.k.a. type RJ45 “unkeyed”) Ethernet ports USB Connector RS-232, DE-9 connector I/O: 5 each Digital, 4 each Analog, 2 each Relay
Application Interfaces	Transmission Control Protocol (TCP)/IP HTTP Secured (HTTPS) SNMP DHCP (Dynamic Host Configuration Protocol) Short Message Service (SMS) GPS
Antenna Connections	Primary [50 ohm (Ω), Threaded Neill-Concelman (TNC)] GPS [50 ohm (Ω), SubMiniature version A (SMA)] Rx Diversity [50 ohm (Ω), SMA]
Other Features	High-precision GPS receiver External Subscriber Identification Module (SIM) card access

	Low Power Mode Remote management and configuration Three (3) year warranty Packet Level Diagnostics
Standards	FCC
Enviromental	Operating Temperature Range: -22˚F to 158˚F {-30˚C to 70˚C} Storage Temperature Range: -40˚F to 185˚F {-40˚C to 85˚C}
Software Management	Remote management and configuration software Has a default IP address

The Contractor shall provide antenna assemblies complete with all necessary cabling hardware, connectors, and appurtenances that is compatible with the above specified cellular modem as specified within this Specification and as shown on the Plans. The Cellular Modem Antenna shall have an RSSI of 40 or less and shall match field conditions per site.

893.05 Camera.

(a) General.

Camera shall be a Closed-Circuit Television (CCTV) camera unit with the following functional requirements:

1. The camera shall be controlled from a computer running the Graphical User Interface (GUI) provided as part of the current version of ALDOT's Intelligent Transportation Systems software applications and manufacturer's software.
2. The camera shall furnish video to the GUI within 3 seconds after the user's execution of the GUI command to display the live video.
3. The camera shall furnish live video at a user defined frames per second.
4. The camera shall furnish live video with a maximum of 3 seconds of latency.
5. The camera shall broadcast user defined text (e.g., name) within 3 seconds after the user's execution of the GUI command.
6. The camera shall broadcast user defined image (e.g., logo) within 3 seconds after the user's execution of the GUI command.
7. The camera shall reset the following features when commanded from the GUI: camera power supply, camera controller, and camera video encoder.
8. The camera shall have assignable user defined block-out zones (e.g., privacy areas).
9. The camera shall provide two (2) simultaneous video streams.

Manufacturer's certification for each camera shall be provided to the Engineer prior to installation to ensure each camera unit has been properly assembled, configured, factory adjusted for color balance, lens tracking, and other configurable items have been set as specified within the Specifications.

The CCTV camera shall meet the following minimum requirements:

DESCRIPTION	SPECIFICATION
Camera Imaging Unit	Digital signal processing (DSP) solid state design
Environmental	Operating: -22˚F to 158˚F {-30˚C to 70˚C}, at Relative Humidity 100% NEMA TS2 rated for power, shock and vibration Sustain winds of 110 mph with a 30% wind gusts factor Remain attached to pole for winds up to 160 mph Camera – Standard IEC 60529 rating of IP 67 Optics housing – shall be heated or pressurized with Dry Nitrogen at 5 psi, Powder Coated Aluminum, and meet IEC Standard 60529 rating of IP67

DESCRIPTION	SPECIFICATION
Image Stabilization	Shall have automatic image stabilization
Resolution	1920 x 1080 (16:9 aspect ratio)
Lens Zoom	30X Optical, 4.4 mm to 129 mm (optical), aperture f1.6 (w) f4.6 (t)
Digital Zoom	12x
Mode	Day/Night switchover: day (color) / night (mono), manual or auto
Horizontal Angle of View	60 degrees to 2.5 degrees
Focus Distance	0.7 inch (wide angle) to 29.5 inches (telephoto), minimum
Focus	Automatic with manual override by remote command selection
Iris	Automatic with manual override by remote command selection
Sensitivity	0.4 lux at 1/30 sec. (color day); 0.025 lux at 1/2 sec. (color day); 0.04 lux at 1/30 (mono night), 0.0025 lux at 1/2 sec (mono night)
Video Protocols	RSTP/Real-time Transport Protocol (RTP), Real-Time Streaming Protocol (RTSP) Interleave, RTP Multicast Open Network Video Interface Forum (ONVIF) Profile S NTCIP 1205 Version 2
Dynamic Range	≥ 80 db
Imager	1/2.8-inch Complementary metal-oxide semiconductor (CMOS) sensor
Camera ID	Programmable text up to 20 characters long, up to 8 elements, American Standard Code for Information Interchange (ASCII) set. Messages – ID characters are white with black border. Preset messages to include: camera title, preset title, event title, date/time, and alarm/service message. Message/logo positioning can be placed at left, right, top or bottom. ID message capability shall be set, controlled, and edited by remote commands and text entries.
Privacy Zones	6 programmable zones for video blanking
Digital Video	2 simultaneous, independently configurable video output streams Internal H.264 and MJPEG encoding in accordance with ITU-T H.264 standard and ISO/IEC MPEG-4AVC standard (formally ISO/IEC 14496- 10-MPEG-4 Part 10, Advanced Video Coding). UDP. video multicasting. Resolution – 1080p, 720p, D1, CIF or 16:9 accepted equiv. Frame rate – 1 fps to 30 fps (National Television Standards Committee (NTSC)) Video bandwidth – 256 kbps to 8 Mbps

DESCRIPTION	SPECIFICATION
Camera Housing	Powder coated 6061-T6 aluminum (no polymer-based housings allowed except window) Sunshield Dome distortion free clear polycarbonate Stainless steel hardware, anti-seizing non-hardening compound on threads Mounts rated to meet camera weight and wind loads For pressurized housings: Gas-tight connectors; wiring sealed to connector using silicon or potting compound Schrader valve for pressurizing Pressure relief valve

(b) Fixed Camera.

Fixed Camera shall be a Closed-Circuit Television (CCTV) camera unit with the following additional minimum requirements :

DESCRIPTION	SPECIFICATION
Camera Power	12 Vdc or PoE (IEEE 802.3)
Automatic Gain Control	managed, 0 to 36 dB
Electronic Shutter	Automatic exposure period with manual override by remote command, selection with a range of: 1/2 second to 1/10,000 second
Connections	1 each 8P8C (a.k.a. type RJ45 “unkeyed”) modular jack (digital; NTSC or Phase Alternating Line (PAL))

(c) Positioner Camera.

Positioner Camera shall be a Closed-Circuit Television (CCTV) camera unit with the following additional minimum requirements:

1. The camera shall include Pan-Tilt-Zoom (PTZ).
2. The camera shall begin panning within 1 second after the user’s execution of the GUI command.
3. The camera shall be panned between 0 and 360 degrees in a continuous motion while the command is being executed.
4. The camera shall be panned based on the user defined speeds; the camera’s maximum pan speed shall be 90 degrees per second or higher.
5. The camera shall begin tilting within 1 second after the user’s execution of the GUI command.
6. The camera shall be tilted based on user defined speeds; the camera’s maximum tilt speed shall be 90 degrees per second or higher. The camera shall be tilted in a continuous motion while the user defined speed command is being executed within the parameters of a vertical range to include +36 to -85 degrees.
7. The camera shall begin zooming within 1 second after the user’s execution of the GUI command to zoom.
8. The camera shall have the following presets: pan, tilt, zoom, and focus.
9. The camera shall begin taking motion within 1 second after the user’s execution of the GUI preset command.
10. Preset return at an accuracy of ± 0.36 degrees at 120 degrees/sec.

The Positioner Camera shall meet the following additional minimum requirements:

DESCRIPTION	SPECIFICATION
Camera Power	PoE
Automatic Gain Control	managed, 0 to 48 dB
Electronic Shutter	Automatic exposure period with manual override by remote command, selection with a range of: 1/2 second to 1/10,000 second
Presets	Positioner - 32 pan, tilt, zoom, and focus presets
Control	Addressable RS-422, compatible with device-controlling software
Connections	1 Each 8P8C (a.k.a. type RJ45 "unkeyed") modular jack port (digital; NTSC or PAL), EIA RS-232/422/485 (control)
Pan, Tilt, Zoom (PTZ) Unit	Weather proof Gold plated electrical pin connectors Corrosion resistant, maintenance free gears Drive motors: Instantaneous reversing Overload protected User defined (i.e., adjustable) pan/tilt (preset) speeds Braking pan/tilt, non-drifting Adjustable limit switches for pan/tilt

(d) Dome Camera.

Dome Camera shall be a Closed-Circuit Television (CCTV) camera unit with the following additional requirements (minimum):

1. The camera shall include Pan-Tilt-Zoom (PTZ).
2. The camera shall begin panning within 1 second after the user's execution of the GUI command.
3. The camera shall be panned between 0 and 360 degrees in a continuous motion while the command is being executed.
4. The camera shall be panned based on the user defined speeds; the camera's maximum pan speed shall be 80 degrees per second or higher.
5. The camera shall be tilted within 1 second after the user's execution of the GUI command.
6. The camera shall be tilted based on user defined speeds; the camera's maximum tilt speed shall be 80 degrees per second or higher. The camera shall be tilted in a continuous motion while the user defined speed command is being executed from +5 degrees horizontal to -90 degrees (straight down).
7. The camera shall begin zooming within 1 second after the user's execution of the GUI command to zoom.
8. The camera shall have the following presets: pan, tilt, zoom, and focus.
9. The camera shall begin taking motion within 1 second after the user's execution of the GUI preset command.
10. Preset return at an accuracy of ± 0.36 degrees at 120 degrees/sec.

The Dome Camera shall meet the following additional minimum requirements:

DESCRIPTION	SPECIFICATION
Camera Power	PoE
Automatic Gain Control	managed, 0 to 48 dB
Electronic Shutter	Automatic exposure period with manual override by remote command, selection with a range of: 1/2 second to 1/10,000 second
Presets	32 pan, tilt, zoom, and focus presets
Connections	1 Each 8P8C (a.k.a. type RJ45 "unkeyed") modular jack port (digital; NTSC or PAL), EIA RS-232/422/485 (control)
Pan, Tilt, Zoom (PTZ) Unit	Weatherproof Gold plated electrical pin connectors Corrosion resistant, maintenance free gears Drive motors: Instantaneous reversing Overload protected User defined (i.e., adjustable) pan/tilt (preset) speeds Braking pan/tilt, non-drifting Adjustable limit switches or stops for pan/tilt

893.06 Vehicle Detection Systems (VDS).

(a) General.

1. Detection Definitions.

The contractor shall provide a VDS that shall detect vehicle presence for the purpose of data collection to be used for signal actuation, volume counts, and/or travel time calculations. The Contractor shall provide a VDS utilizing one of the following technologies, as shown on the Plans:

a. Radar Vehicle Detection System (RVDS).

A RVDS uses an FCC-certified, low-power microwave radar beam to detect and generate volume, occupancy, and speed data.

b. Magnetometer Vehicle Detection System (MVDS).

A MVDS uses a magnetic detector probe as a transducer that detects vehicle presence by converting changes in the vertical component of the earth's magnetic field to changes in inductance to generate volume, occupancy, and speed data.

c. Bluetooth Data Collection System (BDCS).

A BDCS uses a Bluetooth detector probe to detect vehicle presence through Bluetooth devices to generate volume, travel time, and speed data.

2. Communications.

The VDS shall generate and transmit traffic data either: (1) in serial format using an ALDOT traffic signal cabinet TS2 (Type 1 or 2) rack card or through a standard EIA RS-232/422/485 communication port; or, (2) an Internet Protocol (IP) addressable Ethernet interface for ITS projects. The communication interface to be used for installation shall be as shown on the Plans. The VDS shall be IP addressable and be compatible with the network device requirements of this Specification. All device communication addresses shall be user programmable.

The VDS shall support PPP, PMPP (i.e., polled protocols), and Ethernet protocols. The setup program shall assign an IP address to each detection unit. The VDS shall respond to a polling request from the TMC for traffic data. The vehicle detection unit shall respond with the accumulated traffic parameter measurements from the period since the last request was issued.

The VDS shall store all system configuration and traffic parameter data within internal, nonvolatile memory. The traffic data shall be capable of local and remote transfer by issuing requests from a personal computer (PC) across the communication network connecting the detector and the TMC operator workstation or other computer.

3. Configuration Management.

The VDS, with exception of Bluetooth, shall be provided with computer software that allows an operator to program, operate, and read the current status of all system features and functions using a PC or remote TMC workstation.

The software application shall provide PC display of the detection zones and control of any vehicle detector connected to the network.

The Contractor, using a locally connected PC, shall conduct system setup, calibration, diagnosis, and data retrieval operations. The detection system shall allow its configuration data saved to a PC, server, or TMC operator workstation, which can later transfer the data back to the detection system for reloading.

The Contractor shall be able to use a PC or TMC workstation to update firmware over any communication port and edit previously defined detection configurations to permit adjustments to the detection zone's size, placement and sensitivity, and to reprogram the detector's parameters.

The VDS shall accommodate the following configuration modifications: baud rate, response delay, data push, and RS-232/422/485 flow control.

The PC and the detection system shall communicate when connected directly by an EIA RS-232/422/485 cable or CAT 5E/6/6A cable via 8P8C (a.k.a. type RJ45 "unkeyed") modular jack ports. The software shall allow communication between multiple users and multiple field devices concurrently across the same communication network. Once programmed, no periodic adjustments shall be required to the detection zones unless physical roadway conditions change, such as lane shifts or closures.

4. Electrical Requirements.

The VDS field hardware shall meet the requirements in the FCC's 2005 CFR, Title 47, Part 15. The detector shall not interfere with any existing equipment.

The vehicle detection system's cabinet components shall operate using a nominal input voltage of 120 volts of alternating current (Vac). For any device requiring a source input other than the standard 120 Vac, the Contractor shall supply the appropriate means of conversion. Equipment shall be furnished with the appropriate power and communication cables.

In the event that power to the VDS or any subcomponent is interrupted, the equipment shall automatically recover after power is restored. All programmable system settings shall return to their previous configurations when the system resumes proper operation.

5. Environmental Requirements.

The Contractor shall provide VDS that meet all requirements during and after being subjected to an operating temperature range of -22°F to 158°F {-30°C to 70°C} with a maximum noncondensing relative humidity as defined in the environmental requirements section of the NEMA TS2 standard.

The VDS manufacturer shall certify that its device has successfully completed environmental testing as defined in the NEMA TS2 standard. Vibration and shock resistance shall meet the requirements of NEMA TS2 Sections 2.1.9 and 2.1.10, respectively. The system components shall comply with the environmental requirements detailed in the NEMA TS2 standard.

The Contractor shall furnish and install an environmentally resistant and tamper-proof sensor enclosure for any detector assembly exposed to the elements. The enclosure shall be environmentally sealed upon installation.

(b) Radar Vehicle Detection System (RVDS).

Radar Vehicle Detection System (RVDS) shall meet the following functional requirements:

1. The RVDS shall be manufactured for side-fire detection.
2. The vehicle detection unit shall detect vehicles through all weather conditions.
3. The RVDS shall configure manually for zones. The user shall configure zones by defining zone limits through the Graphical User Interface (GUI).
4. The RVDS shall back up detection zones data in non-volatile memory automatically and manually.
5. The detection zones shall restore automatically if the system is interrupted, manually through a GUI command, and without detection disruption.
6. RVDS shall provide a real-time traffic pattern display to the GUI.

7. The RVDS shall reset specified feature when commanded from the GUI for radar detector power supply.

The RVDS equipment shall also meet the following minimum technical requirements:

DESCRIPTION	SPECIFICATION
Type A Type B	Single beam Dual or multi beam
Radar Detector Power	115 Vac, 60 Hz
Frequency	24.00 to 24.25 GHz
Frequency Tuning	No manual tuning to circuitry
Detection Range	6 to 250 ft. {1.8 to 76.2 m}
Lane Detection	6 lanes
Type A Accuracy: Volume Speed Classification	 97% typical 95% typical 90% typical
Type B Accuracy: Volume Speed Classification	 98% typical 97% typical at 70 mph; 95% typical at 40 mph 90% typical
Interval Data Collected for Each Lane	Sensor ID, Timestamp, Volume, Average Speed, Occupancy, Classification Counts, Speed Bin Counts, Direction Counts, Average Headway, Average Gap, 85th Percentile Speed
Event Data for Each Detection	Sensor ID, Timestamp, Lane Assignment, Speed, Length, Class
Presence Data for Each Lane	Sensor ID, Per-Lane Presence
Vertical Beam Width	50°
Horizontal Beam Width	6°

(c) Magnetometer Vehicle Detection System (MVDS).

Magnetometer Vehicle Detection System (MVDS) shall meet the following functional requirements:

1. The MVDS shall operate with three (3) main parts: in-cabinet data processing unit, access point with antenna(s), and in-road magnetometer vehicle detection unit.
2. The in-road detection unit shall wirelessly transmit vehicle data to the access point. All necessary equipment (e.g., transceivers, receivers, etc.) shall be included as part of the MVDS.
3. The in-road detection unit shall wirelessly receive configuration data from the access point.
4. The in-road detection unit shall communicate through snow, water, ice, concrete, asphalt, and epoxy used to fill in around in-road unit.
5. The MVDS shall provide an output compatible for use with NEMA TS2 controllers, Type 2070 controllers, and Type Advanced Transportation Controller (ATC).
6. The MVDS shall provide detection data via wireless communication from in-road units to the access point and communication from the access point to the in-cabinet unit, wirelessly and wired through EIA RS-485 connection.
7. The in-road unit shall sense vehicles within a 3 ft {0.9 m} radius of the in-road unit location.
8. The in-road unit shall recalibrate itself if environmental changes, roadway shifts, and roadway buckles.

9. The MVDS shall configure in-road units manually and into groups for phase designation.
10. The MVDS shall back up detector configurations in internal storage of the in-cabinet unit automatically and manually.
11. The detector configuration shall restore automatically if the system is interrupted, manually through the Graphical User Interface (GUI), and without detection disruption.
12. The MVDS shall provide a real-time traffic pattern display to the GUI.
13. The MVDS shall broadcast fault information on the GUI for power failure, communication errors, and in-road unit low battery.
14. The MVDS shall reset specified features when commanded from the GUI for in-cabinet unit, access point, and in-road unit.

The MVDS equipment shall also meet the following minimum technical requirements:

DESCRIPTION	SPECIFICATION
Detection Area	Each detector shall detect vehicles comparable to that of a 6 ft x 6 ft {1.8 m x 1.8 m} loop
Detector Battery Life	The average lifespan for detector batteries shall be ten (10) years minimum
Average Vehicle Count	95% accurate at 500 VPHPL
Interval (bin) data packet protocol	Shall support: Sensor ID; Timestamp which records year, month, day, hour, minute, and second; Total volumes; Average speed values in either mph or kph; Occupancy in 0.1% increments; Volume in up to eight length-based user-defined vehicle classification bins; Volume in up to 15 user-defined speed bins (bin by speed); Average headway in seconds; Average gap in seconds; 85th percentile speed in either mph or kph
Event (per vehicle) data packet protocol	Shall support: Sensor ID; Timestamp which records year, month, day, hour, minute, second, and millisecond of the time the vehicle left the detection zone; Lane assignment; Speed values in either mph or kph
Real-time true presence data packet protocol	Shall support: Sensor ID; True presence information for each magnetometer being monitored

(d) Bluetooth Data Collection System (BDCS).

Bluetooth Data Collection System (BDCS) shall meet the following functional requirements:

1. The BDCS shall receive media access control (MAC) addresses associated with Bluetooth-enabled devices utilizing either discoverable and/or non-discoverable methods.
2. The BDCS receiver shall identify unique MAC addresses associated with Bluetooth-enabled electronic devices.
3. The BDCS shall compare unique MAC addresses associated with Bluetooth-enabled electronic devices.
4. The BDCS shall temporarily store identification information to use for matching for the purposes of travel time.
5. The BDCS shall be configured through the GUI for setting the duration of time to temporarily store identification formation for matching.
6. The BDCS shall transmit travel-time based on pairing of BDCS sensor locations.
7. The BDCS shall be configured through the GUI for setting pairings for travel time.
8. Travel time pairings shall be configurable for two detectors to be paired for beginning and end designations.

9. Travel time pairings shall be configurable for more than two detectors to be paired for beginning and end designations with the intermediate detectors having to be triggered as a logical parameter check for the match completion (i.e., not a sum of pairings)
10. The BDCS shall transmit average speed based on pairings of BDCS sensor locations.
11. The BDCS shall be configured through the GUI for setting pairings for average speed.
12. Average speed pairings shall be configurable for more than two detectors to be paired for beginning and end designations with the intermediate detectors having to be triggered as a logical parameter check for the match completion (i.e., not a sum of pairings).
13. The BDCS sensor shall maintain MAC addresses unlinked to a specific device.
14. The BDCS shall transfer data using an Ethernet based connection.
15. The BDCS shall detect within a minimum radius of 250 ft. without obstructions.
16. The BDCS detection range shall be adjusted by user configurable transmit power.

The BDCS equipment shall also meet the following minimum technical requirements, but not be limited to:

DESCRIPTION	SPECIFICATION
Detector ID	Each detector shall have a dedicated IP address
Communications (Type to be as shown on the Plans)	Ethernet 10/100 BaseT (static or DHCP IP address) LTE cellular connection
Bluetooth Sensing	Data shall be retrieved for both MAC addresses and/or Bluetooth unit heartbeats.
Detection Information	12 characters of the MAC address shall be detected for discoverable Bluetooth signals 6 characters of the MAC address shall be detected for non-discoverable Bluetooth signals, if included
Bluetooth	2.4 GHz Demodulator
Antennae	2 dBi Omni (discoverable Bluetooth detector) 2 dBi Omni (non-discoverable Bluetooth detector, if included) LTE – MIMO Receive Diversity
Detector Memory	On board 4GB SSD card up to 1 year of storage
Processor	Real time microcontroller
Bluetooth	v5.0 or better

893.07 Dynamic Message Sign (DMS).

(a) General.

1. DMS Descriptions.

The Contractor shall provide and install a Dynamic Message Sign (DMS) that shall display a user defined changeable message for the purpose of relaying traffic, hazard, emergency, or other information to the travelling public. ALDOT uses the following DMS styles:

a. Walk-In DMS.

A Walk-In DMS uses a permanently mounted dynamic message board to display information and can be entered to perform routine maintenance and repair.

b. Front Access DMS.

Front Access DMS uses a permanently mounted dynamic message board to display information and can be accessed for routine maintenance and repair through opening sections of the message board face.

c. Dedicated DMS.

A Dedicated DMS uses a permanently mounted dynamic message board to display travel time information. The Dedicated DMS is mounted to a standard retroreflective sign which explains the dynamic information shown on the Dedicated DMS.

2. Manufacturer Compliance.

The DMS manufacturer is required to fully comply with this Specification. The Contractor shall provide a compliant first-draft submittal and DMS equipment that complies with this Specification. The Department reserves the right to independently verify the compliance of all delivered DMS products prior to acceptance and payment.

The DMS Manufacturer shall be ISO 9001 Certified or ISO 9001 Compliant as determined by the Engineer.

3. Material and Process Standards.

All materials furnished, assembled, fabricated or installed under this item shall be new, corrosion resistant and in strict accordance with the Specifications and as shown on the Plans.

Aluminum for fabricated items shall conform to the requirements of **Section 891**, unless otherwise stated herein. Aluminum DMS housings and control equipment cabinets shall be fabricated, welded or chemically bonded and inspected in accordance with the requirements of the ANSI/American Welding Society (AWS) D1.2 Structural Welding Code-Aluminum (latest version). [See **Item 893.07(a)4, *"Sign Housing"*** for special material submittal requirements regarding welders and welding inspectors.]

DMS shall meet the requirements of NEMA TS4 "*Hardware Standards for Dynamic Message Signs (DMS), with NTCIP Requirements*". DMSs are classified by the type of sign display and the type of mechanical construction. Provide full-color and full-matrix signs as shown on the Plans and required within the Specifications. DMS shall use only equipment and components which meet the minimum requirements specified within the Specifications.

The front of the DMS housing shall have either a flat black matte finish or a semi-gloss black polyvinylidene fluoride (PVDF) coating. This finish coating shall withstand extreme weather conditions and prevent chalking.

4. Sign Housing.

a. General.

Structural mounting hardware (nuts, bolts, washers, etc.) shall be stainless steel and shall be appropriately sized for their application.

The DMS housing shall be fabricated, welded and inspected in accordance with the requirements of ANSI/AWS D1.2 Structural Welding Code-Aluminum. Compliance with this requirement shall include, but is not limited to:

i. The DMS manufacturer's submittal shall contain a copy of the manufacturer's certified welding procedures.

ii. All manufacturing personnel who perform welding on the DMS housing shall be certified to AWS D1.2 for all weld types required for housing fabrication. The DMS manufacturer's submittal shall contain a copy of each welder's certification.

iii. All personnel who perform welding inspection on the DMS housing shall be certified to AWS D1.2. The DMS manufacturer's submittal shall contain a copy of each Certified Welding Inspector's certification, along with their phone number and address.

iv. All DMS housing welding shall be inspected on a daily basis by a Certified Welding Inspector (CWI), who shall complete daily written reports on DMS welding progress, housing weld integrity, and any corrective action taken. These reports shall be archived by the DMS manufacturer and shall be available for immediate review upon request by the Engineer.

b. DMS Housing Test.

The DMS housing, including its front face panels, shall pass the NEMA hose-down test as described in the latest edition of NEMA Standards Publication 250. However, the spray angle need not be more than 75° from straight down.

c. Professional Engineer Certification of DMS Housing Structural Design.

The DMS housing, structural framing, face covering, and mounting members shall be designed to comply with the requirements of AASHTO's "*Standard Specifications for Structural* Supports *for Highway Signs, Luminaries and Traffic Signals, 2009 Edition*" regarding wind loads and gust factors. The DMS housing must also withstand a front face ice load as defined in same AASHTO document. The DMS housing design shall be certified and sealed by a Professional Engineer registered in the State of Alabama.

d. Ventilation and Heater.

The DMS housing shall be provided with the necessary louvered vents positioned such that vehicle exhaust fume intrusion into the sign housing is minimized while the housing is provided with sufficient ventilation to maintain the thermostat temperature settings. Provide fans, thermostatically and parallel timer switch controlled, to pull warm air out of the sign housing to support the venting of the heat within the sign housing to the extent that an interior temperature of no more than 130°F {54°C} is reached with a 120°F {49°C} direct sunlight generated ambient temperature with the access door closed and locked. Documentation of the design calculations to support the performance of the ventilation and heating systems shall be included with the DMS material submittal and delivered to the Engineer. (Similarly, effective positive-pressure ventilation and heating system may be used but must be submitted via an exception letter to the Engineer for review and approval. If approved, this positive-pressure ventilation system must meet same heating and cooling levels and comparable features as those obtained with above ventilation and heating system.)

Use replaceable waterproof washable dust filters across all vents and position them such that when in place a secure dust tight joint exists between the filter and the housing. Install fans in protected fan openings within the DMS housing such that moisture, dust, vehicle exhaust fumes, or insects or birds will not enter the fan opening.

Control the ventilation fan and heater by thermostats adjustable to operate the fan between the range of 70°F to 130°F {20°C to 54°C} and a separate heater thermostat adjustable between the range 30°F to 80°F {-1°C to 27°C}. The on-off temperature delta of the thermostats shall be nominally 3°F {1.7°C}. Verify that the current rating of the thermostats is no less than 200 percent of the respective controlled equipment. Provide a two (2) hour timed-on fan switch for operation of the fans by maintenance personnel that, when placed in the on position will turn on the fans for a period of two hours. Turning the switch into the off position then back on shall reset the timer to two more hours from the off-on cycle of the switch. Install device across the thermostat and switch contacts that will prevent electromagnetic interference being generated with the opening or closing of the thermostat contacts under electrical load.

If required, provide a heating system and thermal insulation to keep condensation on critical elements to a minimum or to maintain performance on temperature sensitive items.

The DMS environmental control system shall also provide the following:

i. The operational status of the fans shall be automatically tested once a day and tested on command from the central controller or laptop computer. The testing of the fan units shall be via solid state airflow sensors mounted within the duct system measuring air flow or the lack thereof. Any lack of flow alarms will cause an error message to be sent to the central controller or laptop computer when the sign controller is polled by the central controller or laptop computer.

ii. All ductwork that impedes access to any sign components shall be easily removable, without tools, for servicing of these components.

iii. All ductwork shall be 0.040-inch minimum aluminum and shall be designed to be extremely efficient with minimal pressure drop throughout the system.

iv. The temperature reading and humidity readings from the sensors shall be continuously measured and monitored by the sign controller. A temperature or humidity reading greater than a user selectable critical temperature shall cause the sign to take action such as the turning on of additional fan units, the turning on of the pixel board heat strips, an automated combination of the two functions or in extreme cases, the sign to go to blank and the sign controller shall report this error message to the central controller.

v. The LED modules and electronic equipment shall be protected by a fail-safe, back-up fan control system in the event of an electronic fan control failure or shutdown of the sign controller.

e. Outdoor Ambient Light and Temperature Sensor System.

Sensors, which measure outdoor ambient light levels and the outdoor ambient temperature at the DMS site, shall be mounted to the DMS housing walls. The system shall consist of three (3) commercially available photo-electric sensors and one (1) temperature sensor. Photoelectric sensors shall each have a minimum photo-sensitive area of 0.25 square inches, and sensor output shall be reported to the DMS Field Controller. Temperature sensor output shall also be reported to the DMS Field Controller. Two of the photoelectric sensors shall be placed such that they measure ambient light levels striking the front and rear of the DMS housing, and the third photoelectric sensor shall face the ground. The temperature sensor shall be placed such that it is never in direct contact with sunlight.

Use photoelectric sensors capable of being continually exposed to direct sunlight without impairment of performance of the sensors.

The photoelectric sensor shall be internally read by the DMS dimming system. The dimming system shall read each of the 255 photoelectric sensor levels. The DMS dimming system shall transmit the read value to the DMS ground mounted controller for distribution to the central system. When the DMS is operating in local mode control, the dimming of the DMS display shall be consistent with the ambient light sensed and the dimming system shall command the display into one (1) of three (3) configurable display intensity levels.

Sense the ambient illumination level by orienting and optimizing the system of three photovoltaic sensors in the following manner to sense the ambient illumination level:

- Photoelectric sensor 1 - Northern sky (or toward rear of sign)
- Photoelectric sensor 2 - Facing towards oncoming traffic (upstream or front of sign)
- Photoelectric sensor 3 - Facing down to the ground (or may face down from bottom of sign)

The actual orientation of these minimum three photoelectric sensors should be as recommended by the manufacturer and as approved by the Engineer.

5. DMS Control Functional Requirements.

a. DMS Control.

All project DMS shall operate from a remote sign control computer, referred to as a Field Controller, which receives instructions remotely via:

i. Remotely via wireless or fiber optic communications from the Central Software

ii. Locally via direct laptop computer connection (RS-232) to the Field Controller (Laptop connection shall be possible at the Field Controller within the housing or at the electronics remote access cabinet mounted on the sign structure itself at ground level.)

iii. Via other local control inputs as described within the Specification

The DMS shall continue to display the current message in the event of communication errors and Field Controller lock-up.

The DMS shall display the current message upon restoration of power.

b. Modes of Operation.

All project DMS shall be able to display static messages, flashing messages, or multiple-frame messages, as described below:

- *Static Message* – The selected message shall be displayed continuously on the sign face until the Field Controller blanks the sign or affects the display of another message.
- *Flashing Message* – All or part of a message shall be displayed and blanked alternately at rates from as fast as three (3) flashes per second to as slow as one (1) flash per 10 seconds. Flash rate shall be programmable in increments of 0.1 seconds. In the flashing mode, message display time shall equal message off time.

- *Multiple-Frame Messages* – The selected message shall consist of up to three different frames, with each frame containing up to three lines of information. The display time of each message frame shall be individually controllable in durations of 0.5 seconds or greater and shall be programmable in increments of 0.1 seconds.

6. Display Requirements.

a. Alphanumeric Characters.

All project signs shall display a message composed of any combination of alphanumeric character fonts and punctuation. This shall minimally include the following character fonts and shapes:

i. "A" through "Z" – all as upper case letters, having a vertical height of seven (7) pixels and higher

ii. "0" through "9" as decimal digits, having a vertical height of seven (7) pixels and higher

iii. A blank or space

iv. Punctuation marks as follows . , ! ? - ' ' " " ( )

v. Special characters as follows # & * + < >

b. Multiple Font Styles.

All project signs shall display alphanumeric character fonts having the following configurations.

The LED DMS shall enable the display of text, consisting of a string of alphanumeric and other characters. The approximate size of the sign shall be as shown on the Plans. Each character shall be formed by a matrix of luminous pixels. The supported fonts shall also meet the latest MUTCD font and pixel requirements.

c. Line and Character Spacing.

Signs shall display all the fonts listed herein with the following inter-character spacing:

i. Single-stroke fonts shall be displayable with two-pixel spacing,

ii. Double-stroke fonts shall be displayable with two-pixel and three-pixel spacing, and

iii. The inter-character pixel spacing for the downloadable fonts is user-selected per NTCIP

7. Diagnostic and Status Features.

The functional status of the DMS communications and major DMS components shall be reportable to the DMS Central Software and displayable on the Central Computer monitor. This shall include:

a. Field Controller Communications – as "normal" or "failed".

b. DMS *Site Power* – including the name of power supply, status (e.g., no error, power fail, voltage out of spec, or current out of spec) and type.

c. DMS Display Status – as {name of message being displayed}, "off", or "disabled due to overheating".

d. DMS Display *Status* shall include: When the sign controller is polled or a message is downloaded from the central controller or laptop computer, each pixel in the sign shall be read and its current state (full on, half on, or off), for the current displayed message, shall be returned to the central controller. This will allow the central controller or laptop computer to show the actual message that is visibly displayed on the sign on an individual pixel basis in a WYSIWYG

(What-You-See-Is-What-You-Get) format. This pixel status read shall not affect the displayed message in any way.

e. *LED* Intensity *Level* – the percentage of the "*Maximum Pulse Width Modulation (PWM) Level*" which is either automatically selected by the Field Controller or is manually selected by a Central Software operator.

f. *LED* Intensity *Control Method* – as "automatic" or "manual".

g. *LED* Pixel *Status* – displayed upon operator request, in a bit-map graphic format – "OK", "Stuck at full on", "Stuck at full off", "Stuck at half on", "Stuck at half off".

h. *LED* Pixel *Failure* – as type of test run, pixel location, error type (e.g., stuck on, color error, mechanical error, stuck off, or partial error).

i. Regulated *DC Power Supply Output* – as "normal", "failed", or "Low".

j. *Internal DMS Temperature* – LED pixel board temperature as measured by two internal sensors – presentable in degrees F and C.

k. *Ambient DMS Site Temperature* – outdoor air temperature as measured by an external temperature sensor – presentable in degrees F and C.

l. DMS Environmental Control Fan Status – as "on", "off", or "failed".

m. Additional status and diagnostic information as specified within this Section.

8. Response to Errors.

In the event of communication errors or a Field Controller lock-up, the DMS shall continue to display the current message. In the event of a power failure, the DMS shall display the current message upon restoration of power. All communications and/or power failures shall be dealt with as defined within the parameters of Section 3.5.2.3.5 of NTCIP 1203 (v02.39), "*Configure Event-Based Message Activation*".

9. Transient Protection.

DMS and Field Controller signal and power inputs shall be protected from electrical spikes and transients, as described herein:

a. AC power for all equipment shall be protected at the load center inside the control equipment cabinet. A parallel-connection surge suppresser, rated for a minimum surge of 10kA, shall be connected to the load center in a manner which protects the load center and the equipment it feeds.

b. AC power for control equipment, such as the Field Controller and communication device (Comm Device), shall be further protected by the use of a series-connected surge suppresser capable of passing 15 amperes of current. This device shall conform to the following requirements:

   i. withstand a peak 20,000 ampere surge current for an 8 x 20 microsecond wave form;

   ii. 20 minimum peak surge occurrences;

   iii. clamp at 20,000 amperes, 340 volts, maximum;

   iv. maximum continuous operating current of 15 amperes at 120 Vac, 60 Hz;

   v. series inductance of 200 microhenrys (µH), nominal;

   vi. temperature range of -40°F to 185°F {-40°C to 85°C};

   vii. approximate dimensions of 3 inches wide x 5 inches long x 2 inches high; and,

   viii. this device shall be UL 1149 recognized.

c. RS-485 communication lines between the Field Controller and the LED driver circuits shall be protected by avalanche diodes rated for 11.5 Volts at 10 amps and 14 Volts at 70 amps.

d. RS-232 and RS-485 communication ports in the Field Controller shall be protected by avalanche diodes connected between each signal line and ground.

e. RS-485 photo and temperature sensor communication ports in the control equipment shall be protected by avalanche diodes connected between each signal line and ground.

f. Incoming wireless communication links shall be protected by a series/parallel two-stage suppression device that provides a 200-volt clamp.

g. Digital input and output lines from the DMS to the control equipment shall be protected at the control equipment by optically-isolated input and output modules, or optically-isolated solid-state relays.

i. Inputs shall include but shall not be limited to: DMS regulated power supply diagnostics and the AC power failure alarm.

ii. Outputs shall include but shall not be limited to: cooling fan and defog/defrost fan control.

10. Sign Display and Visibility.

a. DMS Housing Alignment.

The angular alignment of the sign housing shall be static in the vertical direction.

b. Display Visibility.

The sign display shall be clearly visible and legible from distances between 170 ft. and 900 ft. {52 m and 270 m} under normal freeway operating conditions. The luminous intensity of the pixel shall not decrease more than 50 percent when viewed at an angle of ± 7.5 degrees for freeway signs and ± 15 degrees for arterial signs when centered about the optical axis and perpendicular to the surface of the display.

The luminance level (or luminous intensity level) for different elements cannot vary by more than 10 percent of the mean output of all the elements. The contrast ratio shall be within the following ranges:

EXTERNAL ILLUMINANCE (LUX)	CONTRAST RATIO
40,000	7 to 50
20,000	7 to 50
10,000	7 to 50
4,000	7 to 50
400	7 to 50
40	15 to 100

The contrast ratio is to be calculated as follows:

Contrast Ratio = (LA - LB)/LB

where:

LA is measured intensity resulting from the Active Test Area Under Illumination; and,

LB is measured intensity resulting from the Inactive Test Area Under Illumination.

c. Text Size.

When the sign displays text, the DMS shall display text in appropriate sizes and proportions to allow for sufficient sight distance. In locations with speed limits of 45 mph or higher, letter heights of 18 inches minimum shall be used. In locations with speed limits of less than 45 mph, letter height of 12 inches minimum shall be used.

Text characters on full-matrix signs shall conform to ALDOT's current font library used with ALDOT's Intelligent Transportation Systems software applications.

11. ITS Cabinet.

DMS components not contained within the DMS housing shall be installed within an ITS Cabinet as specified within this Specification of the type and location as shown on the Plans.

12. DMS Field Controller.

Each DMS shall include an associated Field Controller, which shall be installed within the sign housing itself or in an ITS Cabinet mounted on the sign structure.

DMS Field Controller shall be either a Type 2070L controller or a proprietary controller. Both controller types shall be fully programmed with the proper NTCIP protocols.

If a proprietary controller is to be utilized, the DMS sign manufacturer shall be required to enter into a firm price supply contract with ALDOT for no less than five years at an end cost to ALDOT of no more than 80% of the most current State Contract Pricing for a standard Model 2070L controller.

The DMS Field Controller shall conform to the following requirements:

a. Characteristics.

i. Each Field Controller shall be a microprocessor-based integral unit containing its own regulated DC power supply.

ii. Field Controller shall be housed in its own environmentally-resistant, durable, non-corrosive enclosure.

iii. Field Controller enclosure shall: easily fit inside the control equipment cabinet; not exceed volume of five cubic feet; and occupies no more than 1.5 feet of vertical rack space.

iv. Maximum weight of 25 pounds, including its enclosure.

v. Field Controller shall operate successfully throughout a temperature range of -22°F to 185°F {-30°C to 85°C}, and it shall otherwise conform to the environmental standards outlined in NEMA TS2, Section 2.

vi. Within the housing shall reside a remote fiber optic transceiver or a wireless transceiver as shown on the Plans.

vii. Only one sign controller shall be used in each sign. No intermediate control device shall be used.

viii. Field Controller hardware and software shall support all DMS communication, control, and diagnostic features as listed herein, as well as those features listed in the DMS and Central Software requirements.

ix. Field Controller hardware and software shall permit communication with the Central Computer in either of the following modes, which shall be user selectable:

- *Polled Multi-Drop Operation* in which the Field Controller informs the Central Computer of its current status, in response to a periodic automatic query from the Central Computer; or,
- *Event-Driven Operation* in which the Field Controller responds to operator- initiated queries from the Central Computer, and it also calls the Central Computer as required herein.

b. Memory.

DMS Field Controller shall have both permanent and changeable memory. Permanent memory shall be in the form of flash-PROM integrated circuits, or latest technology being utilized as approved by the Engineer, and shall contain the executable Field Controller software. Changeable memory shall be in the form of non-volatile changeable solid-state memory integrated circuit, or utilize latest technology as approved by the Engineer, and shall retain the data in memory for a minimum of one year following a power failure. The changeable memory shall contain the library of messages, the message display schedule and programmable operating parameters. Message storage requirements and attributes shall be as detailed within this Specification. Each message shall have the capability to be defined and stored as a six-frame message.

c. NTCIP Conformance and Management Information Base (MIB).

The DMS Field Controller shall implement an NTCIP protocol stack that is based on the NTCIP Object Definitions for Dynamic Message Signs and Class B profile (NTCIP 1201, NTCIP 1203, NTCIP 2001, NTCIP 2101, NTCIP 2104, NTCIP 2201, NTCIP 2202, and NTCIP 2301). All communication will be made using either SNMP or Simple Mail Transfer Protocol (SMTP) to retrieve and/or update the configuration of the DMS controller. Furthermore, if the DMS Field Controller is required to generate

a response to the SNMP/SMTP request, then it should send the response to the requestor within five (5) seconds of receiving the request.

NTCIP Conformance and MIB Objects shall meet the following functional requirements:

i. The DMS Field Controller shall implement an NTCIP protocol stack based on the NTCIP Object Definitions for DMS and Class B profile.

ii. The configuration of the DMS Field Controller shall update using communication via SNMP and SMTP.

iii. When the DMS Field Controller is required to generate a response to the SNMP/SMTP request, the controller shall send the response to the requestor within five (5) seconds of receiving the request.

d. Data Transmission Requirements.

Each Field Controller shall contain two EIA/TIA RS-232E communication ports:

i. one for remote wireless or fiber optic communications; and,

ii. one for local communication with a laptop computer (using 10/100 BaseT Ethernet port).

Both ports shall be capable of operation at baud rates of 9,600 to 56,000 bits per second or greater. The exact baud rate used shall be user selectable. The Contractor shall install a communications Comm Device as shown on the Plans and shall connect the Comm Device/transceiver to the EIA/TIA RS-232E port and communications device.

e. Clock.

Field Controller shall contain a computer-readable time-of-year clock that has a lithium battery backup. The battery shall keep the clock operating properly for at least ten (10) years without external power, and the clock shall automatically adjust for daylight savings time and leap year through hardware or software or a combination of both. The clock shall be set by the Field Controller's microprocessor, and it shall be accurate to within one (1) minute per month.

f. Password.

The user shall be prompted to enter a password which shall be stored and verified by the Field Controller. The password shall not be echoed on the operator interface when entered by the user. The Field Controller shall be able to store a minimum of three (3) user passwords. Initial access passwords shall be installed by the Contractor as required by the Engineer.

13. Field Controller Software.

The Field Controller shall instruct the LED driver circuitry in a manner which causes the desired message to be displayed on the DMS. At a minimum, signs shall be able to display the alphanumeric character fonts described within the Specification. Software shall handle such details as centering text on a display line, right justification, left justification, and legible spacing of letters and words. Software shall include a mechanism to allow the selection of a particular font style (character width and single-stroke vs. double-stroke, etc.).

The software shall support a flashing feature and the alternating between frames of a multiple-frame message as described within the Specification. Software shall be designed to provide a default value for each display parameter supported.

a. Message Selection.

In the absence of instructions to the contrary from the Central Software, the Field Controller shall implement a message selected from those stored in its memory, based upon date and time as specified by a message schedule feature.

Display of a scheduled message may be overridden by instructions sent from a Central Software operator. A Central Computer or laptop computer shall be able to cause the Field Controller to implement a particular message selected from those stored in its memory, or a new message entered via the Central Software. The Central Software shall be able to edit or completely replace a message stored in the Field Controller's memory or revise the message schedule. In addition, it shall be able to cause the Field Controller to report its schedule or the text of any message stored in its memory.

Software shall incorporate fail-safe procedures to check messages received and shall not change a message stored in memory, the message currently displayed on the sign, the schedule stored in memory, or the current time unless the new message is correctly received.

Normally, a displayed message shall remain on the sign until either a command to change the current message or the schedule in the Field Controller's memory indicates that it is time for a different message. However, it shall be possible to confer a "*priority*" status onto any message, and a command to display a priority message shall overwrite any non-priority message being displayed.

b. LED Intensity Control System.

The sign controller shall monitor the photocell circuits in the sign and convert the measured light intensity into the desired pixel brightness. The photo circuit readings shall be correlated with a brightness table in the sign controller. The brightness table shall have a minimum of 255 brightness levels. Automatic adjustment of the LED driving waveform duty cycle shall occur in small enough increments so that brightness of the sign changes smoothly, with no perceivable brightness change between adjacent levels. The brightness table in each individual sign controller shall be adjustable from the central controller and can be customized according to the requirements of the installation site. Each sign shall have its own, independent brightness table.

Brightness shall be manually settable from the front panel of the controller and remotely from the central computer in 1% increments.

The LED intensity control system shall conform to the following requirements:

i. The DMS shall contain three (3) photoelectric sensors, which shall be provided and installed as described within the Specification.

ii. Manual and automatic intensity control modes shall be provided in a manner which enables the user to select the desired mode of operation, although the typical control mode shall be "*automatic*".

iii. Automatic intensity control shall select one of at least sixteen LED intensity levels based on the sensed ambient light. The threshold points for each intensity levels shall be user programmable. LED intensity levels shall be available in 1% increments and in a range of 1% to 100% of maximum display intensity.

iv. Central Software shall contain a feature which enables the user to set a maximum usable intensity threshold, which is a percentage of the absolute maximum possible intensity. This shall be for the purpose of providing intensity headroom, for future years when the LED's begin to degrade. Daily LED intensity levels, selected via both automatic and manual control, shall be selectable from a range of 1% to 100% of this maximum intensity value. At the time of DMS delivery, this maximum intensity value shall be set to 67%.

v. Manual intensity control shall be achievable both locally and remotely. Local control shall be with a laptop computer connected to the RS-232 port furnished in the Field Controller. Remote control shall be achieved by calling the Field Controller with a Central (remote) Computer.

c. Interference.

The DMS intensity control circuits and power system shall utilize electrical devices to minimize radio frequency interference (RFI) noise generated by the DMS on the power line, as well as noise radiated by the DMS circuitry.

d. Communications.

The Field Controller shall be able to communicate with the Central Computer via the remote-control port in either of two ways: polled multi-drop operation or event-driven direct operation.

In polled multi-drop operation, there is constant communication between each Field Controller and the Central Computer. Several Field Controllers may be on the same communication channel, with each controller assigned a unique identification (ID) number. ID numbers for controllers shall conform to the NTCIP requirements for address numbers as indicated in this Specification, and a Field Controller shall only respond to messages labeled with its ID or to the broadcast address ID. In the polled multi-drop mode, Field Controllers never initiate communication, but merely transmit their responses to commands or queries from the Central Computer. The Central Computer queries each Field Controller frequently about its current status information.

Each sign shall have a unique ID number, which the Region/Area or Central TMC Computer selects when it wants to issue a command or check on the status of the sign. The Field Controller

shall also be able to call the Central Computer whenever it detects restoration of AC power at its DMS site and/or the internal DMS temperature exceeds the programmed safety limit. If the Central Computer's line is busy, the Field Controller shall keep trying at intervals selectable by the operator until communication is established. Once it connects with the Central Computer, the Field Controller shall transmit a status message that includes its identifying number. The Field Controller shall automatically disconnect dial-up communications within five (5) minutes if communication from the Central Computer is not detected.

Upon any status changes initiated either remotely or locally to the DMS Field Controller, the Field Controller shall automatically update the Central Computer.

The Field Controller shall be configured such that if one communication mode is operational (multi-drop vs. wireless), then the functionality of the other mode is disabled.

With either communication mode, it shall be possible for a maintenance technician to connect a laptop computer to the Field Controller's local RS-232 port and carry out all DMS control and diagnostic operations that could be carried out by the Central Computer. However, local laptop control capability shall be limited to only the DMS which is directly connected to that Field Controller.

e. Controller ID.

An 8-byte identification (ID) code shall be assignable to each Field Controller.

f. LED Diagnostic Test Capability.

Upon command from either a remote Central Computer or a locally-connected laptop computer running Central Software, the Field Controller shall test the electrical operation of all LED pixels and determine whether they are operating with: "*normal*" current, "*over*" current (short circuit), or "*under*" current (open circuit). This shall be accomplished via A/D conversion of each pixel's forward current. The alternate method of constant current monitoring may be used. The resulting data shall be communicated to the Central Software using an NTCIP compliant method that can be transmitted according to the NTCIP Class D profile. LED pixel diagnostic data shall be displayable to a system operator as described in ALDOT's Regional Traffic Management Center (RTMC) Standard Operating Procedures Manual.

g. Power Interruptions.

Contents of the Field Controller's memory shall be preserved by battery backup during AC power interruptions and the Controller shall automatically resume operation once AC power is restored. Upon recovering from a power interruption, the Field Controller shall leave the current message on the sign until it receives a command to change it, or until a message change is called for by the sign schedule. The Field Controller shall report to the Central Computer that it has just recovered from a power interruption.

h. DMS Communications Devices.

i. Fiber Optic Data Transceivers.

Fiber Optic Data Transceivers shall be in accordance with **Article 893.04, *"Network Devices"*** and shall be fully compatible with the existing fiber optic network devices and their control and diagnostic bays in Hub and TMC buildings. Network Devices shall be single-mode and RS-232. Fiber optic transceivers shall be mounted within the DMS exterior equipment cabinet mounted on the sign structure itself.

If shown on the Plans, the Contractor shall supply one (1) remote or field fiber optic transceiver and one (1) head-end fiber optic transceiver for each direct connect DMS. These Fiber Optic Data Transceivers both field and head-end shall be paid under their respective pay item number.

ii. Wireless Data Transceivers.

The Wireless Data Transceiver units required on remote signs, those not direct-connected via fiber optic cable, shall be remote data units as supplied by the Department and as indicated on the Plans. These units shall be set up for data transmission, RS-232.

ALDOT shall provide the Contractor with one (1) remote unit per remote sign and one (1) head end unit that has the capability to communicate with a maximum of 30 multiple remote wireless units.

The Contractor shall indicate which DMS will utilize wireless within the material submittal to the Engineer.

14. National Transportation Communications for ITS Protocol (NTCIP) for DMS.

The DMS shall meet the National Transportation Communications for ITS Protocol (NTCIP) requirements as defined within ALDOT's **ITS Test Manual Document No. ITS-035** "*Supplemental Dynamic Message Sign (DMS) NTCIP Requirements*". This Supplemental Specification document may be obtained by contacting ALDOT's Design Bureau – Traffic Engineering Division or Construction Bureau.

Please note that if a Conformance Group is mandatory, then all objects within that group listed as mandatory shall be supported. If the DMS does not support the functionality associated with a specific object or group of objects, yet still meets ALDOT's minimum requirements, then the device must respond with a noSuchName error response when requests are made for those objects.

The NTCIP Protocol supplied shall be the most recent version/release implemented. The originally supplied version of the NTCIP software supplied with the DMS shall be fully capable of upgrade by the DMS supplier and with no cost to the State.

15. Laptop Computer.

The Contractor shall have a laptop computer for testing that will run the field controller and NTCIP testing software as required within the Specifications. The laptop computer shall remain the property of the Contractor after the completion of all DMS testing.

16. Software Upgrades.

The sign manufacturer shall supply to the Department a statewide license for the unrestricted utilization of internal control and remote sign software contained herein. Furthermore, the sign manufacturer shall supply to the Department all future internal control software upgrades of the originally supplied software version at no cost to the Department.

17. Supporting Structure

Supporting Structure used for mounting the equipment shall conform to the requirements given in Section **718**.

DMS shall be attached to their overhead support structures with aluminum support beams comprised of aluminum alloy 6061-T6. The number of support beams needed and the method of attaching the support beams to the sign housing and the overhead sign support structure shall be as required to conform to the current edition of AASHTO's "*Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals*" and all other structural requirements specified for this contract. The support beam attachment shall also be certified by a Professional Engineer in accordance with **Section 718**.

Where overhead support structures extend over both directions of a roadway, these structures shall be designed to accommodate future DMS for the other direction along with any necessary walkway, catwalk or access ladder additions. Also, overhead support structures with indicated future DMS on the Plans shall be designed to accommodate these future features along with any necessary walkway, catwalk or access ladder additions. These overhead support structures shall be supplied and installed with a vibration dampener (as approved by the Engineer) in place of the future DMS. The Contractor's design submittal shall include and indicate these items within their respective support structure design computations and drawings.

18. Concrete Foundation

Concrete Foundation used for Supporting Structure shall conform to the requirements given in **Section 718**.

19. Electrical Power Service

Electrical Power Service shall be in accordance with Article 893.13, *"Electrical Power Service and Transformer"*.

(b) Walk-In DMS.

1. General.

a. Housing Service Access.

The Contractor shall provide each Walk-In DMS with a suitable catwalk for service access to the DMS. Include with all Walk-In DMS housings a 4 ft {1.2 m} wide or greater catwalk that extends from

the right or left shoulder support structure, as shown on the Plans, to flush with or extending underneath the sign enclosure. Safety rails shall be provided as a part of the catwalk. Provide a catwalk that will support at least 2,000 lbs. {907 kg} with no discernible displacement.

The Walk-In DMS housing and all of its equipment and materials shall be designed and constructed so that all maintenance and repair is performed from within the DMS housing, with the exception of structural members and components thereof.

All Walk-In DMS housings shall have a minimum of 2 ft. 10 in. {86 cm} wide pathway inside the sign housing to allow adequate room for maintenance personnel. There shall be 18 inches {46 cm} of clear area between all equipment along the entire length of the sign housing from the 24 inch {61 cm} walkway up to 6 feet {1.8 m} above the 24 inch {61 cm} walkway. The walkway shall conform to NEMA TS4 Section 3.2.8.2 "*Work Area*" unless otherwise specified within this Specification.

Walk-In DMS housing doors shall be installed on each side of the DMS housing and shall open outward toward the housing's rear wall. DMS housing doors shall be rain-tight/dust-tight and shall have minimum 2.5 ft. by 6 ft. {0.76 m by 1.8 m} opening. The Walk-In DMS housing doors shall be furnished with a door lock that is keyed to use a Corbin No. 3 key. The door lock shall be a swing cover, plated brass, tumbler type that is designed for outdoor "*no freeze up*" applications. The latching/locking mechanism shall include a handle on the interior of the housing, so that a person with no key and no tools cannot become trapped inside the housing. The door latch system shall be capable of being locked, unlocked, opened, or closed from either the outside or inside of the housing. The Walk-In DMS housing doors shall contain hold-open braces and door stops that allow the door to be held in the full, 90, 45, and 30 degree open positions without the use of tools. The hold-open braces, doors, and hinges shall be designed to withstand a minimum wind speed as defined on the Plans (reference **ALDOT Index Nos. 71001-71002**, **Standard Dwg. No. IHS-710**, "*Wind Velocity Chart for Roadside Signs*") while the door is held in any of these positions.

One of the two Walk-In DMS housing doors will require removable rails to be mounted on the inside of the housing. Rails shall be installed horizontally and spaced vertically every twelve inches to a height of 42 inches {106 cm} above the internal walkway. Rail size shall be as required to prevent a 300 pound {136 kg} person from falling out of the DMS housing, if the doorway is open. Rails shall be attached to the sign housing with stainless steel hardware and designed for removal with simple hand tools.

Rails shall meet OSHA 1910.36 paragraph 6 safety requirements. Prior to DMS installation, the Engineer will advise the Contractor as to which doorway will require rails.

In each Walk-In DMS housing, provide folding step or a similar mechanism to allow a technician to reach the upper interior of the sign during maintenance without the need of a portable device such as a ladder or step stool and which does not interfere with the normal operation of the sign. External repair of the housing and sign face shall be the only items requiring access to the external portions of the housing.

b. Interior Ventilation.

Walk-In DMS housing shall conform to the ventilation requirements of NEMA TS4 Section 3 "*DMS Mechanical Construction*".

c. Interior Lighting and Duplex Receptacles.

The DMS Walk-In housing shall contain interior lighting which conforms to NEMA TS4 Section 3.2.8.3 "*Nighttime Service Lighting*" utilizing UL Listed LED lighting fixtures rated for outdoor use and extreme temperatures.

Comparable fluorescent lighting may be used but must be submitted via an exception letter to the Engineer for review and approval. If approved, this fluorescent lighting must meet same luminance lighting levels as those obtained with above lighting system. Proposed fluorescent light ballasts shall be rated for operation at 0°F {-18°C}.

The light circuit shall be controlled by a manual timer switch having either an adjustable on time of two (2) hours or a four hour timer with adjustable on time of 15 minute increments; and shall be located on the inside of the housing near the door. The light switch timer shall begin timing a "*lights on*" condition of two hours minimum, but no more than four hours, upon activation of the switch. Turning the switch off and back on will reset the time out to another "*lights on*" cycle from the time of the off-on cycle of the switch. Upon time out of this "*lights on*" period, the switch shall

deactivate the interior lighting by disconnecting the 120 Vac ungrounded circuit from the light fixture.

Use a circuit breaker to protect two separate duplex 120V Ground Fault Circuit Interrupter (GFCI) receptacles that are provided on each end of the sign case for the use of maintenance personnel. Use receptacles rated for 20 amperes. Each receptacle shall be fed from a 20 ampere nominal 120 Vac circuit.

2. Functional Requirements.

The DMS shall display user defined text and images.

The DMS shall display screens statically, flashing, and as a series of displays.

The DMS shall display screens through user defined actions with the DMS user interface and remotely.

The DMS shall display a test screen when defined by the user for: full display (brightness configured), characters (configured alpha, numeric, and special characters), and patterns (configured flashing, corners).

The DMS shall reset display after power interruption.

The DMS shall operate without interruption with a primary power source.

The DMS shall reset automatically when requested by a user from the DMS user interface and remotely.

3. Technical Specifications.

DMS shall include associated control, diagnostic equipment, wireless or fiber optic communications, LED lights, and power source.

The DMS must meet the requirements of NEMA TS4 "*Hardware Standards for Dynamic Message Signs (DMS), with NTCIP Requirements*". A DMS is classified by the type of sign display and the type of mechanical construction.

The Walk-In DMS must meet the mechanical construction requirements of NEMA TS4 Section 3.2.8 "*Walk-In Access DMS*" unless otherwise specified within this Specification.

The **Walk-In DMS** shall meet the following weight, size, power, and display characteristics:

DESCRIPTION	SPECIFICATION	
	Size W-1	**Size W-2**
Weight (maximum):	5000 lbs {2268 kg}	3,500 lbs {1,588 kg}
Housing Dimensions (maximum): Width Height Depth	 38 ft {11.6 m} 11 ft {3.4 m} 5 ft {1.5 m}	 25 ft {7.6 m} 8 ft {2.5 m} 4 ft {1.3 m}
Display Dimensions (minimum): Width Height	 27 ft {8.2 m} 6.25 ft {1.91 m}	 22.67 ft {6.91 m} 6.25 ft {1.91 m}
Power (maximum): For signs ≤ 10 characters wide For signs > 10 characters wide	 6,000 W 13,000 W	 6,000 W 13,000 W
Display Viewing Angle:	30 degrees	30 degrees
Display Type:	Full Color, Full Matrix	Full Color, Full Matrix
Pixel Spacing:	20 mm	20 mm

(c) Front Access DMS.

1. Functional Requirements.

The DMS shall display user defined text and images.

The DMS shall display screens statically, flashing, and as a series of displays.

The DMS shall display screens through user defined actions with the DMS user interface and remotely.

The DMS shall display a test screen when defined by the user for: full display (brightness configured), characters (configured alpha, numeric, and special characters), and patterns (configured flashing, corners).

The DMS shall reset display after power interruption.

The DMS shall operate without interruption with a primary power source.

The DMS shall reset automatically when requested by a user from the DMS user interface and remotely.

2. Technical Specifications.

DMS shall include associated control, diagnostic equipment, wireless or fiber optic communications, LED lights, and power source.

The DMS must meet the requirements of NEMA TS4 "*Hardware Standards for Dynamic Message Signs (DMS), with NTCIP Requirements*". DMS are classified by the type of sign display and the type of mechanical construction.

The Front Access DMS must meet the mechanical construction requirements of NEMA TS4 Sections 3.2.5 "*Front and Rear Access*" and 3.2.6 "*Front Access DMS*" unless otherwise specified within this Specification.

The **Front Access DMS** shall meet the following weight, size, power, and display characteristics:

DESCRIPTION	SPECIFICATION	
	Size FA-1	**Size FA-2**
Weight (maximum):	2,500 lbs {1,134 kg}	3,500 lbs {1,588 kg}
Housing Dimensions (maximum): Width Height Depth	 20 ft {6.1 m} 7.5 ft {2.3 m} 2.5 ft {0.8 m}	 28 ft {8.5 m} 8.5 ft {2.6 m} 2.5 ft {0.8 m}
Display Dimensions (minimum): Width Height	 16.25 ft {5.04 m} 4.16 ft {1.27 m}	 22.67 ft {6.91 m} 6.25 ft {1.91 m}
Power (maximum): For signs ≤ 10 characters wide For signs > 10 characters wide	 6,000 W 13,000 W	 6,000 W 13,000 W
Display Viewing Angle	30 degrees	30 degrees
Display Type	Full Color, Full Matrix	Full Color, Full Matrix
Pixel Spacing	20 mm	20 mm

(d) Dedicated DMS.

1. Functional Specifications.

The DMS shall display images (as applicable per DMS usage) and user defined text.

The DMS shall display screens statically and flashing.

The DMS shall display screens through user defined actions with the DMS user interface and remotely.

The DMS shall display a test screen when defined by the user.

The DMS shall reset display after power interruption.

The DMS shall operate without interruption with a primary power source.

The DMS shall reset automatically when requested by a user from the DMS user interface and remotely.

2. Technical Specifications.

DMS shall include associated control, diagnostic equipment, wireless or fiber optic communications, LED lights, and power source.

The DMS must meet the requirements of NEMA TS4 "*Hardware Standards for Dynamic Message Signs (DMS), with NTCIP Requirements*". DMS are classified by the type of sign display and the type of mechanical construction.

The Dedicated DMS must meet the mechanical construction requirements of NEMA TS4 Sections 3.2.5 "*Front and Rear Access*" and 3.2.6 "*Front Access DMS*" unless otherwise specified within this Specification or shown on the Plans.

The **Dedicated DMS** shall meet the following weight, size, power, and display characteristics:

DESCRIPTION	SPECIFICATION	
	Size D-1 (CSLS)	**Size D-2 (CTTS)**
Display Dimensions (maximum): Width Height Depth	 As shown on the Plans As shown on the Plans 6 in {15.2 cm}	 As shown on the Plans 2.0 ft {61.0 cm} 6 in {15.2 cm}
Character Height:	As shown on the Plans	18 in {45.7 cm}
Power	120/240 Vac	120/240 Vac
Communications	Ethernet, RS-232	Ethernet, RS-232
Display Viewing Angle	30 degrees	30 degrees
Viewing Distance	1,100 ft	1,100 ft
Display Type	Full Color, Full Matrix	Full Color, Full Matrix

where CSLS is Dedicated Changeable Speed Limit Sign
and CTTS is Dedicated Changeable Travel Time Sign.

DESCRIPTION	SPECIFICATION	
	Size D-3 (DLCS)	**Size D-4 (DLCS)**
Display Dimensions (maximum): Width Height Depth	 As shown on the Plans 1.5 ft {45.7 cm} 6 in {15.2 cm}	 As shown on the Plans 2.0 ft {61.0 cm} 6 in {15.2 cm}
Character Height:	12 in {30.5 cm}	18 in {45.7 cm}
Power	120/240 Vac	120/240 Vac
Communications	Ethernet, RS-232	Ethernet, RS-232
Display Viewing Angle	30 degrees	30 degrees
Viewing Distance	1,100 ft	1,100 ft
Display Type	Full Color, Full Matrix	Full Color, Full Matrix

where DLCS is Dedicated Lane Control Sign.

893.08 Environmental Sensor.

(a) General.

1. Data Processing Unit.

The Data Processing Unit shall perform any data processing and storage required on the data received from the sensors. Each data record shall include sensor readings of a user-defined time interval of 5 to 60 minutes.

The Data Processing Unit shall be capable of transmitting an alarm in the event of a low power supply, complete power loss, or return to normal operation.

The Data Processing Unit shall be able to transmit alarms for user-defined thresholds for sensor parameters.

The Data Processing Unit shall operate with a minimum of 20 sensors concurrently.

The Data Processing Unit shall process with a minimum of 512 MB RAM.

DESCRIPTION	SPECIFICATION
Temperature Operating Range	-22˚F to 140˚F {-30˚C to 60˚C} minimum
Housing	Field Hardened
Communications Ports	RS-232, RS-485, Ethernet
Power	24 Vdc, 4 A maximum

2. Communications.

The environmental sensor, whether an individual sensor or working as a system, must be capable of transmitting all collected data. See above table for minimum communication port requirements.

3. Software.

All manufacturer software required to configure and operate the Environmental Sensor system shall be provided.

4. Cabinet.

Any equipment not rated for outdoor use shall be enclosed in a cabinet as specified within the Specifications.

(b) Weather Sensors.

Provide an environmental Weather Sensor that shall provide specified environmental information for the purpose of evaluating environmental conditions for hazards.

1. Air Temperature.

An Air Temperature Sensor determines the temperature of the surrounding environment.

The air temperature sensor shall provide temperature information of the surrounding environment in all weather conditions, without delay.

DESCRIPTION	SPECIFICATION
Temperature Operating Range	-40˚F to 140˚F {-40˚C to 60˚C}
Accuracy	±0.4˚F (±1.0˚F if < -22˚F) {±0.22˚C}
Housing	Weatherproof International Protection (IP) 66 rated
Humidity Operating Range	5 – 100%

2. Relative Humidity.

A Relative Humidity Sensor uses an industry standard sensor to determine the current relative humidity.

The relative humidity sensor shall provide information on relative humidity of the surrounding environment in all weather conditions and all humidity ranges, without delay.

DESCRIPTION	SPECIFICATION
Temperature Operating Range	-40˚F to 140˚F {-40˚C to 60˚C}
Accuracy	± 2% Relative Humidity
Housing	Weatherproof IP 66 rated
Power	12 Vdc
Humidity Operating Range	5 - 100%

3. Visibility.

A Visibility Sensor detects low visibility conditions, which might occur during fog or falling precipitation.

The visibility sensor shall provide information on the visibility seen by drivers in all weather conditions, without delay.

The visibility sensor shall measure a two (2) minute sample, providing the average over that interval.

The visibility sensor shall operate with a heated hood to allow continuous operation in all weather conditions.

DESCRIPTION	SPECIFICATION
Temperature Operating Range	-40˚F to 140˚F {-40˚C to 60˚C}
Accuracy	± 10%
Range	6,560 ft {2000 m} minimum
Housing	Weatherproof IP 66 rated
Power	12 or 24 Vdc
Signal Output	4 - 20 mA
Sensor Type	Light

4. Precipitation **Rate.**

A Precipitation Rate Sensor determines the current rate of precipitation.

The precipitation rate sensor shall provide information on the rate of precipitation for all precipitation types, without delay.

DESCRIPTION	SPECIFICATION
Temperature Operating Range	-40˚F to 122˚F {-40˚C to 50˚C}
Precipitation Type	Rain, Snow
Precipitation Quantity (Reproducibility)	> 90% or ± 5%
Housing	Weatherproof IP 66 rated
Power	12 Vdc
Humidity Operating Range	5 - 100%

5. Barometric Pressure.

A Barometric Pressure Sensor uses an industry standard sensor to determine the current barometric pressure.

The barometric pressure sensor shall provide barometric pressure information in all weather conditions, without delay.

DESCRIPTION	SPECIFICATION
Temperature Operating Range	-40˚F to 140˚F {-40˚C to 60˚C}
Range	850 - 1050 mbar minimum
Accuracy	± 0.5 mbar at 32˚F to 140˚F {0˚C to 40˚C}
Housing	Weatherproof IP 66 rated
Power	12 Vdc
Humidity Operating Range	5 - 100%

6. Wind Speed and Direction.

A Wind Speed and Direction Sensor uses an industry standard sensor to determine the current wind speed and direction.

The wind speed and direction sensor shall provide information on the speed and direction of the wind in all weather conditions, without delay.

DESCRIPTION	SPECIFICATION
Temperature Operating Range	-40˚F to 140˚F {-40˚C to 60˚C}
Range: Direction Speed	 0 - 359.9 degrees 0 - 75 m/s minimum
Accuracy: Direction Speed	 ±3˚ ± 0.3 m/s
Housing	Weatherproof IP 66 rated
Power	12 Vdc
Humidity Operating Range	5 - 100%

(c) Road Sensors.

1. In Road Pavement Temperature.

An In Road Pavement Temperature Sensor uses an in road unit to determine the temperature of the roadway.

The in road pavement temperature sensor shall provide temperature information of the pavement surrounding the sensor in all weather conditions, without delay.

DESCRIPTION	SPECIFICATION
Temperature Operating Range	-40˚F to 158˚F {-40˚C to 70˚C}
Temperature Observation Range	-40˚F to 158˚F {-40˚C to 70˚C}
Accuracy	±2˚F {±1.11˚C}

2. Remote Road Pavement **Temperature.**

A Remote Road Pavement Temperature Sensor uses a non-intrusive remote sensor to determine the temperature of the roadway.

The remote pavement temperature sensor shall provide temperature information of the pavement at which the sensor is directed, without delay.

DESCRIPTION	SPECIFICATION
Temperature Operating Range	-40˚F to 158˚F {-40˚C to 70˚C}
Temperature Observation Range	-40˚F to 158˚F {-40˚C to 70˚C}
Accuracy	±2˚F {±1.11˚C}

3. Pavement Precipitation **Depth.**

A Pavement Precipitation Depth Sensor determines the thickness of ice, water, or snow currently on the roadway.

The pavement precipitation depth sensor shall provide information on the depth of precipitation on the roadway in all weather conditions, without delay.

DESCRIPTION	SPECIFICATION
Temperature Operating Range	-40˚F to 158˚F {-40˚C to 70˚C}
Water Depth Observation Range	0.01 - 0.50 in {0.3 - 12.7 mm}
Water Depth Accuracy	± 0.1 mm
Surface Conditions	Dry, Damp, Wet, Snow, Ice

893.09 Highway Advisory Radio (HAR).

(a) General.

1. HAR Descriptions.

The Contractor shall provide and install a Highway Advisory Radio (HAR) system that shall transmit a user defined changeable message for the purpose of relaying traffic, hazard, emergency, or other information to the public. ALDOT uses the following HAR systems:

a. Permanent HAR.

A Permanent HAR uses a permanently mounted HAR system that transmits a user defined changeable message on AM or FM radio frequencies.

b. Portable HAR.

A Portable HAR uses a portable, trailer mounted, HAR system that transmits a user defined changeable message on low-power AM radio.

c. Configuration and Management.

The HAR shall be configured and managed both locally and remotely.

2. Radio Transmitter.

The Radio Transmitter subsystem shall meet the following requirements:

a. Capability for adjustment of radio frequency (RF) output power and audio input levels through easily accessible controls.

b. A provision for automatic station identification (Automatic ID) shall be included.

3. Digital Recorder/Player.

A Digital Recording Unit shall be provided with the following minimum functional requirements:

a. Digitally record and store messages or audio files.

b. Store a minimum of 250 distinct digital messages or audio files, with variable length messages, which can be recorded, stored, or deleted independently.

c. Provide a minimum of 80 minutes of total recording time.

d. Allow the recording of a message while another message is being played (simultaneous record/playback).

e. Provide capability for message retention (indefinitely) without the use of a battery, in the event main site power is lost.

f. The Digital Recorder/Player shall provide Standard DTMF (dual tone multi frequency) tones as applicable.

g. Audio Frequency Input Impedance: 600 ohm (Ω) and Hi "Z" (The Contractor shall provide a compatible microphone).

h. Modulation Limiter: Built-in 100% peak modulation limiter.

4. Simulcast Synchronization.

a. Each synchronized HAR system shall be equipped with a GPS synchronizer, which shall provide the capability to phase-lock the transmitters to a common reference carrier to minimize heterodyne.

b. The GPS Synchronizer subsystem shall have been successfully tested in conjunction with the transmitter and certified by the FCC in accordance with the provisions of FCC Section No. 90.242.

5. HAR Cabinet.

The cabinet used to contain HAR equipment shall be in accordance with the requirements as specified within the Specifications and as shown on the Plans.

6. Antenna **Subsystem.**

a. Omni-directional, vertically polarized antenna providing high efficiency with low radiation angle performance.

b. Provide an Effective Isotropic Radiated Pattern (EIRP) of 2.0 mV/m @ 1.5Km (0.93 miles) per FCC regulations.

c. Provide an overall VSWR of 1:4 or better with direct feed (without antenna tuner).

d. Antenna shall be constructed from anodized aluminum with adjustable tip to minimize the standing waves.

7. Grounding.

a. The antenna/grounding design shall be provided for each proposed HAR site taking into account local site conditions, soil conditions, antenna type and exact location, along with the ground plane designed.

b. 8 AWG grounding wire shall be installed.

c. The HAR antenna grounding design and design submittal shall be either conducted by or signed off by the HAR equipment manufacturer. The HAR antenna grounding design and submittal package shall include the requirements as specified within this Article and as defined in **Sub-Article 729.03(i)1.c, "*HAR Antenna Grounding*"**.

d. The HAR antenna subsystem shall be provided with an efficient ground plane properly tuned to the operational frequency and ground/soil type and conditions.

e. The grounding subsystem shall consist of a set of horizontal radials of heavy gauge wire or radial loops extending outward from the base of the antenna to ensure proper grounding and performance requirements.

f. An alternate ground system method and configuration may be designed and submitted as part the HAR grounding subsystem design submittal depending on site conditions to the Department for review and approval prior to construction.

g. Regardless of the grounding type, the Contractor shall be responsible for providing a complete grounding subsystem that supports the minimum 4-mile transmission radius system performance as described herein.

h. Antenna mast, or tower sections shall be bonded and grounded through HAR electrode system.

i. Communications cables with metallic sheath and armored cables if used shall be grounded by using appropriate cable grounding kits as recommended by the cable manufacturer.

8. HAR System Software.

In areas where HAR systems exist the Contractor shall integrate new HAR stations with existing HAR server software and hardware.

The HAR software application shall provide centralized operator control and monitoring of dispersed HAR and flashing beacon subsystems with the following minimum features and capabilities:

a. Shall allow the HAR system operator to select, display, schedule, and modify messages, transmit messages, list diagnostic information, and control of HAR field stations via the network.

b. Shall provide for multiple modes of operation as follows: transmitter control, record and monitoring of messages, playing of pre-recorded messages, emergency broadcast mode (live), and National Oceanic and Atmospheric Administration (NOAA) weather radio broadcast when alert is activated.

c. Shall import audio files created externally and log updates.

d. Shall convert typed text into voice that can be used for a clear understandable message.

(b) Permanent HAR.

The Permanent HAR shall also meet the following minimum requirements:

1. broadcast user defined audio;
2. transmit a test broadcast when defined by the user;
3. reset radio transmission after power interruption and when requested by the user;
4. operate without interruption from: hardwired 120 Vac power source, solar panel power source, and battery backup power source; and,

5. operate without interruption from battery backup power source for a duration of three (3) days without charging.

The Permanent HAR shall also meet the following minimum requirements:

DESCRIPTION	SPECIFICATION
Power	120 Vac 12 Vdc Solar 180 Amp Battery Backup providing 3 days of continuous use
Audio Recoding Limit	80 minutes minimum
Transmit Radius	3 - 5 miles {6 - 10 km}
Transmitter	FCC Approved Part 90.242 GPS synchronization
Antenna Height	50 ft maximum
Enclosure	NEMA Type 3R Weatherproof
Broadcast Power	Adjustable up to 10 W
Broadcast Frequency Range	530 - 1700 kHz
Frequency Stability	± 20 Hz
Audio Distortion	< 1.5%, 200 Hz to 3 kHz
Audio Frequency Response	± 3 dB
Noise Level	70 dB maximum below 95% modulation level, 100 Hz to 3 kHz
Modulation	99%, -40 dB to 20 dB
Operating Temperature	-40˚F to 85˚F {-40˚C to 29˚C}
Operating Humidity	95% (non-condensing)
Communication Ports	Ethernet, RS 232 Serial, USB Flash Drive

(c) Portable HAR.

The Portable HAR shall also meet the following minimum requirements:

1. broadcast user defined audio;

2. transmit a test broadcast when defined by the user;

3. reset radio transmission after power interruption and when requested by the user;

4. operate without interruption from: solar panel power source and battery backup power source; and,

5. operate without interruption from battery backup power source for a duration of 10 days without charging.

The Portable HAR shall be mounted on a single axle trailer, supporting the antenna, radio, power supply, and other equipment during operation. The Portable HAR shall be towed with a standard ball hitch. The trailer shall be in compliance with federal and local regulations and be roadworthy.

The Portable HAR shall also meet/provide the following requirements:

DESCRIPTION	SPECIFICATION
Power	Primary Solar 12 Vdc, 2 A maximum 200 A Battery providing up to 10 days of continuous use
Audio Recoding Limit	80 minutes minimum
Transmit Radius	3-5 miles {6-10 km}
Transmitter	FCC Approved part 90.242 GPS synchronization
Antenna Height	25 ft maximum

Enclosure	NEMA Type 3R Weatherproof
Broadcast Power	Adjustable up to 10 W
Broadcast Frequency Range	530 - 1700 kHz
Frequency Stability	± 20 Hz
Audio Distortion	< 1.5%, 200 Hz to 3 kHz
Audio Frequency Response	± 3 dB
Noise Level	70 dB maximum below 95% modulation level, 100 Hz to 3 kHz
Modulation	99%, -40 dB to 20 dB
Operating Temperature	-40˚F to 85˚F {-40˚C to 29˚C}
Operating Humidity	95% (non-condensing)
Communication	Digital modem, RS 232 Serial, USB Flash Drive

893.10 Conduit, Conductor, Locate Tone Wire, Messenger, and Warning Tape.

(a) Non-Metallic Conduit.

1. General Non-Metallic Conduit.

Non-Metallic Conduit for ITS and related applications shall be Rigid Non-metallic Conduit (RNC) [i.e. Rigid Polyvinyl Chloride (PVC) conduit, Liquid-tight Flexible Non-metallic Conduit (LFNC), or High Density Polyethylene (HDPE) conduit] as indicated within this Section. All conduits shall be homogeneous and shall have no visible cracks or holes. Non-metallic conduit shall be of the size and type as shown on the Plans.

Non-metallic conduit shall be colored for intended usage as defined by the American Public Works Association (APWA) Uniform Color Codes unless otherwise shown on the Plans or directed by the Engineer. The color codes for underground utilities as adopted by the Department from APWA are as follows:

COLOR	USAGE
Red	Electrical power and lighting
Orange	Telecommunications, alarm or signal lines (ALDOT uses this color for ITS and fiber optics.)
Yellow	Gas, oil, steam, petroleum, or other gaseous or flammable material
Green	Sewers and drain lines
Blue	Drinking water
Purple	Reclaimed water, irrigation and slurry lines

All non-metallic conduits shall be watertight sealed using solid or split ring compression type duct plugs. Duct seal shall not be allowed. Couplings for HDPE conduits shall be compression type fittings that provide a watertight seal and full pullout resistance meeting ASTM D-3350.

LFNC shall be Underwriters Laboratories (UL) Listed (UL 1660 "*Liquid-Tight Flexible Nonmetallic Conduit*") category code DXOQ and used in accordance with NEC Article 356. Fittings for LFNC shall be mechanical connections manufactured to work specifically with LFNC. PVC cement shall not be used on LFNC. Flex shall be rated for 1000 Volts maximum.

When being installed for power applications, conduit and fittings shall be Underwriters Laboratories (UL) Listed for use as electrical conduit and carry the UL label. This UL label shall be marked as follows: (a) at 10 feet {3 m} length intervals for conduit; and, (b) stamped or molded on each fitting.

2. Exposed Non-Metallic Conduit.

Non-Metallic conduit installed exposed (above grade) shall be Rigid Polyvinyl Chloride Conduit (Type PVC) or Liquidtight Flexible Nonmetallic Conduit (Type LFNC). The exposed conduit shall be

ultra-violet (UV) stable (sunlight resistant) per UL 651. Exposed conduit shall be Schedule 80 PVC and shall comply with the following conduit and fitting standards:

a. NEMA Standards Publication No. TC-2 "Electrical Polyvinyl Chloride (PVC) Conduit",

b. ASTM D4396, "*Standard Specifications for Rigid Poly (Vinyl Chloride) (PVC) and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds for Plastic Pipe and Fittings Used in Non-Pressure Applications*",

c. UL Standards No. 651 "*Standard for Schedule 40, 80, Type EB and A Rigid PVC Conduit and Fittings*", and

d. NEMA TC-3 "*Polyvinyl Chloride (PVC) Fittings for Use with Rigid PVC Conduit and Tubing*".

3. Underground Non-Metallic Conduit.

Non-Metallic Conduit installed underground (below grade) shall be High Density Polyethylene Conduit (Type HDPE). Underground HDPE conduit shall be Schedule 80 or SDR-11 (depending upon UL Listing requirements for non-fiber installations and as shown on the Plans). If rocky soil conditions are encountered during precision directional bore installations, SDR-9 HDPE may be required. Underground HDPE conduit shall comply with the following conduit and fitting standards:

a. NEMA Standards Publication No. TC-7, "Smooth-Wall Coilable Electrical Polyethylene Conduit",

b. ASTM D2239, "Standard Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter",

c. ASTM D3035, "Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter",

d. ASTM F2160, "Standard Specification for Solid Wall High Density Polyethylene (HDPE) Conduit Based on Controlled Outside Diameter (OD)",

e. ASTM D3350, "Standard Specification for Polyethylene Plastics Pipe and Fittings Materials" for a minimum cell classification of PE334480E/C,

f. ASTM F2176, "Standard Specification for Mechanical Couplings Used on Polyethylene Conduit, Duct and Innerduct", and

g. UL Standards No. 651A "Standard for Schedule 40 and 80 High Density Polyethylene Conduit".

(b) Metallic Conduit.

Metallic Conduit for ITS and related applications shall be Rigid Metal Conduit (Type RMC) of Galvanized Steel, thick wall, unless otherwise shown on the Plans. Metallic conduit shall be of the size shown on the Plans.

All metallic conduits shall conform to applicable Underwriters Laboratories (UL), NEC, ANSI, and National Electrical Contractors Association Standard (NECA) conduit and fitting standards.

Galvanized Steel RMC shall also conform to: UL Standards No. 6 "*Electrical Rigid Metallic Conduit - Steel*"; ANSI Standard Publication No. C80.1 "*American National Standard For Electrical Rigid Steel Conduit (ERSC)*" with the applicable zinc protection coating requirements; and, ANSI Standard Publication No. NECA 101 "*Standard for Installing Steel Conduits (Rigid, IMC, EMT)*". All conduits shall be homogeneous and shall have no visible cracks or holes. All metal accessories and fitting used with the conduit shall be compatible and shall also meet the galvanization requirements as specified within the Specification.

Conduit and fittings shall be Underwriters Laboratories (UL) Listed for use as electrical conduit and carry the UL label. This UL label shall be marked as follows: (a) at 10 feet {3 m} length intervals for conduit; and (b) stamped or molded on each fitting.

Use of RMC for electrical cable shall be installed in accordance with the NEC including bond grounds.

When installed on a bridge or similar surface, the couplings shall be designed and factory certified to handle expected expansion and contractions on a bridge application.

(c) Reinforced Thermosetting Resin Conduit (RTRC).

Reinforced Thermosetting Resin Conduit (RTRC) shall be of reinforced thermosetting resin material with outer diameter size as shown on the Plans meeting or exceeding the latest requirements of NEMA Standards Publication No. TC-14 "*Reinforced Thermosetting Resin Conduit (RTRC) and Fittings*" and UL 2515 "*Standard for Supplemental Requirements for Extra Heavy Wall Reinforced Thermosetting Resin Conduit (RTRC) and Fittings*". The conduit design shall be rated for above ground installations such as on a bridge structure. The outer conduit, joints, and any spare used internally, shall be all-dielectric. The conduit shall be ultra-violet (UV) stable (sunlight resistant) per UL 2515.

The joint assembly shall be tested in accordance with ASTM D2105 "*Standard Test Method for Longitudinal Tensile Properties of Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube*". There shall be no water leakage through the joint when tested in accordance to UL Standard No. UL 2515 and CSA Standard C22.2 No. 2515, "*Aboveground Reinforced Thermosetting Resin Conduit (RTRC) and Fittings*".

Conduit joints shall consist of an integral bell and spigot. The spigot end shall have a buttress type, male thread for easy installation. The belled end shall contain the mating female threads. The conduit joint shall be made in such a manner as to form a watertight seal.

The couplings shall be manufactured from a high impact thermoplastic material and shall be supplied with lead-ins to facilitate assembly.

The couplings shall be designed and factory certified to handle expected expansion and contractions on a bridge application.

Appropriate termination kits shall be provided by the conduit manufacturer for terminating the conduit in manholes and junction boxes.

(d) Pull Tape and Pulling Grip.

Pull Tape shall be manufactured of aramid yarn and rated at 2500 lbs minimum for the purpose of attaching to, and the pulling of fiber optic and electrical cables into a conduit system. Pull Tape shall have low elasticity to minimize surge-induced fluctuation in pull tape tension. Pull Tape shall not damage the conduit or cut the innerduct when under tension. Pull Tape shall be factory or field installed within conduit.

Pulling grips shall be used in accordance with the cable manufacturer's recommendations and Standard Operating Procedures. Pulling grips shall be factory or field installed along with a breakaway swivel; and shall be designed and rated for pulling fiber optic and electrical cables. Pulling grips shall provide effective coupling of pulling loads to the jacket, aramid yarn, and central member of the fiber optic cable per the cable manufacturer's requirements. The use of a swivel between the pull tape and pulling grip is required to prevent twist to the cable during the pulling operation and to limit exceeding the cable's maximum pulling tension.

(e) Friction Reduction Multiduct Sleeves.

Friction reduction multiduct sleeves are required for installing new fiber where indicated on the Plans and with cell quantity specified. When size and quantity are not indicated on the Plans, a minimum of 3-cells shall be provided. Size shall be based on conduit size. Each cell shall contain a Pull Tape, as specified within the Specifications. Friction reduction multiduct sleeves shall be manufactured of flexible polyester and nylon resin polymer textile material rated for the installed environment.

(f) Conductor.

All conductors shall be Type XHHW-2 stranded copper with 1000 Vac rated cross-linked polyethylene insulation, high heat, and moisture resistance conforming to ANSI/NEMA Standard No. WC 70 and ICEA Standard No. S-95-658, "*Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy*". Conductors shall be rated for conduit, direct burial, and sunlight resistance. Conductors shall be suitable for wet or dry conditions at temperatures not to exceed 194°F {90°C}.

Conductor size shall be such to exceed the amperage rating of the upstream breaker. Conductors shall be soft drawn annealed copper having a conductivity of at least 98 percent of pure copper. Wires shall be single conductor type for sizes smaller than 8 AWG. Wires shall be stranded for sizes 8 AWG and larger.

Insulation marking and color coding of conductors shall meet NEC standards.

(g) Locate Tone Wire.

Locate Tone Wire shall be a 12 AWG, solid copper wire with an orange jacket (a.k.a. trace wire or locate wire) and also meet the CONDUCTOR requirements as specified within this Specification. Locate Tone Wire shall be suited for direct burial and shall be continuous.

(h) Messenger and Guy Wire.

Messenger Wire (a.k.a. span wire) and Guy Wire (a.k.a. guy strand or down guy) for ITS and related applications shall be steel, seven (7) wire strand, Class A (double galvanized) and conform to the requirements of ASTM Standards Publication No. A 475, "*Standard Specifications for Zinc-Coated Wire Strand*". The cable shall be extra high-strength grade steel (EHS) with a minimum nominal diameter of 1/4 inch {6 mm} and a minimum breaking strength of 3,136 pounds {14.0 kN}.

All cable attachment hardware and fittings shall be new and stainless steel or non-corrosive material and shall be provided with tensile strength adequate for the application. Cable attachment hardware and fittings shall include, but not limited to: pole attachment hardware, cable ties and straps, lashing, extension arms, and pole extensions. Fiberglass insulators are to be provided in accordance with applicable NESC, NEC and local Utility standards.

Down guy shall have a guy marker (a.k.a. guy guard) with materials as specified in accordance with applicable NESC, NEMA and local Utility standards.

(i) Warning Tape.

Warning Tape shall consist of an underground/buried tape marking the locations of conduits containing fiber optic cables and/or electrical conductors as indicated on the Plans.

Warning tape shall be 3 inch {7.6 cm} wide, elastic PVC, tear resistant, corrosion resistant and durable to extreme weather conditions. The color of the tape shall be orange with "ALDOT FIBER OPTIC CABLE - CALL ALDOT [insert phone number to be provided by the TSMO Engineer]" printed every 3 feet {0.9 meter} in black letters, unless otherwise noted on the Plans.

The physical test methods along with typical properties and values are specified below:

TEST METHOD	TEST SPECIFICATION	TEST VALUE/UNITS
Standard Weight	ASTM-D2103	20 lbs/100 feet
Thickness-overall	ASTM-D2103	4 mil
3 in. Tensile Break-MD	ASTM-D882	35 lbs/ft
3 in. Tensile Strength-MD	ASTM-D882	4 kpsi
3 in. Tensile Break-TD	ASTM-D882	38 lbs/ft
3 in. Tensile Strength-TD	ASTM-882	5 kpsi
Elongation-MD	ASTM-882	530%
Elongation-TD	ASTM-882	660%
Tear Strength	ASTM-D2261	1.5 lbs/ft

893.11 Grounding.

All grounding conductors shall be either bare or insulated with green jacket in accordance with the NEC.

Grounding electrodes (rods) installed for ITS equipment installations shall be copper clad rods of minimum size 5/8 inch {16 mm} in diameter and 10 ft {3.0 m} long. All non-current carrying conductive material shall be bonded together and grounded to earth through the grounding electrode. Grounding electrodes shall be bonded by seven (7) strand copper wire or strap of the same cross-sectional area as a 6 AWG {4.25mm} wire. Grounding electrodes shall conform to the NEC requirements and be approved by the Underwriter's Laboratory (UL).

[See **Sub-Article 729.03(k), *"Grounding, Lightning Protection, Insulation, and Circuit Continuity"*** for grounding system installation and testing requirements.]

893.12 Intelligent Transportation System (ITS) Cabinet.

(a) General.

All Intelligent Transportation System (ITS) Cabinets shall be of the same manufacturer per cabinet type, identical in size and shape, and of the same quality throughout the entire project. The ITS Cabinet shall be equipped internally as specified herein, and as required to suit the specific complement of equipment as shown on the Plans.

ITS Cabinets shall meet the following general requirements:

1. Material.

ITS Cabinet housing shall be Aluminum alloy 5052-H32 at 0.125 inch thick (minimum) with a natural aluminum finish and continuously welded seams. ITS Cabinet housing shall be UL listed and meet below NEMA environmental rating requirements. ITS Cabinet exteriors shall be free of any sharp edges and spurs.

For pole mounted applications, mount-side cabinet walls shall be designed to minimize deflection and cabinet movement. Some cabinet wall reinforcement may be necessary.

2. Cabinet Dimensions.

ITS Cabinet dimensions are to be as indicated within each cabinet type and are approximate. A tolerance of -0% to +15% shall be allowed on each cabinet dimension indicated within their respective cabinet type table.

3. Environment.

ITS Cabinet shall meet or exceed NEMA Type 3R standard requirements and NEMA TS2 standard requirements for shock and vibration. ITS Cabinet shall withstand ambient operating temperatures from -40°F to 185°F {-40°C to 85°C}.

Louvered vents shall be installed on doors of the cabinet for ventilation. The bottom of the vents shall be within 3 to 6 inches from the bottom of the door. Vents shall be framed in to allow installation of air filter. The air filter shall be held in place securely against the door by a bottom bracket and a spring loaded upper clamp. No incoming air shall bypass the air filter. The bottom filter bracket shall be formed into a waterproof sump with drain holes to the outside housing.

An UL listed thermostatically controlled power vent and dual fans shall be provided. The thermostat shall activate the fans at 110°F {43°C} and de-activate the fans at 90°F {32°C} with an accuracy of ±5°F {±3°C}. Fans shall be rated at 100 cfm. Fans shall also be rated for three (3) year continuous service life and have ball bearings.

4. Cabinet Lighting.

ITS Cabinets shall utilize high efficiency Light-Emitting-Diode (LED) lighting fixtures. These light fixtures shall be 120 Vac or have a power supply conversion. Each light fixture shall have a lumen output of 600 to 1200 lumens at 4000°K to 5000°K (with a tolerance of ±300°K). The initial light fixture output level is to be set at 1,000 lumens minimum per door, unless otherwise directed by the Engineer. The light fixture shall be covered by a protective shield that prevents glare. These LED light fixtures shall be operated by a UL listed Class 2 power supply.

These LED lighting fixtures shall be provided and mounted inside the top portion of the ITS Cabinet for each door opening and under the cabinet drawer(s) so that it remains stationary when drawer is extended. LED light fixtures shall be mounted such that they can be easily removed and replaced without interference from other devices mounted in the ITS Cabinet.

All light fixtures shall be activated upon any door opening. Door switches along with necessary connections to the respective light fixture shall be provided. Door switches shall be made of durable materials and mounted in a manner that will withstand repeated use.

5. Doors.

Doors shall be weather-resistant and dust-tight with a closed cell gasket. Mating surface of the doors shall be covered with a silicone lubricant to prevent sticking. Top gasket shall be the width of the door, side gaskets shall begin below top gasket and bottom gasket shall be within the side gaskets. Doors shall include a retaining ring installed on the inside of the gasket for protection. Three-point latching system is required with each point controlled by the door handle for each door. The three-point latch points shall be at center, top, and bottom of each door. No plastic parts other than nylon rollers for top/bottom door secure is allowed. Door hinges, bolts, three-point latch system and pins

shall be stainless steel or equivalent corrosion resistant material. When doors are open, a manufactured doorstop shall be included to hold the door open at a minimum of two positions, 90 degrees and 120 degrees.

ITS Cabinet doors shall be equipped with a brass or stainless-steel lock. Lock shall be ALDOT's standard Corbin #3 lock and key set. The Contractor shall coordinate with the Engineer to obtain cylinder code and key code. Two keys shall be provided for each lock. Locks will be permanently lubricated and be covered with a weatherproof tab. Door handle shall turn away from the lock to open the door. The keys shall be removable in the locked position only.

A plastic documentation pouch to store the ITS Cabinet and equipment documentation shall be provided. Pouch shall be side-opening, reseal-able, opaque, and of a heavy-duty plastic material. The pouch shall have metal or hard plastic reinforced holes for hanging from hooks included on the cabinet door. The pouch shall be of the size and strength to easily hold all wiring diagrams, equipment documentation and the maintenance logbook.

6. Rack Assembly.

ITS Cabinets shall be equipped with a 19-inch industrial rack frame assembly with a four-post design for mounting components in accordance with EIA/ECA-310 standard. Rack shall span the entire height of the ITS Cabinet. Depth of rack shall be adjustable for differing field conditions. Rack mounting panel(s) and mounting tray(s) shall be provided for installing the surface mount and standalone equipment, respectively. All cage nuts and screws required for mounting equipment to the rack shall also be provided. Additional cage nuts and screws, for mounting future equipment, shall be provided and placed in a plastic sealable bag attached to the rack.

7. Shelves.

All ITS Cabinets shall have a drawer that opens or is capable of sliding in and out for placing a notebook or laptop computer. Adjustable shelves shall be vented and provided in quantities as indicated in Dimension and General Requirements Table for each cabinet type. A hinged, aluminum shelf and integrated storage compartment shall be installed inside the front door for two-door cabinets. The shelf shall have a smooth, non-slip surface sufficient for use for a writing platform and laptop workspace. The shelf shall have rounded or insulated edges that do not have the potential to physically harm the user. The shelf and storage compartment shall have the ability to lock into place when folded for storage; locking, unlocking, and use of the components shall not require tools. Storage component shall be at least 1.5 inch {38 mm} deep and capable of holding letter-size (8.5 inch x 11 inch) documents/manuals, at minimum.

8. Electrical.

The following ITS Cabinet electrical requirements are minimum requirements and shall be adapted to field conditions as shown on the Plans. Each ITS device type (e.g. camera, VDS, DMS, etc.) shall have a separate dedicated circuit (i.e. branch circuit with circuit breaker).

Stranded copper wire shall be used with exception of earth ground conductor which shall be solid wire. Wiring shall be UL listed and 1000 Volts rated per NEC. Wiring shall be neatly arranged, labeled/tagged, and managed using wire management system and ties; wire to be appropriate lengths before assembly (i.e., no double backs to take up slack). Color of wires shall be in accordance with the NEC. Wiring within ITS Cabinet shall be continuous (i.e., no splices) landing on busbars, terminal strips, device clamp, or lug.

Minimum 12 AWG (American Wire Gage) wire for all conductors on 120 Vac circuits unless otherwise shown on the Plans. Terminal blocks shall be provided for incoming power with a rating greater than wire being terminated on the block and shielded for contact protection. Grounding bus shall be provided for both earth ground and AC neutral/common (each isolated from the other). Electrical terminations shall be shielded (i.e., touch safe) to protect from accidental shock.

The ITS Cabinet shall contain minimum two (2) 15-amp rated convenience receptacles (NEMA Type 5-15R) with GFCI protection and be on an isolated circuit protected by a 20-amp breaker. These GFCI protected receptacles are to be designated for "Technician Service Use Only".

Mounted power distribution unit(s) or power strip outlet(s) shall be provided near the top of each ITS Cabinet for providing power to the ITS equipment. The power strip shall incorporate eight (8) NEMA Type 5-15R receptacles and be on an isolated circuit protected by a 20-amp breaker unless otherwise shown on the Plans. The power strip receptacle shall face the back of the cabinet and shall

be recessed within the cabinet rack to provide a minimum spacing of 3 inches {76 mm} between the outlet's face and the cabinet door when the door is closed.

Only circuit breakers that are Underwriters Laboratories (UL) approved and plainly marked with trip and frame sizes and ampere rating shall be used. All circuit breakers shall be quick-make, quick-break on either automatic or manual operations. Contacts shall be silver alloy and enclosed in an arc-quenching chamber. Circuit breakers shall be standard panel-mount or channel-mount. Overload tripping shall not be influenced by an ambient air temperature range from -0.5°F to 122°F {-18°C to 50°C}. Minimum interrupting capacity shall be 5,000 amperes RMS.

Busbars shall be fabricated from a copper alloy material compatible with copper wire. Busbars shall be used for termination of ground or neutral conductors. The earth ground busbar shall have at least two positions capable of terminating a 6 AWG conductor. With multiple busbars, each busbar shall be interconnected via a 10 AWG conductor.

Terminal blocks and strips with voltage and current ratings greater than the voltage and current ratings of the wires that are terminated on the blocks or strips shall be used. The terminal block for the 120 Vac cabinet service entrance (SE) shall be a tubular clamp compression device that is fully insulated (Marathon 1103P or approved equivalent). Terminal blocks for 120 Vac power wiring (TB1, TB2) shall be on dual-screen barrier type terminal blocks with 9/16 in {14.3 mm} spacing using nickel-plated brass 8-32 Philips slot screw and fork terminal lugs (Cinch 142 or approved equivalent). TB1 and TB2 shall have at least eight (8) terminal positions. Compression-type and tubular clamp terminal blocks shall be used only for service entrance block. Spade lug terminals shall not be used for any terminal block.

A 30-amp generator male receptacle, in a NEMA Type 3R rated enclosure shall be provided external to cabinet for quick generator connection.

9. Surge Protection.

Surge-Protective Device(s) are required in accordance with Item 729.03(q)7, "*Installation of Surge-Protective Devices*" and shall be as specified in Sub-Article 893.17(i), "*Surge Protection*".

10. Foundation (Mounting Pad).

Where the ITS Cabinet is pad mounted, the mounting pad foundation shall be concrete and as shown on the Plans.

The concrete mix used for mounting pads shall comply with the requirements of **Section 501** for Class A concrete and **Section 620**, unless otherwise shown on the Plans. Mounting pad shall be formed separately from any ITS concrete pole or structure foundations; and, the concrete shall include wire mesh.

Reinforcing steel shall meet the requirements of **Section 502** and as shown on the Plans.

11. Concrete Pad (Service Platform).

Where the ITS Cabinet is pole or structure mounted, the service platform pad shall be concrete and as shown on the Plans.

The concrete mix used for this service platform shall comply with the requirements of **Section 501** for Class A concrete and **Section 620**, unless otherwise shown on the Plans. Concrete pad shall be formed separately from any ITS concrete pole or structure foundations; and, the concrete shall include wire mesh.

Reinforcing steel shall meet the requirements of **Section 502** and as shown on the Plans.

12. Uninterruptible Power Supply.

The Uninterruptible Power Supply (UPS) unit for the ITS Cabinet shall be rack mounted and as shown on the Plans. The UPS unit shall also meet the minimum requirements of **Sub-Article 893.17(j) "Uninterruptible Power Supply (UPS)"**.

The UPS unit shall include all battery packs, power cables, mounting brackets and all appurtenances necessary for a complete operational backup power system; adequately sized to support the ITS cabinet equipment and operations.

The UPS unit shall typically support the ITS cabinet equipment as follows (unless otherwise shown on the Plans): Managed Ethernet Switch and ITS Cabinet equipment (e.g. cabinet lighting, fans, ITS equipment receptacles, and convenience receptacle).

(b) Type 337.

ITS Cabinet Type 337 shall also meet the following requirements:

DESCRIPTION	SPECIFICATION
Height	35.25 in.
Width	20.50 in.
Depth	18.125 in.
Mounting	POLE/PEDESTAL
Number of Doors	2
Door Location(s)	FRONT/REAR
Number of Adjustable Shelves	1
Rack Assembly	Yes
Louvered Vent Size (length x vent depth)	3.00 in. x 0.25 in. (24 each front door only)
Air Filter Size	12 in. x 16 in.
GFCI Receptacles	1-Duplex
Equipment Receptacles	1-Duplex
Breakers	DIN rail mounted breakers. One 30-amp main breaker; one 20-amp breaker for cabinet lights, fans, and convenience receptacle; one 20-amp breaker for device receptacle; and additional 20-amp breakers required for any and each additional convenience receptacle as required on the Plans

(c) Type 332S.

ITS Cabinet Type 332S shall also meet the following requirements:

DESCRIPTION	SPECIFICATION
Height	66.75 in.
Width	24.25 in.
Depth	30.25 in.
Mounting	BASE
Number of Doors	2
Door Location(s)	FRONT/REAR
Number of Adjustable Shelves	2
Rack Assembly	Yes
Louvered Vent Size (length x vent depth)	3.00 in. x 0.25 in. (24 each per door)
Air Filter Size	12 in. x 16 in.
GFCI Receptacles	One Duplex
Equipment Receptacles	One Duplex
Breakers	DIN rail mounted breakers. One 30-amp main breaker; one 20-amp breaker for cabinet lights, fans, and convenience receptacle; one 20-amp breaker for device receptacle; and additional 20-amp breakers required for any and each additional convenience receptacle as required on the Plans

(d) Type 332D (Quad).

ITS Cabinet Type 332D (QUAD) shall also meet the following requirements:

DESCRIPTION	SPECIFICATION
Height	66.00 in.
Width	44.25 in.
Depth	28.50 in.
Mounting	BASE
Number of Doors	4
Door Location(s)	(2 each) FRONT, (2 each) REAR
Number of Adjustable Shelves	4
Rack Assembly	Yes, Qty. (2)
Louvered Vent Size (length x vent depth)	3.00 in. x 0.25 in. (24 each per door)
Air Filter Size	12 in. x 16in.
GFCI Receptacles	One Quadruplex per side
Equipment Receptacles	One Quadruplex per side
Breakers	Panelboard shall be 100-amp rated with 30-amp main breaker and 6 bolt-on type breakers unless specified otherwise on the Plans; one 20-amp breaker for cabinet lights, fans, and convenience receptacle; one 20-amp breaker for device receptacle; and additional 20-amp breakers required for any and each additional convenience receptacle as required on the Plans

(e) Type 336S.

ITS Cabinet Type 336S shall also meet the following requirements:

DESCRIPTION	SPECIFICATION
Height	46.25 in.
Width	24.25 in.
Depth	22.25 in.
Mounting	BASE/POLE
Number of Doors	2
Door Location(s)	FRONT/REAR
Number of Adjustable Shelves	2
Rack Assembly	Yes
Louvered Vent Size (length x vent depth)	3.00 in. x 0.25 in. (12 each per door)
Air Filter Size	12 in. x 16 in.
GFCI Receptacles	One Duplex
Equipment Receptacles	One Duplex

Breakers	DIN rail mounted breakers. One 30-amp main breaker; one 20-amp breaker for cabinet lights, fans, and convenience receptacle; one 20-amp breaker for device receptacle; and additional 20-amp breakers required for any and each additional convenience receptacle as required on the Plans

(f) Type 334.

ITS Cabinet Type 334 shall also meet the following requirements:

DESCRIPTION	SPECIFICATION
Height	67 in.
Width	24.3 in.
Depth	30 in.
Mounting	BASE/POLE
Number of Doors	2
Door Location(s)	FRONT/REAR
Number of Adjustable Shelves	2 (minimum)
Rack Assembly	Yes
Louvered Vent Size (length x vent depth)	3.00 in. x 0.25 in. (12 each per door)
Air Filter Size	12 in. x 16 in.
Technician Receptacles	One Duplex (non-GFCI)
Equipment Receptacles	One Duplex and One Quadruplex
Breakers	DIN rail mounted breakers. One 30-amp main breaker; one 20-amp breaker for cabinet lighting, fans, and (non-GFCI) convenience receptacle; one 15-amp breaker for device receptacle, powered from UPS if available; and additional 15-amp breakers required for any and each additional convenience receptacle as required on the Plans.
Relays	When an Uninterruptible Power Supply (UPS) is present, both equipment receptacles shall be powered through the UPS. The Duplex receptacle shall be powered through a relay that is switched on/off by dry contacts on the UPS.
Cabinet UPS Status LEDs	When a UPS is present, cabinet LEDs shall be provided which indicate the UPS status. These cabinet LEDs shall be installed on the door with the best visibility from the road unless otherwise specified. These cabinet LEDs shall be connected through relays such that a green LED is ON under normal circumstances and an amber LED is ON when the relay is activated via dry contact from the UPS.

Fiber Distribution Unit	Secondary Fiber Distribution Unit (SFDU) shall be a slidable 1U rack-mounted unit for terminating the optical fiber drop cable. SFDU shall be a 2-connector panel design. Cable management shall be accessible from the top of the SFDU when the drawer is in an open position. There shall be sufficient cable slack to allow the drawer to be fully functional. This SFDU shall also meet all other requirements as specified in **Article 893.03** and as shown on the Plans.

(g) Hub (Quad).

ITS Cabinet, Hub (Quad) shall also meet the following requirements:

DESCRIPTION	SPECIFICATION
Height	72 in.
Width	60 in.
Depth	48 in.
Mounting	BASE
Number of Doors	4
Door Location(s)	(2 each) FRONT, (2 each) REAR
Number of Adjustable Shelves	4 (minimum)
Rack Assembly	Yes, Qty. (4)
Louvered Vent Size (length x vent depth)	3.00 in. x 0.25 in. (24 each per door)
Air Filter Size	12 in. x 16 in.
Technician Receptacles	One Duplex (non-GFCI) per side
Equipment Receptacles	One Duplex and One Quadruplex per side
Breakers	DIN rail mounted breakers. One 30-amp main breaker; one 20-amp breaker for cabinet lighting, fans, and (non-GFCI) convenience receptacle; one 15-amp breaker for device receptacle, powered from UPS if available; and additional 15-amp breakers required for any and each additional convenience receptacle as required on the Plans.
Relays	When an Uninterruptible Power Supply (UPS) is present, both equipment receptacles shall be powered through the UPS. The Duplex receptacle shall be powered through a relay that is switched on/off by dry contacts on the UPS.
Cabinet UPS Status LEDs	When a UPS is present, cabinet LEDs shall be provided which indicate the UPS status. These cabinet LEDs shall be installed on the door with the best visibility from the road unless otherwise specified. These cabinet LEDs shall be connected through relays such that a green LED is ON under normal circumstances and an amber LED is ON when the relay is activated via dry contact from the UPS.

Fiber Distribution Unit	Primary Fiber Distribution Unit (SFDU) shall be used for terminating the optical fiber drop cable. This PFDU shall also meet all other requirements as specified in **Article 893.03** and as shown on the Plans.

893.13 Electrical Power Service and Transformer.

Electrical Power Service assembly shall consist of equipment to provide a pole attached raceway and disconnect switch for use with power cable routed from the service entrance to the ITS Cabinet. The electrical power service assembly shall include (at a minimum): service pole, weatherhead, conduit and fittings, electrical cable/conductors (from utility power source to service pole), riser, disconnect switch(es) with enclosure, grounding, and attachment clamps. Lateral/horizontal conductors, after the service disconnect/meter base and to the ITS cabinets/equipment, are not part of the Electrical Power Service assembly.

Electrical power service shall be in accordance with these Specifications, Plans, NEC requirements, and local utility codes. Electrical power shall be provided by a Utility Company transformer that does not provide power to any other equipment or clients unless otherwise noted on Plans or approved by the Engineer.

Electrical service power runs will typically be a 120/240 Vac system unless otherwise supplied by the Utility Company and/or shown on the Plans. For 480 volt systems or greater, a meter disconnect switch shall be installed on the supply side of the meter and meter base in accordance with NEC Article 230 (especially Sub-Article 230.82) and as directed by the Utility Company.

Depending upon the electrical service provided, step-up and step-down transformers may be required (e.g. for DMS or long-runs) as shown on the Plans. Typically, these transformers shall be provided by the contractor and installed at the service pole location with another corresponding transformer at the ITS Cabinet/equipment site as indicated on the Plans.

Materials shall be tested and approved by a nationally recognized testing laboratory and shall meet the following requirements:

(a) Service Pole (Wood Pole).

Service Pole shall be southern yellow pine treated in accordance with the latest American Wood-Preserver's Association (AWPA) standards and shall conform with requirements given in **Section 833**.

Unless otherwise shown on the Plans, service pole used for service lateral drop shall be a 35 foot {10.7 m} Class 3 wood pole and shall conform to the requirements of ANSI Standards Publication No. O5.1, *"American National Standard for Wood Utility Products – Wood Poles: Specifications and Dimensions"* as published by American Wood Protection Association (AWPA), Birmingham, Alabama.

The poles shall not have more than 180 degrees of twist in grain over the full length and the sweep shall be no more than 4 inches {100 mm}.

(b) Electrical Cable and Conductors.

Phase or current carrying conductors shall be of the type RHH, RHW, USE, or XHHW. Size shall be of the size shown on the Plans and in accordance with the NEC.

Conductors shall be stranded annealed copper with not less than 98 percent conductivity and shall be insulated for 1000 Volts or more with rubber insulation and a neoprene jacket, or with cross-linked polyethylene insulation.

Electrical Power Service Cable and Conductors shall also meet the requirements of **Sub-Article 893.10(f), *"Conductor"***.

(c) Conduit.

Conduit shall conform to the requirements specified in these Specifications and as shown on the Plans. Only UL Listed conduit shall be used for electrical power service installations.

(d) Weatherhead.

Weatherhead shall be made of a copper-free aluminum alloy or galvanized ferrous material.

(e) Attachment Hardware.

Attachment hardware shall meet the requirements of this Section and as shown on the details in the Special and Standard Highway Drawings, unless otherwise shown on the Plans.

(f) Guy Wire.

Guy Wire (a.k.a. down guy) shall meet the requirements of this Section and as shown on the details in the Special and Standard Highway Drawings, unless otherwise shown on the Plans.

(g) Meter Base and Meter Disconnect.

When a meter base is required, the meter base shall be a meter base approved by the local Utility Company. When a meter disconnect is required, the meter disconnect switch shall be a meter disconnect meeting below service disconnect requirements (without key option unless otherwise specified by the Utility Company), NEMA rated enclosure for intended outdoor use, rated for the service supply voltage, and approved by the local Utility Company.

(h) Service Disconnect.

1. Enclosure Cabinet:
   The Enclosure Cabinet shall conform to NEMA standards, made of galvanized steel, aluminum, stainless steel or other material approved by the Engineer. The enclosure shall have a hinged door with a padlock. Padlock No. 3210 keyed for a No. 3 key shall be provided. One key for the enclosure cabinet shall be hung within the corresponding ITS Cabinet.
2. Circuit Breaker:
   A manually re-settable circuit breaker shall be installed, which has a current rating of the circuit to which electrical power is provided.
3. Transient Protective Device:
   A surge lightning arrestor rated for a maximum permissible line to ground voltage of 175 Vac shall be installed; and meeting the requirements of NEMA standards for surge arrestors and also as specified in **Sub-Article 893.17(i), "*Surge Protection*"**.

(i) Grounding.

Grounding and grounding electrodes shall be as specified in this Specification unless otherwise shown on the Plans.

(j) Transformer (Step-Up/Step-Down).

If required, Step-Up/Step-Down Transformer(s) shall be provided for each Dynamic Message Sign (DMS) installation site where power is not available in close proximity to the DMS equipment and voltage drops will require a higher distribution voltage than the Utility Company supplied power (typically 120/240 volt service). If required, a step-down transformer may also be provided for each ITS Cabinet installation site as indicated on the Plans.

The step-up/step-down transformer shall be a dry type transformer as recommended by the local Utility Company and approved by the Engineer. The transformer KVA size and primary/ secondary voltages shall be as indicated on the Plans and approved by the Engineer. The transformer shall be mounted in a NEMA 3R enclosure and have all the appurtenances necessary for a complete electrical power service installation and to accommodate the required ITS equipment and ITS Cabinet. Disconnecting means (disconnect switch) shall be required for all transformers in accordance with NEC Article 450.14 and shall be located in close proximity to each transformer as allowed by NEC.

893.14 Intelligent Transportation System (ITS) Pole.

(a) General.

Intelligent Transportation System (ITS) Poles shall primarily be a concrete pole for ITS applications (e.g. cameras with or without other ITS devices). Metal poles with either auger base or concrete foundations are typically used for vehicle detection equipment (i.e. radar or magnetometers) only. ITS Pole shall be in accordance with the Plans and these Specifications. ITS Poles shall also conform to the requirements of **Section 718** and **Section 891**.

Unless otherwise shown on the Plans, the ITS Pole shall have the following minimum accessories:

- a 4 inch x 8 inch {10 cm x 20 cm} conduit entrance opening, centered 18 inches {46 cm} below grade; and,

- a 4 inch x 8 inch {10 cm x 20 cm} reinforced hand hole frame with cover, located 24 inches {61 cm} above grade and centered on same side as the below grade conduit entrance.

In addition to the requirements of **Section 718**, deflection shall not exceed 1 inch {25 mm} in 30 mph {45 km/h} wind for poles 70 ft. {21.3 m} or less.

(b) Concrete Foundations.

Concrete Foundations for metal ITS Poles shall be in accordance with the Plans and these Specifications. Concrete Foundations shall also conform to the requirements of **Section 718** and **Section 891**.

(c) Auger Base Foundations.

Auger Base Foundations (screw-in helix type) shall be ***for vehicle detection installations only (i.e. radar and magnetometer)*** as shown on the Plans and in accordance with these Specifications. Auger Base Foundations shall also conform to the requirements of **Section 718** and **Section 891**.

Materials used for auger base foundations must meet the requirements of ICC Evaluation Service (ICC-ES) AC358, "*Acceptance Criteria for Helical Foundation Systems and Devices*" and Earth Contact Products (ECP) "*Utility Industry Anchor Design and Maintenance Manual*", Second Edition (2013).

The design of the auger base foundations (screw-in helix type) must be done by a licensed design professional specialized in the engineering and design of auger base foundations and helical piles. The designer shall be a licensed Professional Engineer in the State of Alabama and must have designed at least five projects utilizing helical piles. Supporting documentation for license and minimum design experience shall be provided upon request of the Engineer. Design calculations shall be in accordance with the requirements of **Section 718**. The selected auger base size shall be a standard manufacturer size based upon the Professional Engineer's pole and foundation calculations at each ITS pole location. Pre-drilled bolt patterns for the auger base foundation base plate and corresponding metal pole base plate shall match. No drilling or modifications to the base plates will be allowed in the field.

All welds shall be made in accordance with the American Welding Society Standard ANSI/AWS D1.1, "*Structural Welding Code - Steel*", latest edition. Welders shall be certified in accordance with the ANSI/AWS Code. The completed foundation shall be hot dipped galvanized for underground use.

893.15 Hub Building.

(a) General.

Hub Building shall consist of a reinforced concrete or concrete composite building with concrete foundation, generator, automatic transfer switch and an uninterruptible power supply. This Hub Building is to be manufactured for the explicit use of housing the electronic communication equipment, power supplies, fiber optic equipment and cabling, measuring devices, and other related components necessary for the proper operation of an ITS deployment.

(b) Hub Building and Equipment.

Hub Building shall be reinforced concrete or concrete composite precast design in a size as shown on the Plans. Hub building shall be produced in its entirety at the manufacturer's facility and delivered and set-up complete at the Engineer's designated location as shown on the Plans. Each building shall have minimum 6.5 inch {165 mm} thick walls and minimum 4 inch {102 mm} thick ceiling and floor. The wall thickness should consist of, at a minimum, 4 inch {102 mm} concrete plus insulation and paneling for a total thickness of 6.5 inches {165 mm}. Hub Building shall be capable of withstanding minimum loads in accordance with local wind loads and environmental conditions where building is to be installed. Design must also consider stresses induced during handling, shipping and installation in order to avoid product cracking or other handling damage. Hub building shall maintain an interior building height of 9 ft. 6 in. {2.9 m} minimum from finished floor to finished ceiling.

Hub Building's exterior shall have a bullet-resistant surface in accordance with UL 752 "*Standard for Bullet-Resisting Equipment*". Hub building's exterior shall also be a concrete aggregate finish where color is earth tone to blend with its surroundings, unless otherwise shown on the Plans. Alternative exterior finishes or colors must have prior Engineer approval before hub building is manufactured.

Hub Building's interior floor covering shall be an industrial-grade vinyl flooring fastened to the building's floor with waterproof glue.

Hub Building shall be supplied with vapor shield in walls and ceiling to prevent moisture penetration. Hub building shall also have an air gap between the building floor and the slab, or alternatively, construct the slab with a vapor barrier as recommended by the hub building manufacturer to prevent moisture penetration. Hub Building shall be insulated as follows: ceiling/roof with a minimum Type R-21 insulation factor; walls with a minimum Type R-14 insulation factor; and floor with a minimum Type R-11 insulation factor. Roof is to be constructed with a 1/8 inch per foot minimum pitch for drainage.

Hub Building shall be furnished complete with the following installed equipment, at a minimum:

1. Electrical and Rack Equipment:
   a. 200-Amp load center;
   b. (11 each) 20-amp 120 volt duplex receptacle [divided into a minimum of 4 circuit groups];
   c. copper grounding electrode system;
   d. (55 feet) 2 AWG copper ground wire Halo ground, green insulation;
   e. (24 each) Clic Strap or equivalent for 2 AWG ground Halo support or equivalent;
   f. (6 each) compression fitting for 2 AWG by two wire;
   g. (30 feet) 6 AWG copper ground wire, green insulation;
   h. (9 each) compression fitting for 6 AWG by two wire;
   i. (25 each) two hole crimp fitting for 6 AWG wire;
   j. (11 each) one hole ring terminal for 6 AWG wire;
   k. two hole copper lug for 2 AWG wire;
   l. (26 each) ceramic insulators for 2 AWG wire;
   m. 12 inch by 12 inch NEMA enclosure;
   n. 50 point reliable terminal strip;
   o. 65.5 feet of 61 inch cable rack central steel painted;
   p. (2) pieces 2 inch by 3 feet mounting channel;
   q. (16 each) cable rack wall mounting bracket;
   r. (4 each) plastics end caps;
2. Surge Protection:

MOV type with peak surge rating of 50,000 amps (8x20 uS) with a response time of <5 nanoseconds with a maximum clamp voltage of 420 volts at 1 mA and 700 amps at 700 volts;

3. Door and Entrance:

   a. approximate 3 ft by 7 ft {0.91 m by 2.1 m} by 1-3/4 in {45 mm} thick armor shield bullet resistant door with standard door drip cap;
   b. door is to be a minimum of 18 gauge galvanized steel with stainless steel ball bearing hinges;
   c. door to be primed, painted brown and cast into the wall panel;
   d. 56 inch wide by 24 inch deep {142 cm wide by 61 cm deep} door awning;
   e. best Mortise lockset with deadbolt;
   f. hydraulic door closure with thumb turn;
   g. weather-stripping;
   h. magnetic door contact;
   i. concrete or concrete composite steps with hand rail installed so the distance from the grade to the hub building floor does not exceed 8 inches {20 cm};
4. Lighting**:**

   a. *Exterior*: outdoor security LED floodlight with adjustable dual-heads (minimum), switched photocell, motion sensor (minimum 180° up to 50 feet, selectable duration), weatherproof NEMA 3R rated, and UL Listed; die-cast aluminum housing with powder coated paint finish; outside/exterior mount by door for security of entry area; and Warm White (3000K), 2000 lumens (minimum) LED lights unless otherwise indicated on the Plans;

   b. *Interior*: (6 each) 4 feet LED light fixture with two 50-Watt equivalent, 5000 lumens, 5000K color temperature, LED tubes along with diffuser lens for inside hub building unless otherwise indicated on the Plans;

   c. (2 each) 20-amp 120 volt light switch;

5. Heating/Air-Conditioning:
   a. (2 each; one for operation and one for backup) 24,000 BTU 50-amp @ 240 Volt HVAC with 8kW Heat and 30-amp Dehumidifier;
   b. high/low temperature thermostat (for dual backup system);
   c. HVAC thermostat (for dual backup system);
   d. Humidistat (for dual backup system);
6. Fire Protection:
   a. (2 each) 120 volt smoke detector with remote contact;
   b. fire extinguisher, 110 lbs. ABC dry chemical, wall mounted (rated for electrical equipment);
7. Fence:
   a. 10 feet high fence chain link encircling the hub with the fence set off from the building by minimum of 10 feet, with 18 in. diameter of razor wire strung around the top of the fence and gate [*this item shall be paid separately and as shown on the Plans*];
   b. with (2 each) 6 feet drive gates [this item shall be paid separately and as shown on the Plans];
   c. and a lock with two (2) sets of keys shall be provided at each gate. The locks shall be approved by the Engineer.
   d. Fencing materials shall also meet the requirements of **Section 871** and as shown on the Plans.

[*PLEASE NOTE*: Quantities and items listed are minimum. Latest codes and building manufacturer may require additional quantities and items not listed above nor shown on the Plans.]

Hub Building and equipment racks shall also be furnished with a Halo Grounding Ring System which meets the applicable grounding requirements of ANSI/TIA-607-B "*Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises*".

(c) Hub Building Foundation.

Hub Building Foundation shall be reinforced concrete as shown on the Plans.

The concrete mix used for the foundation shall comply with the requirements of **Section 501** for Class A concrete, unless otherwise shown on the Plans.

Reinforcing steel shall meet the requirements of **Section 502** and as shown on the Plans.

(d) Generator.

The Generator shall be fully compatible and interoperable with the Automatic Transfer Switch. The Generator's electrical characteristics (i.e. size, power inputs and load outputs, line conditioning, etc.) shall be as shown on the Plans. The Generator shall include the manufacturer's recommended concrete pad installed as shown on the Plans. The Generator shall include the gas utility service and connections in accordance with the gas Utility Company requirements, these Specifications (see **Sub-Article 729.03(p)** and **Article 893.16, *"Gas Utility Service"***), and as shown on the Plans.

(e) Automatic Transfer Switch.

The Automatic Transfer Switch shall be fully compatible and interoperable with the Generator. The Automatic Transfer Switch shall be in accordance with the NEC and Utility Company requirements and as shown on the Plans.

(f) Uninterruptible Power Supply.

The Uninterruptible Power Supply (UPS) units for the Hub Building shall be two (2) each, rack mounted (or as indicated on the Plans), and as shown on the Plans. The UPS units shall also meet the minimum requirements of **Sub-Article 893.17(j) "Uninterruptible Power Supply (UPS)"**.

The UPS units shall include all battery packs, power cables, mounting brackets and all appurtenances necessary for a complete operational backup power system; adequately sized to support the hub building equipment and operations.

The UPS units shall typically support the hub building equipment as follows (unless otherwise shown on the Plans): each UPS will be plugged directly into one dedicated NEMA L5-30 two-pole twist-lock plug, while one UPS will feed the power supply in the Managed Ethernet Switch (MES) and the other UPS will feed the redundant power supply side of this Managed Ethernet Switch. The remaining hub building equipment will be distributed evenly between these two UPS units, allowing both a circuit

and/or UPS failure on one side while still allowing the Hub Building's Managed Ethernet Switch to continue working.

893.16 Gas Utility Service.

Gas Utility Service shall consist of equipment to provide a natural gas feed to the Hub Building Generator, unless otherwise indicated on the Plans. The gas utility service components shall include (at a minimum): a gas meter, gas line pressure regulator (if required), piping and fittings, along with any appurtenances as required by the local gas Utility Company. All gas utility service components shall meet applicable material requirements of the American Gas Association (AGA), National Fuel Gas Code (NFGC), and the local gas Utility Company.

Gas Utility Service shall also meet the requirements of **Section 646** and **Section 861**.

893.17 Miscellaneous Infrastructure.

(a) Fusion Splicing.

All fiber optic cable splices shall be Fusion Splices. Mechanical splices are prohibited.

Maximum core alignment shall be verified prior to splicing and splice estimated loss measured after the fusion process by the use of local injection and detection (LID) devices and/or profile alignment algorithms. Not only shall the fusion splicer automatically align fibers, determine cleave quality and fuse the fibers, but they shall also provide the operator with reference estimated splice loss measurements.

Splice loss attenuation for fusion splicing for single-mode shall be 0.15 dB maximum.

1. Fusion Heat Shrink Sleeves.

   The Contractor shall use heat-shrink sleeves to protect the fusion splice of 250 µm coated fibers while offering individual access to each fusion splice. The heat-shrink sleeves shall be compatible with the splice trays (whether existing or provided on this project). The heat-shrink sleeve protector parameters shall meet the following:

   a. Dimensions (length) Single-Fiber Sleeve: 2.36 inches {60 mm} lengths;

   b. Bare Fiber Length not more than 1.18 inches {30 mm} or 2 inches {51 mm} (based on length of sleeve)

   c. Shrink Temperature Single-Fiber Sleeve: 248°F {120°C};

   d. Heating Time Single-Fiber Sleeve as recommended by the manufacturers.

2. Fusion Splice Protection.

   When splicing all fiber optic cables outdoors, the Contractor shall provide and utilize an industry acceptable, lighted, and clean fiber optic splicing trailer/lab or comparable facility. Prior to the Contractor performing any fiber optic work, the Engineer shall approve the fiber optic splicing trailer/lab or comparable facility to be used on this project.

3. Cleave Tool.

   Cleave tool's minimum end angle average shall be < 0.7 degree angle with none of the 150 cleaves sampled exceeding a 1.5 degree angle.

   If requested by the Engineer, the Contractor shall submit the part number and manufacturer of the cleave tool along with an "*end angle*" distribution chart which demonstrates the actual 150 cut end angles.

(b) Splice Closure.

The following material specifications covers Splice Closure equipment requirements for housing and managing outside plant fusion splices, whether installed in underground or aerial applications.

1. General.

   For outside plant installations, the Contractor shall provide inline or dome-type sealed splice closures that meet the requirements herein for use in the most severe conditions such as moisture, vibration, impact, cable stress and flex temperature extremes. Splice closures shall pass the factory test procedures per accepted industry standards: i.e. Telcordia/Bellsouth GR-771-CORE, ASTM G-26 (UV resistance), ASTM G-21 (fungus resistance), water immersion, freeze/thaw, salt fog, acidified saltwater, chemical immersion, compression, impact/drop, torsion/bending, current surge, bond clamp retention, and cable pullout among others. If requested by the Engineer, the Contractor shall submit copies of these manufacturer's factory test results.

The splice closure housing shall be a thermoplastic body design and suitable for butt, inline and branch splices. The splice closure shall have corrosion resistant aluminum or stainless-steel hardware. Splice closure shall be resistant to solvents, stress cracking, and creep. The housing materials shall also be resistant to chemicals and other materials to which they might be exposed in normal applications.

The installation of the splice closure shall not require specialized tools or equipment, other than those normally carried by installation and maintenance crews.

Splice closures shall be totally re-enterable without damage to fiber optics, their jackets and closure seal(s). The splice closure end cap shall be capable of accepting additional cables without removal of the sheath retention or strength member clamping hardware on previously installed cables or disturbing existing splices. The optical fiber splice closure shall provide a clamping mechanism to prevent piston movement of the central member or strength members and to prevent cable sheath slip or pullout.

The Contractor shall use splice closures that seal around cables with mechanical processes. Splice closure shall provide adequate strain relief to meet fiber cable manufacturer recommendations. The splice closure shall have flexible thermoplastic rubber end seals with pre-template cable ports. The splice closure shall have a single clamping mechanism for accessing splice trays and cable management. A single rubber gasket shall be used to seal the closure using the single clamping mechanism. The rubber gasket shall be continuous without any holes and shall not require replacement for re-entry.

Aerial splice closure shall be of an inline housing design, unless otherwise indicated on the Plans or approved by the Engineer. Aerial splice closure shall be designed to eliminate the need for drip collars and sealing collars.

2. Mounting Hardware.

The Contractor shall supply splice closures with manufacturer recommended mounting hardware, whether installed aerially or underground. This mounting hardware shall be non-corrosive metallic material (hot dipped galvanized steel, stainless steel or aluminum) unless otherwise specified by the splice closure manufacturer and approved by the Engineer.

The splice closure shall have appropriate hardware and installation procedures to facilitate the bonding and grounding of metal components in the closure and the armored cable sheath. The cable bonding hardware shall be able to accommodate a copper grounding conductor equal to or larger than 6 AWG.

3. Optical Fiber Organizer.

Fiber organization shall be handled within the splice closure in such a way to protect and support the fiber optic cable and splices in a secure environment. The organizer shall store fiber splices, splice trays, slack buffer tubes and readily accept these cable configurations (trunk/butt, in-line and branch (up to four drop cables)). The organizer should be of a stackable splice tray design where tray assembly swings out to allow individual tray access without disassembly of trays above and below. The splice closure organizer shall accept a minimum of four splice trays, one-piece cable strapping system, bonding and grounding hardware as required for the project.

4. Splice Tray.

Fiber splices shall be housed in Splice Trays inside the splice closure. The proper splice tray shall be selected based on the type of protection required by the single-mode fiber splice, quantity of splices, and manufacturer of closure. Splice trays shall provide adequate strain relief tie down points for the buffer tubes (using channel snaps) and fiber as well as provide a snug fit for heat shrink sleeves. Splice trays shall be of stackable design. Splice trays shall provide adequate area for bare fiber slack storage and management. Spliced fiber shall not be subjected to a bend radius smaller than 1.2 inches {30mm}. Buffer tubes shall not be subjected to a bend radius smaller than 1.5 inches {38 mm}.

The Contractor shall supply splice trays compatible and of the same manufacturer as the supplied splice closure.

When identified on the Plans that new splice trays are required for existing closure, the Contractor shall provide splice trays that shall work within the existing closure using the same methodology, connections, firmness, and supports as existing splice trays.

(c) Hangers.

Conduits required on structures shall be installed using a conduit hanger for conduit with spacing and support as detailed on the Plans.

The conduit hangers shall utilize anchors, brackets, or clamps to provide attachment to a bridge structure. Mechanical anchors for connection required when attachment to bridge will be in tension. Otherwise, epoxy type anchors may be allowed. Drilling into bridge steel structure or concrete girders is not allowed except with written approval by the Engineer. Bridge attachment shall be submitted to committee for review and approval prior to installation.

Conduit hanger system used shall be recommended by the conduit manufacturer for the application.

The conduit hanger shall be capable of supporting a load equal to the weights of the conduits, cables, the weight of the hanger itself, plus 200 pounds.

Metal brackets, supports, and hardware components of the conduit hangers shall be manufactured galvanized steel.

(d) Riser Assembly.

The Contractor shall furnish and install Riser Assembly in accordance with the Plans. The Riser Assembly shall consist of a metallic riser, mounting brackets, straps, supports, any accessories, and required hardware. All attachment hardware shall be made of galvanized steel.

For electrical service installations, the riser shall be 2 inch {53 mm} galvanized steel Rigid Metal Conduit (RMC), unless otherwise shown on the Plans.

For fiber optic installations, the riser shall be a minimum 2 inch {53 mm} galvanized rigid steel U-Guard with backplate, unless otherwise shown on the Plans.

(e) Communication Box (CommBox).

1. Materials and Load Requirements.

Communication Box (CommBox) shall have the following properties: high strength, resistance to sunlight, resistant to petrochemicals, unaffected by freeze/thaw cycles, straight sided, flush fit with sidewalk or grass, and be capable of anchor inserts to allow for mounting Cable Rack. CommBox shall be manufactured of a composite mixture of polymer and concrete; and, be reinforced by a heavy-weave fiberglass. All CommBoxes shall be open bottomed one-piece box construction with cover and Cable Rack. No stacking of box sections allowed. CommBox sizes shall be in accordance with the Standard Drawings.

CommBox (both box and cover) shall conform to all test provisions of ANSI/Society of Cable Telecommunication Engineers (SCTE) National Standard No. ANSI/SCTE 77 "*Specifications for Underground Enclosure Integrity*" for Application Tier 22. CommBoxes shall meet or exceed the Tier 22 structural load test requirements which has the following defined test values:

Vertical	*Design Load* =	22,500 lbs. {100.1 kN}
	Test Load =	33,750 lbs. {150.1 kN}
Lateral	*Design Load* =	800 lbs./sq. ft. {38.3 kPa}
	Test Load =	1,200 lbs./sq. ft. {57.5 kPa}

CommBox shall be reinforced by a heavy-weave fiberglass creating a material compressive strength of no less than 110 psi. Each CommBox shall be designed and tested to temperatures of -50°F {-46°C}.

2. Cable Rack.

CommBox shall include manufacturer recommended Cable Rack for storage of cable slack and splice closure(s). The Cable Rack shall be designed so it supports both the cable maintenance coils (while maintaining cable bend radius) and the splice closure such that they are not stressed while hanging on the rack. The Cable Rack shall also hold the cable and splice closure up off the bottom of the CommBox. The Cable Rack shall be non-corrosive metallic material (hot dipped galvanized steel, stainless steel or aluminum) with no sharp edges. The Contractor shall submit, for Engineer approval, the Cable Rack shop drawings/cut-sheets of the materials and installation.

3. CommBox Cover.

All CommBoxes shall be supplied with a heavy-duty cover that meets the ANSI/SCTE 77 application Tier rating requirements as defined in above "*Materials and Load Requirements*".

All covers shall be supplied with a minimum of two (2) stainless steel hex head bolts with stainless steel washers used to secure the cover to the CommBox.

CommBox covers shall be embossed on the outside of the Cover with "*FIBER OPTICS*" when used for fiber optic installations and "*ELECTRIC*" when used for electrical power service installations. CommBox covers shall have "*J*" hook slots (reference **ALDOT Index No. 72920**, **Standard Dwg. No. ITS-729-020**, "*CommBox Installation for Fiber Optic Cable And Conductors*").

4. Grounding.

Where required per NEC for conductive optical fiber cables or electrical service conductors, CommBox shall require a grounding electrode (ground rod) installed within the CommBox and meet the Grounding requirements of this Specification.

5. Concrete Collar.

Each CommBox shall be surrounded by a minimum 12 in. wide x 6 in. deep concrete collar and shall include wire mesh.

The concrete mix used for concrete collar shall comply with the requirements of **Section 501** for Class A concrete and **Section 620**, unless otherwise shown on the Plans.

Reinforcing steel shall meet the requirements of **Section 502** and as shown on the Plans.

(f) Pull Box.

1. Materials.

Pull Box shall be manufactured of a minimum of 0.125 inch {3 mm} thick aluminum and be supplied with a screw-on cover (hinge optional). Exposed surfaces shall be treated with rust resistant material. Pull Box shall meet the requirements of NEMA Type 3R. Pull boxes shall have fixed external mounting brackets for structure mounting (4 total, 2 per side on opposite sides). Conduit penetrations shall be watertight through rigid hubs for the size conduit required on the Plans.

2. Cable Rack.

Pull Box shall include manufacturer recommended Cable Rack for storage of cable slack. The Cable Rack shall be designed so it supports the cable maintenance coils (while maintaining cable bend radius) such that they are not stressed while hanging on the rack. The Cable Rack shall also hold the cable up off the bottom of the Pull Box. The Cable Rack shall be non-corrosive metallic material (hot dipped galvanized steel, stainless steel or aluminum) with no sharp edges. The Contractor shall submit, for Engineer approval, the Cable Rack shop drawings/cut-sheets of the materials and installation.

3. Grounding.

Where required per NEC for conductive optical fiber cables or electrical service conductors, Pull Box shall require a grounding electrode (ground rod) installed and meeting the Grounding requirements of this Specification.

(g) Fiber Marker Post.

The Marker Post for fiber optic cable shall be of composite material and weigh less than 4 lbs. {1.8 kg}. All Fiber Marker Posts shall be dome designed for a minimum of twenty (20) year service life and shall include the manufacturer's tubular anchor system. Fiber marker post dimensions and installation shall be in accordance with the Standard Drawings. The fiber marker post shall be white, UV resistant and durable to extreme weather conditions. The dome area of the polyethylene post containing graphics shall be black text on orange background and as shown on the Standard Drawings. The graphics shall not fade, peel or chip and last the lifetime of the fiber marker post. The dome cover graphic system shall be Engineer approved prior to being printed; and, shall be printed on opposite sides of dome cover while maximizing the print space.

See corresponding Construction Section for fiber marker post label "*proof check*" sample and approval requirements.

(h) Frequency Locate Marker.

An electronic marker for detecting the CommBox shall be included. The electronic marker shall use the Telephone dedicated frequency (101.4 kHz). It shall be a passive device, requiring no batteries, with an RF field detectable with any standard marker locator. Working with a locator, the frequency locate marker shall indicate the marker's exact position within a five (5) feet diameter area.

(i) Surge Protection.

1. Coaxial Video Surge Protection.

Each video Surge-Protective Device shall provide inline overvoltage/overcurrent protection for a single coaxial cable. The video surge-protective device shall employ a hybrid technology of gas discharge tubes, silicon avalanche diode and current limiting components. Video surge-protective devices shall have the following features:

a. UL Listed UL 497B
b. Maximum voltage: 8 volts (16 volts peak-to-peak)
c. Frequency range: 0 to 10 MHz
d. 10kA nominal discharge (surge) current
e. 50/75 ohm (Ω) BNC connection
f. EMI attenuation: < 0.5 dB at 10 Hz
g. Designed for mounting on standard 35mm German Institute for Standardization (DIN) rail.
h. NEMA TS2 temperature rated

2. Ethernet Surge Protection.

Each Ethernet Surge-Protective Device shall provide inline overvoltage/overcurrent protection for an outdoor rated CAT5/5E/6/6A data/control cable. The data surge-protective device shall employ a hybrid technology of gas discharge tubes, silicon avalanche diode and current limiting components. Data surge-protective devices shall have the following features:

a. UL Listed UL 497B
b. Frequency range: 0 to 100 MHz
c. 100 A nominal discharge (surge) current
d. < 8V clamping voltage
e. 8P8C (a.k.a. type RJ45 “unkeyed”) modular jack connectors – 8 wire
f. Designed for mounting on standard 35mm DIN rail
g. NEMA TS2 temperature rated

3. Power over Ethernet (PoE) Surge Protection.

Each Power over Ethernet (PoE) Surge-Protective Device shall provide inline overvoltage/overcurrent protection for an outdoor rated CAT5/5E/6/6A data/control cable. The data surge-protective device shall employ a hybrid technology of gas discharge tubes, silicon avalanche diode and current limiting components. Data surge-protective devices shall have the following features:

a. UL Listed UL 497B
b. Frequency range: 0 to 100 MHz
c. 2kA nominal discharge (surge) current
d. 68 Vdc maximum continuous operating voltage
e. < 0.1db loss for 8P8C (a.k.a. type RJ45 “unkeyed”) modular jack connectors – 8 wire
f. Designed for mounting on standard 35 mm DIN rail
g. NEMA TS2 temperature rated

4. Data Surge Protection (Serial).

Each Data Surge-Protective Device shall provide inline overvoltage/overcurrent protection for a two-pair (4-wire + shield) serial data/control cable. The data surge-protective device shall employ a hybrid technology of gas discharge tubes, silicon avalanche diode and current limiting components. Data surge-protective devices shall have the following features:

a. UL Listed UL 497B
b. 10kA nominal discharge current
c. < 27V clamping voltage OR < 46V as required by the device being protected
d. 5 position cage clamp terminals for 24 AWG to 12 AWG conductor
e. Designed for mounting on standard 35 mm DIN rail
f. NEMA TS2 temperature rated

5. Power Surge Protection.

Each Power Surge-Protective Device shall provide inline overvoltage/overcurrent protection for a three conductor 120-volt AC power feed within an ITS Cabinet. The power surge-protective device shall employ a hybrid technology Metal Oxide Varistors (MOV) and thermal sensitive device for

disconnecting power from the load after an MOV failure. Power surge-protective devices shall have the following features:

a. UL Listed UL 1449
b. 700 voltage protection rating
c. ≥ 40kA nominal discharge current per phase
d. Maximum load current: ≥ 50kA
e. Visual indicated for every MOV including neutral and ground
f. 5 position cage clamp terminals for 24 AWG to 12 AWG conductor
g. Designed for mounting on standard 35 mm DIN rail
h. NEMA TS2 temperature rated

6. Electrical Surge Protection.

A surge-protective device consisting of directly connected MOV shall be installed at the incoming electrical service lines and shall be located such that the connection leads are of minimum length. Conductor leads shall be cut to length to ensure quick reaction time. The Contractor shall connect the surge protector to the load side of the main disconnect in the controller cabinet. The surge-protective devices shall have the following features:

a. UL Listed UL 1449
b. 20kA I-nominal rating
c. Line-neutral, line-ground, and neutral-ground modes of protection
d. Directly connected MOVs exceeding 32mm in diameter from line-neutral, line-ground, and neutral-ground
e. Surge current rating shall equal or exceed 50kA per mode, 100kA per phase
f. Voltage Protection Rating shall not exceed 700V on any mode.
g. Each MOV shall include a thermal safety disconnector(s).
h. Gas Tubes or Spark Gaps shall not be accepted due to high initial clamp overshoot.
i. MOV's operational status shall be monitored via visual indicator, including neutral-ground.
j. One set of normally open, normally closed form C contacts for remote monitoring.
k. Unit shall be NEMA Type 4 rated for outdoor installation.

7. Field Management Unit Surge Protection.

A surge-protective device consisting of directly connected MOV shall be installed at cabinet locations at the incoming electrical service lines. The surge-protective device shall have the following features:

a. UL Listed UL 1449;
b. 20kA I-nominal rating;
c. Line-neutral, line-ground, neutral-ground, and line-line modes of protection;
d. Surge current rating shall equal or exceed 50kA per mode, 100kA per phase;
e. Voltage Protection Rating shall not exceed 600V for 208Y/120V or 1,000V for 480Y/277V;
f. Less than 1 ns response time;
g. Individually fused and thermally protected MOVs;
h. MOV shall be 34 mm square minimum;
i. Shall have diagnostic monitoring on every MOV;
j. MOV operational status shall be monitored via visual indicator, including neutral ground; and,
k. Unit shall be enclosed in a NEMA Type 4X enclosure.

(j) Uninterruptible Power Supply (UPS).

The Uninterruptible Power Supply/battery backup system (UPS system) shall be used for the management of power supplies to ITS devices. The UPS shall provide output power with user option to function as single, dual, or line interactive conversion. The UPS unit shall be field hardened. The UPS shall have trickle charge capabilities. The UPS shall provide backup power for a minimum of three days for permanent and ten days for portable highway advisory radios. If providing backup power for other ITS equipment as shown on the Plans, it shall be provided for a minimum of one hour. Batteries used for a power supply shall be sealed gel type in the quantity and location (separate enclosure from the ITS equipment) as shown on the Plans.

The UPS shall be monitored through a Graphical User Interface (GUI) capable of monitoring performance and alarms as well as provide system management. The UPS shall display battery status, input and output voltage, Amp hours, load, and run time.

DESCRIPTION	SPECIFICATION
Input Voltage: AC DC	 90 - 150 Vac 48 Vdc
Output Voltage: AC DC	 120 Vac, true sine wave 12, 24, 48 Vdc
Power Regulation	± 4%
Response Time	< 5 ms
Output Power	Rated for intended load
Connection Type	Dry Contacts, Type B receptacle
Temperature Operating Range	-40˚F to 165˚F {-40˚C to 74˚C}
Humidity Operating Range	0 - 95% non-condensing
Housing	Free standing or rack mountable (as shown on the Plans)
Communication Ports	Ethernet SNMP, RS-232
Audible Alarm	Utility power interruption, inverter failure, low battery