CITY OF HENDERSONVILLE, TN

TRAFFIC MANAGEMENT SYSTEM IMPROVEMENTS

SUMNER COUNTY

Federal Project No.: CM-NHE-9307(13)

State Project No.: 83LPD1-F1-002

PIN: 108809.00

TECHNICAL SPECIAL PROVISION (TSP) 725

TECHNICAL SPECIAL PROVISION (TSP) 730

Prepared for:

City of Hendersonville, TN

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January 8, 2016

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GENERAL

Application of this Document

This Technical Special Provision (TSP) specifies the minimum requirements for equipment supplied, furnished and/or installed as a part of this contract. All Section 725 items included in the contract are specified herein. Some Section 730 items are included in this TSP. All items included in this TSP are project-specific and have no application to any other project. Any Section 730 item included in the contract and not specifically addressed herein shall be governed by the latest edition of Section 730 of the current edition of the TDOT Standard Specifications.

SECTION 1

DEMARCATION CABINET

1.1 Description

This Section specifies the minimum requirements for equipment cabinets furnished and installed on this project as shown in the Plans. The cabinet will provide a protective outdoor housing enclosure in which to install fiber optic termination modules required for ITS devices to communicate with the Traffic Operations Center (TOC). Major elements of the equipment cabinet include the cabinet housing and equipment mounting hardware, interior wiring and termination facilities, 4 fiber optic Termination Modules and ST to ST patch cords, power supplies, electrical accessories, lighting, and field installation.

1.2 Materials

1.2.1 General

1) Furnish only new equipment and materials.

2) Furnish equipment cabinets and integral materials recommended by the manufacturers for outside plant use and the intended application. This requirement includes wiring and electrical materials and configurations that are wholly or partially related to the field equipment.

3) Furnish and configure equipment cabinets to be installed at locations as shown in the Plans. Furnish and configure all equipment and materials for each specific location as shown in the Plans.

4) Provide electrical system and components with UL-listings.

5) Unless otherwise specified, provide wire and cable with stranded copper conductors, 75°/90° Celsius wet/dry rated insulation, and sized for the maximum voltage and current in the circuit.

6) All components specified as rail-mounted shall be compliant as follows:

   a. DIN EN 50022 (NS35) component rails

   b. Component rails shall be the perforated type and of sufficient length as to protrude beyond the mounted components for fastening to cabinet panels as specified herein

   c. UL 1059

   d. UL 486E

   e. NEMA ICS-4

7) Terminal blocks and component terminals shall be nickel-plated copper, copper alloy or brass.

8) Terminal blocks shall have voltage and current ratings greater than the ratings of the wires that are terminated, be able to terminate wires from #8 AWG to #2/0 AWG wiring and shall be assembled into housing enclosures such that all exposed surfaces are touch-safe. Conductor fastening screws shall be captive. Terminal block housings shall be colored as follows:

   a. 120 VAC line/hot: black

   b. 120 VAC neutral: white

   c. 24 VDC positive: red

   d. 24 VDC negative: gray

   e. RS485 communications: orange

   f. Ground: green or green/yellow

9) The main door lock for the cabinet shall have a No. 2 pin-tumbler cylinder lock. Provide two (2) keys with each cabinet.

10) Provide agency name and device name on all cabinets. Labels shall meet the following minimum requirements:

   a. Labels shall be flat black lettering on a reflective white background. Lettering shall be a minimum of 1 inch in height.

b. Labels shall be manufactured from pre-coated adhesive backed reflective sheeting material meeting the minimum requirements of AASHTO M268 Type 1.

c. The agency name label shall be "City of Hendersonville" in one continuous adhesive sheet.

d. The device name labels shall include the device name "DMARC", as an acronym for Demarcation Cabinet, and shall be one (1) continuous adhesive sheet.

e. Labels shall be installed along the top of the cabinet door (front cabinet door on Type B cabinets), with "City of Hendersonville" label at the top and the device name labeled immediately underneath.

11) Provide a voltage label on all cabinets or enclosures in accordance with the NEC labeling requirements. Voltage labels shall meet the following minimum requirements:

a. Labels shall be flat black lettering on a reflective yellow background. Lettering shall be a minimum of 1 inch in height.

b. Labels shall be manufactured from pre-coated adhesive backed reflective sheeting material meeting the minimum requirements of AASHTO M268 Type 1.

c. Labels shall include the voltages entering the cabinet and shall be one continuous adhesive sheet. Examples are "120VAC" or "24VDC".

d. Labels shall be installed on all cabinet doors.

1.2.2 Cabinet

The Contractor shall provide a ground-mounted cabinet for each demarcation shown on the Plans. The Demarcation Cabinet shall meet the following requirements:

1) Shall meet the same lighting, 19" rack, and ventilation requirements as Caltrans Type 170 model 334 cabinet with full-size front and rear doors and should have dimensions of 64H" x 24W" x 30D".

2) Shall be ground mounted.

3) Shall be constructed of 5052 sheet aluminum alloy with a minimum thickness of 1/8 inch.

4) All inside and outside edges shall be free of burrs.

5) The outside surface of the cabinet shall have a smooth, uniform and natural aluminum finish.

6) All welds shall be neatly formed and free of cracks, blow holes and other irregularities.

7) All welds shall be made by using the Heliarc welding method.

8) The cabinet should be of sufficient size to hold all of the field junction support equipment as shown in the Plans.

9) Cabinet hinges shall be 14 Gauge diameter stainless steel or 1/8 inch diameter aluminum.

10) The hinge pins shall be constructed of stainless steel.

11) Shall be furnished with a three point latching system (top, bottom, center locations)

12) Shall be furnished with a doorstop, which retains the door at 90 degree and 120 degree positions.

13) Shall have a thermostatically controlled fan located at the top of the cabinet.

14) Minimum fan rating of 100 cubic feet per minute.

15) Fan thermostat shall have a user adjustable range from 80 to 125 degrees F.

16) Minimum of two one-half inch diameter galvanized anchor bolts shall be used to secure the cabinet to the foundation.

17) Shall be provided with a minimum 20-Watt fluorescent lamp with a clear shatter-proof shield.

18) The lamp shall automatically turn ON when either cabinet door is opened.

19) Shall include a three wire GFCI 115 VAC duplex convenience receptacle.

20) The receptacle shall be protected by a 15 Amp circuit breaker

21) Shall include a main circuit breaker, which shall turn off all power to the cabinet

22) Shall include transient suppression meeting the following requirements:

a. Withstand a 20 Kiloampere surge current with an 8x10 us waveform twenty times at three minute intervals between surges without damage to the suppressor.

b. Limit surge voltage to 500 V peak

23) Provide Type C cabinet electrical subsystems meeting the following requirements:

a. Includes an electrical distribution module comprised of the following DIN rail-mounted components:

i. Service entrance terminal block with positions for 120VAC line, neutral, and ground and capable of terminating minimally #8 through #6 AWG wire, located at one end of the mounting rail with an approximately 0.75 inch blank spacer module adjacent to the main cabinet breaker.

ii. Main cabinet automatic overcurrent 15A circuit breaker that is UL-listed and of the mechanical-magnetic type rated for use from -18° C to 50° C minimum.

iii. Main cabinet surge suppressor for single-phase 120VAC service entrance, parallel wired with a clamp voltage of approximately 280V and capable of a surge current of at least 20,000 amps.

iv. Main cabinet filter for power line noise and switching transient suppression, integral to, or separate from and wired to, the main cabinet surge suppressor.

v. Electrical distribution terminal block for line and neutral conductors parallel wired to the main cabinet surge suppressor but non-filtered, with a minimum terminating capability of six conductors of #10 to #18 AWG. Label the terminal block as “ACCY POWER”

vi. Electrical distribution terminal block for line and neutral conductors for circuits on the load/equipment side of the power line filter, with a minimum terminating capability of six conductors of #10 to #18 AWG. Label the block as “EQUIP POWER”.

vii. Electrical distribution terminal block for grounding and bonding conductors located on the same rail but separate from the service entrance terminal block and connected to the entrance ground with a #6 AWG green insulated wire. The grounding block shall have a minimum terminating capability of two #6 AWG conductors and ten #10 to #18 AWG conductors.

viii. Ground fault interrupt duplex receptacle (NEMA 5-15R) with 2.5A circuit breaker connected to the ACCY POWER distribution block. Permanently affixed to the receptacle, provide two red, orange or green/yellow labels with minimum 0.25 inch lettering with the legend "300 WATTS MAX". This receptacle is for technician use only and shall not be used to power equipment.

b. Include a cabinet lighting subsystem comprised of the following components:

i. One fluorescent lighting fixture, minimum 20 watt, mounted on the inside top front portion of the cabinet, with a cool white lamp with shatter-proof cover and operated by a normal power factor UL listed ballast.

ii. A resistor-capacitor network noise suppressor installed across the light fixture power terminals

iii. Two door-actuated switches installed to turn on the cabinet light when either door is opened.

iv. Powered from the ACCY POWER distribution block.

c. Include two duplex non-GFCI equipment power receptacles (NEMA 5-15R) connected to the EQUIP POWER distribution block mounted on the upper rear corner of the cabinet upper right side panel. Permanently affixed to the receptacle, Provide two red, orange or green/yellow labels with minimum 0.25 inch lettering with the legend "75 WATTS MAX" permanently affixed to the receptacle.

1.3 Installation Requirements

1.3.1 General

1) Install and configure cabinets as shown in the Plans and in accordance with TDOT Standard Drawings, including installations and dimensions given for ground-mounting in relationship to the surrounding grade.

2) Bond all cabinets to grounding lug with minimum #6 AWG stranded copper bare or green-insulated cabinet grounding wire.

3) Do not install electrical service or electronic devices in the cabinet or connect to the cabinet until ground testing for the pole or structure has been successfully completed and accepted, and the cabinet ground connection has been installed.

1.3.2 Cabinet

1) Install and configure equipment in the cabinet in accordance with the requirements for that equipment.

2) Do not install electronic devices in the cabinet until electrical service has been installed and activated, and the cabinet ventilation fan is operational.

1.3.3 Fiber Optic Termination Module

1) Provide fiber optic termination cabinets in communications hubs and the TOC as shown in the Plans for termination of 72 fibers outside plant (OSP) cable. Fiber Optic Termination Cabinets as outlined in this specification are also known as Fiber Distribution Centers or Modules.

2) Use termination cabinets that are fully compatible with all components of the fiber optic infrastructure as specified, including but not limited to fiber optic cable, fiber optic fusion splices, and fiber optic connectors.

3) Use rack-mount termination cabinets designed to fit standard 19-inch EIA equipment racks.

4) Provide all mounting hardware and supports to mount the termination cabinets in the locations shown in the Plans.

5) Use fiber optic termination cabinets providing 72 fiber connectors and capable of storing 72 fusion splices in splice trays.

6) Use termination cabinets that integrate the splice trays and connector modules into one compartment within one cabinet, or houses the splice trays and connector modules in separate compartments integrated into one cabinet.

7) Maximum dimensions of a complete termination cabinet shall be 7 rack units high (12.25 inches) by 16 inches deep.

8) Use fiber optic termination cabinets with fully enclosed metallic construction and with a protective hinged front cover for the connector ports.

9) Provide cable access on all sides of the enclosed area behind the connector port panel.

10) Provide sufficient splice trays for storing 72 fusion splices in 12 or 24 splice increments.

11) Provide termination cabinets with fiber optic connector modules in a 12 fiber configuration of 6 rows of 1 duplex connector couplers.

12) Connector modules shall mount vertically or horizontally in the termination cabinet front panel.

13) Connector modules shall include clearly legible and permanent labeling of each of the 12 fiber connector couplers, and shall be labeled and identified as shown in the Plans.

14) Provide factory-assembled 12 fiber termination interconnect cables (pigtail cables) to be fusion spliced to the outside plant cable and connected to the rear of the connector modules.

    a. Termination interconnect cables shall be all-dielectric single jacketed cable with high tensile strength yarn surrounding 12 individual 900 micron fibers following EIA/TIA-598B color identification with factory-installed connectors.

15) Provide all incidental and ancillary materials including but not limited to grommets, cable strain relief and routing hardware, blank connector panels, and labeling materials.

1.3.4 Project Testing

1) General Requirements

    a. The Contractor shall conduct a project testing program for all equipment cabinets governed by this section. The project testing program for equipment cabinets shall include but is not limited to the additional specific requirements in this subsection.

    b. All test results shall confirm physical and performance compliance with this TSP.

    c. Submit all test results documentation to the Engineer within 14 days of completion of the tests for test documentation review by the Engineer.

2) Standalone Acceptance Test (SAT)

a. Perform an SAT on all equipment cabinets on this project after field installation is complete, including but not limited to all field devices (RDS, CCTV, communications electronics, etc.) to be installed in or connected to that given cabinet.

b. A SAT for a given equipment cabinet shall only be performed in conjunction with the SAT for all devices installed in or connected to that given cabinet.

i. Visual inspection of installation.

ii. Functional test of all cabinet equipment, including circuit breaker, receptacles, fan and thermostat, and lights and door switches.

1.3.5 Warranty

The Fiber Termination Modules shall be warranted to be free of manufacturer defects in materials and workmanship for a period of five (5) years from the date of Final Acceptance. Equipment covered by the manufacturer's warranties shall have the registration of that component placed in City of Hendersonville's (City) name prior to Final Inspection. The Contractor is responsible for ensuring that the vendors and/or manufacturers supplying the components and providing the equipment warranties recognize the City as the original purchaser and owner/end user of the components from new. During the warranty period, the supplier shall repair or replace with new or refurbished material, at no additional cost to the City, any product containing a warranty defect, provided the product is returned postage-paid by the City to the supplier's factory or authorized warranty site. Products repaired or replaced under warranty by the supplier shall be returned prepaid by the supplier.

During the warranty period, technical support shall be available from the supplier via telephone within four hours of the time a call is made by the City, and this support shall be available from factory certified personnel. During the warranty period, updates and corrections to control unit software shall be made available to the City by the supplier at no additional cost.

1.4 Measurement

Cabinets will be measured in units of each and paid for at the contract price per each. The price bid shall include furnishing and installing the equipment cabinet and all related material and equipment, to include fiber optic termination modules and ST to ST patch cords, specified in the Plans and this TSP, and all labor, system integration, testing, system documentation and miscellaneous materials necessary for a complete and accepted installation. The unit price shall also include but is not limited to the cabinet and all interior materials, mounting hardware foundations, external conduit entrances including conduit bodies and nipples, electrical service and grounding terminations. This price shall be full compensation for all labor, tools, materials, equipment and incidentals necessary to complete the work.

1.5 Payment

The contract unit price shall be full compensation for all work specified in this Section.

Payment will be made under:

Item No.	Description	Unit
725-02.12	Demarcation Point (w/ 334 Cabinet)	EACH

Equipment Cabinet will be paid per each as follows:

1) 40% of the contract unit price for delivery of the cabinet housings.

2) Additional 40% of the contract unit price for complete installation of equipment cabinet and all interior components, electrical service feed (activated), interior cabinet components, all conduit entrances, grounding connection, and testing.

3) Additional 10% of the contract unit price for completion of Stand Alone Site Test of all field devices housed or connected to the equipment cabinet.

4) Final 10% of the contract unit price upon Final System Acceptance.

SECTION 2

RADIO AND ANTENNA

2.1 Description

This section specifies the minimum requirements for radio and antenna units furnished and installed on this project as shown on the plans or as directed by the Engineer.

2.2 Materials

The Contractor shall be responsible for providing all equipment needed to connect the 5.8 GHz Broadband Ethernet Radios to the fiber network designed in the plans and implemented in this project.

The Contractor shall provide all elements necessary to connect this device to the system including such items as radios, antennas, coaxial cable and connectors, lightning suppressors, mounting and grounding hardware, and any other equipment, hardware, enclosures, and cabling required to make a complete operational system.

2.2.1 Radio and Antenna (Type A)

This is a single 5.8 GHz Broadband Ethernet radio with a connector for one (1) external panel antenna.

2.3 Installation Requirements

All equipment shall be installed according to the manufacturer's recommendations, the Plans, and as follows:

2.3.1 Installation Services

1) Contractor must prepare a comprehensive Network Design and Installation Plan for the wireless network to document how it will integrate with the Fiber Optic System. All Federal Communications Commission (FCC) license applications, if necessary will be prepared by the Contractor on behalf of the City of Hendersonville (City), including any modifications to existing licenses. Contractor shall submit a copy of the Network Design, Installation Plan, and copies of any FCC license applications to the City Engineer. The City reserves the right to reject any network designs and installation plans submitted. If rejected, the Contractor will be responsible for submitting a revised Network Design and/or Installation plan.

2) The Contractor shall provide the City with a written inventory of items received and the condition in which they were received. Inventory shall be inclusive of make, model, serial number, MAC address, and installation GPS coordinates. All equipment shall be installed according to the manufacturer's recommendations or as directed by the City of Hendersonville.

2.3.2 Testing

The Contractor shall conduct a Project Testing Program as required below. All costs associated with the Project Testing Program shall be included in overall contract prices; no separate payment will be made for any testing.

2.3.2.1 General Requirements

1) The Engineer is only responsible for attending and observing each test, and reviewing and approving the Contractor's test results documentation. The Engineer reserves the right to attend and observe all tests. The Contractor is required to perform the Standalone Acceptance Test (SAT) with the Engineer present.

2) Each test shall fully demonstrate that the equipment being tested is clearly and definitely in full compliance with all project requirements.

3) Test procedures shall be submitted and approved for each test as part of the project submittals. Test procedures shall include every action necessary to fully demonstrate that the equipment being tested is clearly and definitively in full compliance with all project requirements. Test procedures shall cross-reference to this Technical Special Provision (TSP) or the Plans. Test procedures shall contain documentation regarding the equipment configurations and programming.

4) No testing shall be scheduled until approval of all project submittals and approval of the test procedures for the given test.

5) The Contractor shall provide all ancillary equipment and materials as required in the approved test procedures.

6) The Contractor shall request in writing the Engineer's approval for each test occurrence a minimum of fourteen (14) days prior to the requested test date. Test requests shall include the test to be performed and the equipment to be tested. The Engineer reserves the right to reschedule test request if needed.

7) All tests shall be documented in writing by the Contractor in accordance with the test procedure and submitted to the Engineer within seven (7) days of the test. Any given test session is considered incomplete until the Engineer has approved the documentation for that test session.

8) All tests deemed by the Engineer to be unsatisfactorily complete shall be repeated by the Contractor. When the Contractor requests a test occurrence that is a repeat of a previous test, the Contractor shall summarize the diagnosis and correction of each aspect of the previous test that was deemed unsatisfactory. The test procedures for a repeated test occurrence shall meet all the requirements of the original test procedures, including review and approval by the Engineer.

9) The satisfactory completion of any test shall not relieve the Contractor of responsibility to provide a completely acceptable and operating system that meets all requirements of this project.

2.3.2.2 Standalone Acceptance Test (SAT)

1) The Contractor shall perform a complete SAT on all equipment and materials associated with the field device site, including but not limited to electrical service, conduit, pull boxes, communication links, control cables, poles, etc. A SAT shall be conducted at every field device site.

2) The SAT shall demonstrate that all equipment and materials are in full compliance with all project requirements and fully functional as installed and in final configuration. The SAT shall also demonstrate full compliance with all operational and performance requirements of the project. All SATs will include a visual inspection of the cabinet and all

construction elements at the site to ensure they are compliant with the specifications.

2.3.2.3 Local Ethernet System Testing

1) Successful communications are defined as the ability of a wireless transceiver to send video and an error-free data message and view the video and data from the receiving station. A minimum of thirty (30) test transmissions shall be attempted at each test site. If a failure occurs at the locations selected, it will be the responsibility of the Contractor to re-check the test area to determine if a problem exists. If there is a problem, it will be the Contractor's responsibility to run additional tests as required to define the cause of the problem. If areas of non-performance represent more than the Contractor's predicted link reliability, it will be the Contractor's responsibility to correct such problems at the sole expense of the Contractor. Any additional costs associated with further testing will be solely borne by the Contractor.

2) The Contractor must prepare and execute a detailed system acceptance test plan, including detailed system acceptance test procedures. The Contractor shall submit a copy of all System Acceptance plans to the Engineer through the standard City submittal process.

2.3.3 Warranty

The wireless radio interconnect system shall be warranted to be free of manufacturer defects in materials and workmanship for a period of three (3) years from the date of Final Acceptance. Equipment covered by the manufacturer's warranties shall have the registration of that component placed in City's name prior to Final Inspection. The Contractor is responsible for ensuring that the vendors and/or manufacturers supplying the components and providing the equipment warranties recognize the City as the original purchaser and owner/end user of the components from new. During the warranty period, the supplier shall repair or replace with new or refurbished material, at no additional cost to the City, any product containing a warranty defect, provided the product is returned postage-paid by the City to the supplier's factory or authorized warranty site. Products repaired or replaced under warranty by the supplier shall be returned prepaid by the supplier.

During the warranty period, technical support shall be available from the supplier via telephone within four hours of the time a call is made by the City, and this support shall be available from factory certified personnel. During the warranty period, updates and

corrections to control unit software shall be made available to the City by the supplier at no additional cost.

2.3.4 Maintenance and Technical Support.

The supplier shall maintain an adequate inventory of parts to support maintenance and repair of the wireless radio system components.

The manufacturer of the wireless radio equipment must provide, and have a parts support system capable of providing parts for a period of five (5) years from the date of system acceptance. Spare parts shall be available for delivery within thirty (30) days of placement of an acceptable order at the supplier's then current pricing and terms of sale of said spare parts.

The suppliers shall maintain an ongoing program of technical support for the wireless radio interconnect system. This technical support shall be available via telephone or via personnel sent to the installation site upon placement of an acceptable order at the supplier's then current pricing and terms of sale of said technical support services.

2.4 Method of Measurement

Radio interconnect will be measured per each installation. Such measurement shall be inclusive of radio, software, base stations, power supply, antennas, cables and connectors, lightning suppressors, mounting and grounding hardware, enclosures, receivers, transceivers, and all other items necessary to complete the installation to provide appropriate Radio Frequency (RF) Data Link that is fully integrated and operational with the Fiber Optic System. Measurement shall also include all system documentation including shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams and other materials necessary to document the installation and operation of the Wireless Radio Interconnect System.

2.5 Basis of Payment

Radio interconnect, measured as prescribed above, will be paid for at the contract unit price per each for each type(s) specified in the contract. The price shall be full compensation for furnishing all materials; for all installing, connecting and testing; and for all equipment, labor, tools, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	Description	Unit
725-03.04	Radio & Antenna (Type A)	EACH

Progress payments for radio interconnects will be paid per each as follows:

1) 30% of the contract unit price upon delivery to the site. Delivery cannot be more than 60 days before anticipated installation;

2) An additional 40% of the contract unit price upon complete installation and Stand Alone Testing of the wireless network;

3) An Additional 20% of the contract upon conditional system acceptance; and

4) Final 10% of the contract unit price upon Final System Acceptance.

SECTION 3

NETWORK SWITCH

3.1 Description

This project calls for the use of network switches furnished and installed with the minimum requirements as specified below.

3.2 Materials

3.2.1 Type A Network Switches

Type A Network Switches will be placed in the field device cabinets with no Fiber Optic connections and shall meet the following requirements:

1) Minimum of six 10/100 Base-TX ports. Each port shall connect via RJ-45 connector.

   a. Minimum of two of the six 10/100 Base-TX ports with 802.3af Power over Ethernet (PoE) Standard.

2) Rack, shelf or DIN Rail mountable. If shelf mounted, the Contractor must furnish and install the shelf. The shelf shall be ventilated as per the Network Switch manufacturer recommendation.

3) Operate between -34 to +74 degree Celsius (-29ºF to +165ºF), including power supply.

4) Operate from 100 VAC to 200 VAC.

5) Operate from 10% to 90% non-condensing humidity.

6) Meet the IEEE 802.3 (10Mbps Ethernet) standard.

7) Meet the IEEE 802.3u (Fast Ethernet 100 Mbps) standard.

8) Meet the IEEE 802.3x (Full Duplex with Flow Control) standard.

9) Meet the IEEE 802.1p (Priority Queuing) standard.

10) Meet the IEEE 802.1Q (VLAN) standard per port for up to four VLAN’s.

11) The switch shall meet the IEEE 802.1D (Spanning Tree Protocol) and IEEE 802.1w (Rapid Spanning Tree Protocol) standards.

12) Meet the IEEE 802.3ad (Port Trunking) standard for a minimum of two groups of four ports.

13) Capable of mirroring any port to any other port within the switch.

14) Password manageable through:

    a. SNMP

    b. Telnet/CLI

    c. HTTP (Embedded Web Server) with Secure Sockets Layer (SSL)

15) Full implementation of SNMPv1 and SNMPv2c.

16) Full implementation of Generic VLAN Registration Protocol (GVRP).

17) Full implementation of Internet Group Management Protocol (IGMP) and IGMP snooping.

18) Minimum Mean Time Between Failures (MTBF) of 100,000 hours using Bellcore TR-332 standard.

19) Full implementation of RFC 783 (TFTP) to allow remote firmware upgrades.

20) UL approved.

21) All power transformers provided shall be “fastening mechanism” type. No plug-in types shall be permitted. All corded transformers shall be mountable with the ability to neatly secure power cords.

22) The field switch shall provide status indicators as follows:

    a. Power on an off,

    b. Network status per port (transmit, receive, link, speed), and

    c. Status indicators shall be LED.

23) Unused ports (copper and optical) shall be covered with rubber or plastic dust caps/cover.

3.2.2 Type B Network Switch

Type B Network Switches will be placed in the field device cabinets with Fiber Optic connections and shall meet the following requirements:

1) Minimum of six 10/100 Base-TX ports. Each port shall connect via RJ-45 connector.

   a. Minimum of two of the six 10/100 Base-TX ports with 802.3af PoE Standard.

2) Minimum requirements of two 1000 Base Long Reach ports with the following optical properties:

   a. The minimum optical budget between transmit and received ports shall be 19dB.

   b. The Small Form-Factor Pluggables (SFP's) shall include SX, LX, and ZX 1000Base Options.

   c. Optical receiver maximum input power level shall not be exceeded. Optical attenuators shall be added as needed; fiber optic attenuator patch cords shall be in accordance with Section 4 of this Technical Special Provision (TSP). It is the Contractor's responsibility to determine where attenuators are needed and shall be included in the cost of the switch.

   d. Each port shall connect via duplex small form-factor connectors.

3) Rack, shelf or DIN Rail mountable. If shelf mounted, the Contractor must furnish and install the shelf. The shelf shall be ventilated as per the Network Switch manufacturer recommendation.

4) Operate between -34 to +74 degree Celsius (-29ºF to +165ºF), including power supply.

5) Operate from 100 VAC to 200 VAC.

6) Operate from 10% to 90% non-condensing humidity.

7) Meet the IEEE 802.3 (10Mbps Ethernet) standard.

8) Meet the IEEE 802.3u (Fast Ethernet 100 Mbps) standard.

9) Meet the IEEE 802.3x (Full Duplex with Flow Control) standard.

10) Meet the IEEE 802.1p (Priority Queuing) standard.

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11) Meet the IEEE 802.1Q (VLAN) standard per port for up to four VLAN's.

12) The switch shall meet the IEEE 802.1D (Spanning Tree Protocol) and IEEE 802.1w (Rapid Spanning Tree Protocol) standards.

13) Meet the IEEE 802.3ad (Port Trunking) standard for a minimum of two groups of four ports.

14) Capable of mirroring any port to any other port within the switch.

15) Password manageable through:

    a. SNMP

    b. Telnet/CLI

    c. HTTP (Embedded Web Server) with Secure Sockets Layer (SSL)

16) Full implementation of SNMPv1 and SNMPv2c.

17) Full implementation of Generic VLAN Registration Protocol (GVRP).

18) Full implementation of Internet Group Management Protocol (IGMP) and IGMP snooping.

19) Minimum Mean Time Between Failures (MTBF) of 100,000 hours. using Bellcore TS-332 standard.

20) Full implementation of RFC 783 (TFTP) to allow remote firmware upgrades.

21) UL approved.

22) All power transformers provided shall be "fastening mechanism" type. No plug-in types shall be permitted. All corded transformers shall be mountable with the ability to neatly secure power cords.

23) The field switch shall provide status indicators as follows:

    a. Power on an off,

    b. Network status per port (transmit, receive, link, speed)

    c. Status indicators shall be LED.

24) Unused ports (copper and optical) shall be covered with rubber or plastic dust caps/cover.

3.2.3 Type C Network Switch

Traffic Operation Center (TOC) Core Switches will be deployed in the TOC and shall meet the following requirements:

1) Layer 3 core modular switch equipped with redundant fans, power supplies, and support for redundant supervisor engines.

2) A minimum of six (6) slots for switch/routing processor modules, but at least one spare slot shall remain after configuring required ports/interfaces herein.

3) Equipped with ninety-six (96) ports of 10/100/1000 Base-T. No more than forty-eight (48) ports per module, and no more than three (3) modules in total.

4) The SFP switch module shall support a minimum of twenty-four (24) SFP ports.

5) Equipped with six (6) SFP ports for connectivity between TOC and MHS switches using GigE. –LX/LH, or –ZX SFPs shall be provided to support distances shown in the Plans.

6) Equipped with two (2) SFP ports for short-range connectivity between the two (2) TOC switches using GigE.

7) Equipped with two (2) SFP ports for connectivity between TOC and Local Field switches using GigE. –LX/LH, or –ZX SFPs shall be provided to support distances shown in the Plans.

8) Security:

   a. Dynamic Host Configuration Protocol (DHCP) Snooping

   b. Dynamic ARP Inspection (DAI)

   c. Secure Shell (SSH) Protocol, Kerberos, and Simple Network Management Protocol Version 3 (SNMPv3)

   d. Bi-directional data support on the Switched Port Analyzer (SPAN) port

   e. TACACS+ and RADIUS authentication

   f. MAC Address Notification

   g. Port Security

   h. Bridge protocol data unit (BPDU) guard

i. Spanning Tree Root Guard (STRG)

j. IGMP filtering

k. Dynamic VLAN assignment

9) Standards: Supply a Layer 3 Ethernet switch that meets or exceeds the following standards:

a. IEEE 802.1s Multiple Spanning Tree Protocol

b. IEEE 802.1w Rapid Reconfiguration Spanning Tree Protocol

c. IEEE 802.1x

d. IEEE 802.3ad

e. IEEE 802.3af

f. IEEE 802.3x full duplex on 10BASE-T, 100BASE-TX, and 1000BASE-T ports

g. IEEE 802.1D Spanning Tree Protocol

h. IEEE 802.1p CoS Prioritization

i. IEEE 802.1Q VLAN

j. IEEE 802.3 10BASE-T specification

k. IEEE 802.3u 100BASE-TX specification

l. IEEE 802.3ab 1000BASE-T specification

m. IEEE 802.3z 1000BASE-X specification

10) Supply a Layer 3 Switch with the following Indications:

a. Per-port status LEDs: link integrity, disabled, activity, speed, and full duplex indications

b. System-status LEDs: system, power supplies, fans, and bandwidth utilization indications

11) Backplane Bandwidth: 720-Gbps switch fabric, with an equivalent virtual switch processor supervisor engine

12) Layer 3 Forwarding Performance: up to 400 mpps

13) Redundant Supervisor Engines: Spare; for cold standby between both TOC switches

14) Redundant Components

    a. Power supplies (1+1)

    b. Switch fabric (1+1)

    c. Replaceable clock

    d. Replaceable fan tray

15) High-Availability Features

    a. Hot Standby Router Protocol (HSRP)

    b. Rapid Spanning Tree Protocol (RSTP)

    c. Multiple Spanning Tree Protocol (MSTP)

    d. Per-VLAN Rapid Spanning Tree

    e. Rapid Convergence Layer 3 protocols

16) Dimensions

    a. Rack Unit (RU): 19” RU

    b. Weights

        i. Chassis Only (kg): 30 kg maximum

        ii. Fully Configured (kg): 60 kg maximum

17) Environmental Parameters

    a. Operating Temperature: 32 to 104°F (0 to 40°)

    b. Storage Temperature: -4 to 149°F (-20 to 65°C)

    c. Relative Humidity: 10 to 90%, non-condensing

18) Mean Time Between Failure (MTBF): seven (7) years for system configuration

3.2.4 Cat 6 Patch Cords

The Cat 6 Patch Cords shall be furnished and installed as needed to connect the Network Switches with other equipment within the cabinet and TOC. Cat 6 Patch Cords shall be considered an incidental component for this project and furnished and installed as needed to provide a functional system. Cat 6 Patch Cords shall meet the following minimum requirements:

1) All patch cords shall be from the same manufacturer.

2) Shall incorporate four (4) pair 24 AWG UTP stranded PVC Category 6.

3) Shall be factory made; contractor or vendor assembled patch cords are not permitted.

4) Shall be TIA/EIA 568-B.2-1 compliant. Patch Cords shall be compliant to T568B pin configuration (*whichever is used*).

5) Certified by the manufacturer for Category 6 performance criteria.

6) Standard lengths as needed. Excessive slack is not permitted.

3.3 Project Submittal Program Requirements

General Requirements:

1) The Contractor shall provide project submittals for network switches, including scheduling requirements. The project submittals for network switches shall include but are not limited to the additional specific requirements in this subsection.

2) The Contractor shall submit documentation and proof of manufacturer-recommended training and certification for the installation and configuration of network switches.

3) The Contractor shall submit technical specifications for the minimum transmitter port to receiver port optical attenuation required for the switches to function in accordance with this TSP for the following optical links:

   a. Network Switch FX port to Network Switch FX port

3.4 Installation Requirements

3.4.1 General

The Contractor shall follow the following installation requirements:

1) Network switches shall only be configured and installed by the switch manufacturer trained personnel.

2) Network switches shall be installed in accordance with manufacturer's guidelines and requirements.

3) The Contractor shall request from the City of Hendersonville (City), switch configuration information (such as IP address, VLAN Tag values, etc.) not more than 30 days after the switch cut-sheets have been approved.

4) The Contractor shall provide as needed the necessary Cat 6 patch cords and fiber optic patch cords for a complete and functional installation.

5) The Contractor shall provide training for proper management of the equipment installed. This training should cover daily operation as well as maintenance and configuration of the switching equipment installed as part of this project.

6) The Contractor shall integrate all Network Switches into the Network Management software at the TOC.

3.4.2 Testing

General Requirements:

1) The Contractor shall conduct a project testing program for all network switches. The project testing program for network switches shall include but is not limited to the additional specific requirements in this subsection.

2) All test results shall confirm physical and performance compliance with this TSP.

3) The Contractor shall submit all test results documentation to the Engineer within 14 days of completion of the tests for the approval by the Engineer.

4) Bench Test System (BTS)

   a. The Contractor shall perform BTS on the Network subsystem.

   b. Configured as required per Switch Configuration Requirements.

c. All other configuration settings as required to meet the project requirements including performance.

d. Communication redundancy at Layer 2 and Layer 3.

5) Stand Alone Test (SAT)

a. The Contractor shall perform SAT on the Network Switch. The SAT test shall demonstrate that each switch has been configured as required per Switch Configuration Requirements and all other settings as required to meet the project requirements including performance.

3.4.3 Switch Configuration Requirements

1) The Contractor may submit an alternate switch configuration to the Engineer for review and approval. The goal of the switch configuration is to reduce the network delay, as well as provide network redundancy at the Layer 2 and Layer 3 levels.

2) Configuration Requirements for Network Switch.

Configuration of the Network Switch Type A shall be as follows:

a. All 100 Base-TX ports shall be configured as follows:

i. RSTP/STP – Off.

ii. IGMP Snooping – On.

iii. Unused TX ports shall be disabled.

iv. Operating TX ports shall be programmed to filter only for the MAC address of the connected device.

v. All used TX ports shall be tagged to the proper VLAN is applicable

b. All 1000 Base-FX ports shall be configured as follows:

i. RSTP/STP – On.

ii. IGMP Snooping – On.

c. All network switches shall be installed and configured with the same firmware configuration. The optimum settings shall be used consistently system-wide. Any locations that require different settings for optimum performance shall be approved by the Engineer.

d. All network switches shall be delivered with the latest firmware available from the manufacturer.

e. Switch configuration must support use of multicasting video streams between any defined VLANS/subnets.

3.4.4 Warranty

The network switches shall be warranted to be free of manufacturer defects in materials and workmanship for a period of five (5) years from the date of Final Acceptance. Equipment covered by the manufacturer's warranties shall have the registration of that component placed in the City's name prior to Final Inspection. The Contractor is responsible for ensuring that the vendors and/or manufacturers supplying the components and providing the equipment warranties recognize the City as the original purchaser and owner/end user of the components from new. During the warranty period, the supplier shall repair or replace with new or refurbished material, at no additional cost to the City, any product containing a warranty defect, provided the product is returned postage-paid by the City to the supplier's factory or authorized warranty site. Products repaired or replaced under warranty by the supplier shall be returned prepaid by the supplier.

During the warranty period, technical support shall be available from the supplier via telephone within four hours of the time a call is made by the City, and this support shall be available from factory certified personnel. During the warranty period, updates and corrections to control unit software shall be made available to the City by the supplier at no additional cost.

3.5 Measurement

Network Switches will be measured in units of each and paid for at the contract price per each. The price bid shall include furnishing, installing, configuration, integration and testing of a Network Switch including all chassis, modules, power cables, power supplies, software, license, ST to LC fiber optic patch cords, Cat 6 patch cords, media converters (if needed), and all incidental components, attachment hardware, mounting shelf and hardware, testing and training requirements, and all work, equipment and appurtenances as required to provide a fully functional switch ready for use. The price bid shall also include all configuration and control software, system documentation including: shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the switch and network. This price shall be full compensation for all labor, tools, materials, equipment and incidentals necessary to complete the work.

3.6 Payment

The contract unit price shall be full compensation for all work specified in this Section.

Payment will be made under:

Item No.	Description	Unit
725-03.09	Ethernet Switch (Type A)	EACH
725-03.10	Ethernet Switch (Type B)	EACH

Network Switch will be paid per each as follows:

1) 50% of the contract unit price upon satisfactory Bench Test Component, Bench Test System and Pre-installation test results.

2) Additional 20% of the contract unit price upon satisfactory Stand Alone Site acceptance test.

3) Additional 20% of the contract unit price upon satisfactory Conditional System Acceptance test.

4) Final 10% of the contract unit price upon Final System Acceptance, which includes delivery of training, all documentation and documentation of warranties for all equipment.

SECTION 4

FIBER OPTIC INFRASTRUCTURE

4.1 Description

This Section specifies the minimum requirements for fiber optic infrastructure furnished and installed on this project. This work includes but is not limited to cable, splicing, termination, connectors, closures, panels, installation, and testing.

The fiber optic infrastructure will serve as the backbone for the communications systems (wireline) and will be used to transport data and video signals to/from field device locations using an Ethernet protocol.

4.2 Materials

4.2.1 General

1) The Contractor shall furnish fiber optic infrastructure materials that meet applicable industry standards including but not limited to:

   a. EIA/TIA

   b. RUS

   c. IEEE

   d. ICEA

   e. Telcordia

   f. ASTM

   g. UL

   h. NEC

2) Upon request of the Engineer, the Contractor shall provide certification from an independent testing laboratory that certifies that the cable conforms to industry standards.

3) The Contractor shall furnish fiber optic infrastructure materials recommended by the manufacturer for outside plant use and the intended application.

4) The Contractor shall furnish all optical fiber, fiber optic cable, fiber optic drop cable, optical termination and connectorization materials, and all ancillary and incidental materials that are single-mode and/or compatible. All materials shall meet the following requirements:

   a. Listed with and conform to RUS 7 CFR 1755.900 and associated fiber optic test procedures (FOTPs), ICEA 640, EIA/TIA-598B, and Telcordia GR-20 core requirements.

   b. Manufacturer is currently ISO 9001 certified. This requirement applies to assemblers of manufactured components, such as patch cords and termination cabinet interconnection cables.

   c. All cables and termination infrastructure shall be assembled from Corning SMF28e, OFS All Wave or approved equivalent single-mode optical fiber.

   d. All fibers and buffer tubes shall follow EIA/TIA-598B identification using colors. Do not use printed legends.

   e. All cables shall have been manufactured and labeled no earlier than in the third calendar month preceding the letting date of the contract.

5) Fiber optic installation and testing tools shall be maintained and calibrated in accordance with the tool manufacturer's recommendations. The Contractor shall provide tool manufacturer's certified calibration documentation upon Engineer's request. Installation and testing tools include but are not limited to:

   a. Fusion splicers

   b. Cable pulling strain dynamometers and breakaway links

   c. Cable air jetting/blowing systems

   d. OTDRs

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

6) Fiber optic installation and testing tools shall be operated only by Contractor personnel who have been trained and certified by the tool manufacturer. Installation and testing tools requiring certified operators include but are not limited to:

   a. Fusion splicers

   b. Cable air jetting/blowing systems

c. OTDRs

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

4.2.2 Fiber Optic Cable (FO Cable)

1) The Contractor shall provide fiber optic cable that meets the following requirements:

   a. All-dielectric outside plant loose tube cable with central strength/anti-buckling member

   b. Dry water blocking materials and construction

   c. Reverse oscillating "SZ" stranded buffer tube construction

   d. High tensile strength yarn

   e. Medium density polyethylene outer jacket

   f. 72 fiber cable with six (6) active buffer tubes and twelve (12) individual stranded fibers per buffer tube

   g. Cable construction design that allows no more than six (6) buffer tube positions

   h. Maximum diameter 0.48 inches

   i. Maximum weight 0.07 pounds per foot

2) Provide Corning ALTOS All-Dielectric, Pirelli FlexLink, OFS MiDia, or approved equivalent cables.

3) Designate this cable as a trunk cable.

4) Ensure that the cable can withstand a maximum pulling tension of 600 lbf during installation and 180 lbf installed long term (at rest).

5) Provide cable with shipping, storage, and operating temperature range of -30°C to +70°C (-22ºF to +158ºF).

6) Provide cable with an installation temperature range of -30°C to +60°C (-22ºF to +140ºF).

7) Provide cable with outer jacket marking using the following template:

Manufacturer's Name – "Optical Cable" – Month/Year of Manufacture - Telephone Handset Symbol – "HENDERSONVILLE" – "72F SM"

8) Include in the outer jacket marking the cable sequential length in accordance with the following:

   a. In English units every 2 feet

   b. Within -0/+1% of the actual length of the cable

   c. In contrasting color to the cable jacket

   d. Marking font height no less than 0.10 inches

   e. On any single length of cable on a reel, the sequential length markings do not run through "00000".

4.2.3 Fiber Optic Drop Cable (FO Drop Cable)

1) Provide fiber optic drop cable that meets the following requirements:

   a. All-dielectric outside plant loose tube central core cable

   b. High tensile strength yarn surrounding the central tube core

   c. Dry water blocking materials and construction

   d. Six (6) individual stranded fibers contained within the central tube core

2) Provide Corning Freedm LST All-Dielectric, Pirelli CentraLink, or approved equivalent cables.

3) Designate this cable as drop cable.

4) Ensure that the cable can withstand a maximum pulling tension of 300 lbf during installation.

5) Provide cable with shipping, storage, and operating temperature range of -30°C to +70°C (-22ºF to +158ºF) and an installation temperature range of -10°C to +60°C (-22ºF to +140ºF).

6) Provide cable with outer jacket marking using the following template:

   a. Manufacturer's Name – "Optical Cable" – Month/Year of Manufacture - Telephone Handset Symbol – "HENDERSONVILLE" – "12F SM"

7) Include in the outer jacket marking the cable sequential length in accordance with the following:

   a. In English units every 2 feet

   b. Within -0/+1% of the actual length of the cable

   c. In contrasting color to the cable jacket

   d. Marking font height no less than 0.10 inches

   e. On any single length of cable on a reel, the sequential length markings do not run through “00000”.

4.2.4 Fiber Optic Fusion Splice (FO Splice, Fusion)

1) Provide fusion splices for splicing of all fibers on the project. Do not provide any other type of fiber splicing.

2) Perform fusion splicing with a fully automatic portable fusion splicer that provides consistent low loss (max 0.10 dB) splices. Splicer shall provide three-axis fiber core alignment using light injection and loss measurement techniques. The fusing process shall be automatically controlled. The splicer shall provide splice loss measurements on an integral display, as well as a magnified image of the fiber alignment.

4.2.5 Fiber Optic Connectors

1) Provide fiber optic connectors compliant with this Technical Special Provision (TSP) for all fiber optic infrastructures including but not limited to fiber optic termination cabinets, fiber optic drop panels, and fiber optic patch cords.

2) Provide only factory-installed compatible connectors for all fiber optic infrastructures. Do not use field-installed connectors. Do not use adapter couplers to change connector types.

3) Use ceramic ferule connectors factory-installed with a thermal-set heat-cured epoxy and machine polished mating face. Install connectors as per manufacturer application and recommendations, including proper termination to the outer-tubing (900 micron tubing, 3 mm fan out tubing, etc.) required for the application.

4) Use connectors rated for an operating temperature of -40°C to +75°C (-40ºF to 167ºF).

5) Provide connectors that have an installed insertion loss of less than 0.50 dB, a typical loss of 0.20 dB, and a reflectance level of less than -40dB.

6) Label each fiber position on panels and termination cabinets containing duplex couplers with the port/position ID as shown in the Plans.

7) Provide dust caps for all exposed male connectors and female couplers at all times until permanent connector installation.

4.2.6 Splice Enclosure (Under Grade)

1) Provide fiber optic closures (splice closures) designed for underground outside plant (OSP) use for splicing cables in pull boxes.

2) Use fiber optic splice closures that are impact and corrosion resistant and waterproof when immersed in 10 feet of water.

3) Use fiber optic splice closures that are fully compatible with all components of the fiber optic infrastructure as specified, including but not limited to fiber optic trunk cable, fiber optic drop cable, and fiber optic fusion splices.

4) Use a cylindrical dome-type splice closure with cable entry at one end only and a sealed single-molded piece dome body of high density polyethylene or equivalent non-metallic material.

   a. The cable entry end shall be manufactured of a similar material as the dome body and shall seal the closure with flexible thermoplastic rubber or polymer gasket seals.

   b. The cable entry end shall include cable entrance ports that shall seal the cable and port opening with flexible thermoplastic rubber or polymer gasket seals with mechanical compression.

   c. Closures shall be re-enterable and re-sealed without the need for specialized tools or equipment, or the use of any additional parts.

   d. Do not use any heat shrink or caulk/encapsulate materials for sealing the assembled closure or terminated cables.

5) Provide splice closures with maximum outer dimensions of 8 inches diameter and 21 inches length.

   a. Splice closures shall provide cable entrance ports for at least five (5) fiber optic cables.

b. At least two (2) cable entrance ports shall accommodate cables of at least 0.60 inches outer diameter.

c. The closure shall allow for the storage and express of at least six (6) unopened buffer tubes.

6) Provide a splice closure with a cable entry end with pre-template cable ports and a split-plate design permitting installation of the closure in mid-span cable segments.

7) The splice closure size shown in the Plans specifies the minimum number of fusion splices to be accommodated by the closure. With the splice closure, provide all materials to accommodate the number of splices specified by the closure size, including splice tray, storage, and organizing materials.

8) The Contractor shall provide documentation of water immersion test results performed by the manufacturer or independent testing laboratory to the Engineer.

4.2.7 Fiber Optic Drop Panel (FO Drop Panel, 12F)

1) Provide fiber optic drop panels designed for outside plant use for terminating drop cables in equipment cabinets.

2) Use fiber optic drop panels that are fully compatible with all components of the fiber optic infrastructure as specified, including but not limited to fiber optic trunk cable, fiber optic closures, fiber optic fusion splices, and fiber optic connectors.

3) Use fiber optic drop panels that are factory manufactured assemblies of fiber optic drop cable with factory-installed fiber connectors and integral ruggedized fiber connector enclosures.

4) Use drop panels with 12 fiber (6 duplex LC to ST) connectors.

5) Use permanent labels on the enclosure with contrasting color to identify each connector body by its associated fiber number.

6) Provide an outer non-metallic cable strain-relief boot where the drop cable enters the fiber connector enclosure and that secures the cable to the enclosure; the strain-relief boot shall fully encircle the cable for a minimum of 2 inches from the enclosure’s outer surface.

4.2.8 Cable Labels

1) The Contractor shall provide cable labels that meet the following requirements:

   a. Self-coiling wrap-around type

   b. PVC or equivalent plastic material with UV and fungus inhibitors

   c. Base materials and graphics/printing inks/materials designed for underground outside plant use including solvent resistance, abrasion resistance and water absorption

   d. Minimum size of 2.5 inches wide by 2.5 inches long

   e. Minimum thickness of 0.010 inches

   f. Orange label body with pre-printed text in bold black block-style font with minimum text height of 0.375 inches.

2) Pre-print the following text legibly on labels used for all fiber optic trunk cables (FO Cable):

   HENDERSONVILLE

   OPTICAL CABLE

3) Pre-print the following text legibly on labels used for all fiber optic drop cables (FO Drop Cable):

   HENDERSONVILLE

   OPTICAL DROP CABLE

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

4.2.9 Fiber Optic Patch Cords

1) Provide fiber optic patch cords consisting of a length of fiber optic cable terminated on both ends.

2) All patch cords shall be factory preconnectorized assemblies adhering to all applicable cable and fiber specifications stated in this TSP.

3) Provide patch cords of the appropriate length for the necessary connections, maintaining minimum bend radius, and with no residual strain at the connector or anywhere on the patch cord itself beyond self-support. Patch cords shall not have excess length beyond what is necessary for equipment connection and routing.

4) All patch cords shall be duplex zip-cord fiber cable, except as otherwise submitted and approved by the Engineer.

   a. The two connectors of each end of the patch cord shall be differentiated by different colors.

   b. Provide sufficient flexibility at each end to disconnect one connector without disturbing the other, or to allow swapping of the two connectors within the same duplex coupler without disturbing the remainder of the patch cord.

   c. Provide strain relief and reinforcement at the point where the duplex cable separates for the individual simplex connectors.

5) Fiber cable shall be 3 mm jacketed cable with high tensile strength yarn protecting the inner fiber manufactured into a duplex zip-cord configuration.

6) Connector strain relief boots shall be fixed to the outer jacket and strength yarn.

7) Use yellow outer jackets for single mode fiber.

8) No splices of any type are allowed within a patch cord assembly.

9) Fully test each patch cord assembly at the source of manufacture and place those test results on a test tag for each mated pair of connectors. Attach the associated tag to one end of each fiber within the duplex assembly.

4.2.10 Project Submittal Program Requirements

1) General Requirements

   a. The Contractor shall provide project submittals for all fiber optic infrastructures, including scheduling requirements. The project submittals for fiber optic infrastructure shall include but are not limited to the additional specific requirements in this subsection.

2) Fiber Optic Installation and Testing Tools

   a. Provide project submittals including manufacturer-recommended operations, maintenance and calibration procedures for the following equipment:

      i. Fusion splicers

      ii. Cable pulling strain dynamometers and breakaway links

      iii. Cable air jetting/blowing systems

      iv. OTDRs

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

   b. Submit documentation and proof of manufacturer-recommended operator training and certification for the following equipment:

      i. Fusion splicers

      ii. Cable air jetting/blowing systems

      iii. OTDRs

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

4.3 Installation Requirements

4.3.1 General

1) Install all fiber optic infrastructures according to the manufacturer's recommended procedures and specifications.

4.3.2 Cable Shipping and Delivery

1) Package the cable for shipment on reels. Each package shall contain only one continuous length of cable. Construct the packaging so as to prevent damage to the cable during shipping and handling.

2) Seal both ends of the cable to prevent the ingress of moisture.

3) Include with each reel a weatherproof reel tag attached identifying the reel and cable that can be used by the manufacturer to trace the manufacturing history of the cable and the fiber. Include with each cable a cable data sheet containing the following information:

   a. Manufacturer name

   b. Cable part number

   c. Factory order number

   d. Cable length

   e. Factory measured attenuation of each fiber

4) Cover the cable with a protective and thermal wrap.

   a. Securely fasten the outer end of the cable to the reel head so as to prevent the cable from becoming loose in transit.

   b. Project the inner end of the cable a minimum of 6.5 feet into a slot in the side of the reel or into a housing on the inner slot of the drum, in such a manner to make it available for testing.

   c. Plainly mark each reel to indicate the direction in which it is to be rolled to prevent loosening of the cable on the reel.

4.3.3 Cable Handling and Installation

1) Do not exceed the maximum recommended pulling tension during installation as specified by the cable manufacturer.

2) Continuously monitor pulling tensions with calibrated measuring devices, such as a strain dynamometer.

3) Protect all pulled installations with calibrated breakaway links.

4) Do not violate the minimum recommended bend radius during installation as specified by the cable manufacturer. Unless the manufacturer's recommendations are more stringent, use the following guidelines for minimum bend radius:

   a) 20 X Cable Diameter Short Term - During Installation

   b) 10 X Cable Diameter Long Term – Installed

5) Before cable installation, carefully inspect the cable reels and reel stands for imperfections or faults such as nails that might cause damage to the cable as it is unreeled.

6) Take all necessary precautions to protect reeled cable from vandals or other sources of possible damage while unattended. Any damage to reeled cable or the reel itself shall necessitate replacement of the entire cable section at Contractor's expense.

7) Whenever unreeled cable is placed on the pavement or surface above a pull box, provide means of preventing vehicular or pedestrian traffic through the area in accordance with the Maintenance of Traffic provisions in the TDOT Standard Specification.

8) Keep the cable continuous throughout the pull. Cable breaks and reel end splices are permitted only as shown in the Plans.

9) Where a cable ends in an underground fiber optic closure, secure and store all unused fibers and buffer tubes in splice trays in preparation for future reel end splicing and continuation.

4.3.4 Cable Storage

1) Properly store all cable to minimize susceptibility to damage.

   a. Maintain proper bend radius, both short and long term, during cable storage.

   b. Storage coils shall be neat in even length coils, with no cross over or tangling.

   c. Storage coils of different cables shall be kept completely separate except when the cables terminate in the same splice closure.

   d. Storage coils shall be secured to cable racking hardware with tie wraps, Velcro straps, or non-metallic cable straps with locking/buckling mechanism.

e. Do not use adhesive or self-adhering tapes, metal wires and straps, or rope/cord.

2) Unless otherwise noted on the Plans, the following are the requirements for minimum cable storage for underground applications:

a. Trunk cable in Type A pull box – 100 feet

b. Trunk cable in Type B pull box – 200 feet

c. Drop cable in Type B pull box – 20 feet

d. Communications hub or Control Center (interior) – Do not store slack cable inside the communications hub building or Control Center.

4.3.5 Fiber Optic Fusion Splice (FO Splice, Fusion)

1) Perform fusion splicing of all fiber optic splices as shown in the Plans.

2) Perform fusion splicing only in enclosed spaces such as splice trailers or tents specifically intended for this operation

3) Completed fusion splices shall have no more than 0.10dB optical loss.

4) Adequately protect all fusion splices in splice trays in a splice closure or termination cabinet. Provide the splice with strain relief and protection of the stripped fiber splice in a manner recommended by the fiber and the splice tray manufacturers.

5) Use fusion splice protectors of a heat shrink tubing that protects the splice and extends over the fiber coating. Splice protectors shall be compatible with and as recommended by the fiber and the splice tray manufacturers.

6) No bare fiber may be exposed.

4.3.6 Fiber Optic Termination Cabinet (also known as FO Distribution Center or Module)

1) Install only one (1) outside plant cable per termination cabinet, including within the separate splice tray storage compartment. These units are to be rack mounted in a standard 19” rack. Install the connector modules in the termination cabinet for fibers 1 through 72 as shown in the Plans. Equip any remaining unused connector module slots with blank panels.

2) Install all fibers, buffer tubes, and cables following minimum internal and external bend radius, proper management, routing, fastening and protection, and with no residual strain on any connector, fiber, buffer tube or cable.

3) Install one (1) cable buffer tube to one (1) termination cabinet interconnect cable, matching fiber to fiber. The buffer tubes shall be terminated in order of color, left to right on the panel face, and as shown on the plans. Keep all fibers of the outside plant cable buffer tube and its corresponding termination interconnect cable complete within the same splice tray.

4) Label the front and rear of the termination cabinet with the trunk cable segment ID of the cable terminated within; use permanent clearly legible labels with minimum 0.5 inch text height.

5) Label each end of termination cabinet interconnect cables to identify the 12 trunk cable fibers/buffer tube connected; use permanent overlapping cable labels with clearly legible text.

4.3.7 Fiber Optic Closure (FO Closure)

1) Install fiber optic splice closures where and of the size shown in the Plans. Install splice closures in the center ± 3 feet of the entire length of stored cable coils, or install at the end of cables that terminate in the pull box.

2) Store FO closures and cable coils on the pull box cable rack hooks. Keep all closures and cable coils off of the bottom of the pull box. Secure closures and/or cable coils as needed to hold them in place.

4.3.8 Cable Labels

1) Install cable labels on all trunk and drop fiber optic cables. Clean the installed cable of all dirt and grease before applying any label.

2) Label all cables in or at every location where the cable is exposed outside of a conduit, innerduct or pole, using the cable IDs for trunk cables or the device number for drop cables. As a minimum, install cable labels in the following locations:

   a. Within 12 inches of every cable entry to a pull box, equipment cabinet, communications hub, or the TOC.

   b. Within 12 inches of the exterior entry point of every fiber optic splice closure, termination cabinet, and drop panel.

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

4.3.9 Fiber Optic Patch Cords

1) Install fiber optic patch cords to connect all electronic equipment with the fiber optic infrastructure. Follow port assignments as shown in the Plans.

2) Install fiber optic patch cords to connect all active optical paths between fiber optic termination cabinets in communications hubs as shown in the Plans.

3) Neatly route and dress all patch cords to the connected devices and within cable management facilities.

4.3.10 Project Testing

1) General Requirements

a. The Contractor shall conduct a project testing program for all fiber optic infrastructures. The project testing program for fiber optic infrastructure shall include but is not limited to the additional specific requirements in this subsection.

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

c. In addition to notification, provide the tentative date, time and location of fiber optic infrastructure testing no less than seven (7) days in advance of the test. Provide confirmed date, time and location of fiber optic infrastructure testing no less than 48 hours before conducting the test.

d. Provide test results documentation in electronic format (one (1) copy) and printed (one (1) copy) format. Electronic formats shall be readable in Microsoft Excel or other approved application. Printed copies shall be bound and organized by cable segment.

e. Provide all test results in English units of measure of length.

f. Submit all test results documentation to the Engineer within fourteen (14) days of completion of the tests for approval by the Engineer.

2) Standalone Acceptance Test (SAT)

a. Perform an SAT on all fiber optic infrastructure on this project after field installation is complete, including but not limited to all splicing and terminations.

b. An SAT for each fiber in each cable shall include OTDR Tests and Optical Attenuation Tests.

c. All fibers in all FO Cables and FO Drop Cables shall be tested from termination point to termination point, including:

i. Fibers from FO Termination Cabinet to FO Termination Cabinet

ii. Fibers from FO Termination Cabinet to FO Drop Panel

iii. Fiber from FO Drop Panel to FO Drop Panel

iv. Fibers from FO Termination Cabinet to the end of the cable run in the last FO Closure.

d. Test documentation shall include but is not limited to:

i. Cable & Fiber Identification

- Cable & Fiber ID and Location – Physical location (device ID and station number of FO Termination Cabinet, FO Drop Panel, or cable end FO closure), fiber number, and trunk or drop cable ID for both the beginning and end point.
- Operator Name
- Engineer
- Date & Time

ii. Setup and Test Conditions Parameters

- Wavelength
- Pulse width Optical Time Domain Reflectometer (OTDR)
- Refractory index (OTDR)
- Range (OTDR)
- Scale (OTDR)
- Ambient Temperature

iii. Test Results for OTDR Test (each direction and averaged)

- Total Fiber Trace (miles)
- Splice Loss/Gain (dB per mile)
- Events > 0.05 dB
- Measured Length (Cable Marking)
- Total Length (OTDR Measurement)

iv. Test Results for Attenuation Test (each direction and averaged)

- Measured Cable Length (Cable Marking)
- Total Length (OTDR Measurement from OTDR Test)
- Number of Splices (Determined from As-Builts)
- Total Link Attenuation

e. OTDR Test

i. Conduct the OTDR Test using the standard operating procedure and recommended materials as defined by the manufacturer of the test equipment.

ii. Use a factory patch cord (“launch cable”) of a length equal to the “dead zone” of the OTDR to connect the OTDR and the fiber under test.

iii. Conduct bi-directional OTDR Tests for each fiber. Calculate bi-directional averages.

iv. Conduct all tests at 1310 and 1550 nm for single mode cable.

f. Optical Attenuation Test

i. Conduct the Optical Attenuation Test using the standard operating procedure and recommended materials as defined by the manufacturer of the test equipment.

ii. Conduct bi-directional Optical Attenuation Tests for each fiber. Calculate bi-directional averages.

iii. Conduct all tests at 1310 and 1550 nm for single mode cable.

4.4 Measurement

4.4.1 Fiber Optic Cable (FO Cable, 72F)

Fiber Optic Cable (FO Cable, 72F) will be measured in units of linear feet and paid for at the contract price per linear foot. The price bid shall include the length in feet of actual cable installed as measured from the cable sequential length markings, all of the reel-to-reel trunk cable splicing, cable labels, patch cords, ancillary and incidental materials, testing, documentation and all labor and equipment necessary to complete the work. No measurement for payment will be made for cable storage amounts in excess of that required in this TSP or the Plans. No measurement for payment shall be made for reel-to-reel splices, and incidentals of the reel-to-reel splicing, including but not limited to the splice enclosure, splice trays, and prep kitting for the reel-to-reel splicing. All reel-to-reel splicing shall be full buffer tube to buffer tube splicing, and shall match color for color. Cross splicing of buffer tubes for reel-to-reel splicing shall not be allowed, unless shown on the plans. This price shall be full compensation for all labor, tools, materials, equipment and incidentals necessary to complete the work from beginning to end of trunk Fiber Optic Cable.

4.4.2 Fiber Optic Drop Cable (FO Drop Cable, 12F)

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

4.4.3 Fiber Optic Closure (FO Closure)

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

4.4.4 Fiber Optic Connectors

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

4.4.5 Fiber Optic Splice, Fusion (FO Splice, Fusion)

Fiber Optic Splice, Fusion (FO Splice, Fusion) will be measured in units of each and paid for at the contract price per each. The price bid shall include but not limited to all ancillary and incidental materials, testing, documentation and all labor and equipment necessary to complete the work. This price shall be full compensation for all labor, tools, materials, equipment and incidentals necessary to complete the work.

4.4.6 Fiber Optic Drop Panel (12F)

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

4.4.7 Cable Labels

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

4.4.8 Fiber Optic Patch Cords

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

4.5 Payment

The contract unit price shall be full compensation for all work specified in this Section.

Payment will be made under:

Item No.	Description	Unit
725-02.41	Fiber Optic Termination Splice Unit	EACH
725-02.81	Fiber Entrance (Hendersonville City Hall)	EACH
725-23.10	Fiber Optic Cable (72F)	LF
725-23.21	Fiber Optic Drop Cable (12F)	LF
725-05.04	Splice Enclosure (Under Grade)	EACH
725-23.28	Fiber Optic Splice, Fusion	EACH
725-23.31	Fiber Optic Drop Panel (12F)	EACH

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

1) 25% of the contract unit price upon delivery and reel test.

2) Additional 35% of the contract unit price for complete installation of cables.

3) Additional 30% of the contract unit price for completion of testing and documenting of all fibers in any lineal foot and in each splice or termination/connectorization location, and submission of and acceptance of all test documentation.

4) Final 10% of the contract unit price upon Final System Acceptance

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

1) 60% of the contract unit price upon completion of the splice.

2) Additional 30% of the contract unit price for completion of testing and documenting of all fibers in any lineal foot and in each splice or termination/connectorization location, and submission of and acceptance of all test documentation.

3) Final 10% of the contract unit price upon Final System Acceptance

SECTION 5

CONDUIT

5.1 Description

This section specifies the minimum requirements for conduit furnished and installed on this project as shown on the Plans or as directed by the Engineer.

5.2 Materials

The Conduit shall meet the following material requirements:

5.2.1 General Requirements

1) All continuous flexible conduit products and structure mounted multi-cell conduit shall meet the requirements specified herein.

2) All continuous flexible conduit and structure mounted multi-cell conduit shall have been manufactured and labeled no earlier than in the sixth calendar month preceding the letting date of the contract.

5.2.2 Continuous Flexible Conduit (Conduit Duct Bank)

1) Continuous Flexible Conduit shall be manufactured from virgin high-density polyethylene (HDPE) resin compound with a minimum cell classification of PE 345434C for PE 3408 materials in accordance with ASTM D-3350.

   a. Physical and Mechanical Properties and Test Methods:

      i. Tensile Strength @ yield - 3,000 PSI min. ASTM D-638

      ii. Density – 0.941 g/cc min. ASTM D-4883/1505

2) Conduit shall be extruded from colored material for uniform full-thickness coloring.

3) All continuous flexible conduit shall be labeled with durable identification giving the name of the manufacturer, conduit size (inner diameter trade size and wall thickness/rating), manufacturer/date codes, the legend “HENDERSONVILLE” and sequential foot marking. Labeling shall occur a maximum of every 2 feet.

4) Conduit to be used in bends and sweeps shall have a minimum burn through time of 30 minutes when tested in accordance with Generic Requirement GR-356-CORE, Issue 1, October 1995.

5) The conduit manufacturer shall have a documented Quality Control/Assurance System.

6) All conduit used on this project shall conform to the color scheme and use described below:

   a. Conduit Bank Type 1

      i. Green (Drop Fiber or Relational Database Service (RDS) Comm)

   b. Conduit Bank Type 2

      i. Green (Drop Fiber or RDS Comm)

      ii. White (RDS Comm, 2nd Drop Fiber or Spare)

   c. Conduit Bank Type 4

      i. Orange – (Trunk Fiber Cable)

      ii. Blue – (RDS Comm or Drop Fiber)

      iii. White – (Spare or 2nd RDS Comm)

      iv. Brown – (Spare)

   d. 2” Electrical Conduit

      i. Grey (Electrical wire)

7) The 1¼ inch conduit shall conform to ASTM D-3035 and meet the following requirements:

   a. Smoothwall SDR 11

   b. Nominal outer diameter: 1.660 inch

   c. Minimum inner diameter: 1.313 inch

   d. Minimum wall thickness: 0.151 inch

8) The 2 inch conduit shall conform to ASTM D-3035 and meet the following requirements:

   a. Smoothwall SDR 11

   b. Nominal outer diameter: 2.375 inches

   c. Minimum inner diameter: 1.885 inch

9) Coupling

   a. Make every effort to minimize coupling. Couplings are permitted only with the Engineer's prior approval.

   b. Couplings shall be airtight and watertight. All couplings shall be installed in accordance with the conduit and the coupling manufacturer's recommendations. Only couplings of the type specified below and approved by the conduit manufacturer are permitted.

   c. Couplings shall be accomplished only by hydraulic press-on or electro-fusion coupling methods.

      i. Use hydraulic press-on couplings of seamless tool-grade tubular aluminum with sealing ring barbs and center stop.

      ii. Use hydraulic compression duct coupling tools and follow all manufacturer's installation procedures, fully inserting both conduit sections to the coupling center stop.

      iii. Use pre-fabricated electro-fusion couplings that are field-installed using the coupling manufacturer's recommended automatic self-monitoring fusing machine and installation procedures.

      iv. Do not use any other coupling methods.

5.2.3 Rigid Galvanized Steel (RGS) Conduit

1) Shall meet TDOT Standard Specifications for Road and Bridge Construction.

5.2.4 PVC Schedule 40 Conduit

1) Shall meet TDOT Standard Specifications for Road and Bridge Construction.

5.2.5 Marking Tape

The Marking Tape shall meet the following requirements:

1) The color of the tape shall be orange with the legend "HENDERSONVILLE FIBER OPTIC CABLE" printed at intervals no greater than every 6 ft.

2) The tape shall be a dielectric, polyolefin film tape, 0.004 in. thick and 3 in. wide. The tape shall be constructed using material and ink colors which will not change when exposed to acids and other destructive substances commonly found in the soil.

3) Physical and Mechanical Properties and Test Methods:

   a. Standard Weight – 0.02 lb/ft^2 ASTM-D2103

   b. Thickness-Overall - 0.004 in. ASTM-D2103

   c. 3" Tensile Break-MD - 35 lbf ASTM-D882

   d. 3" Tensile Strength-MD - 2900 PSI ASTM-D882

   e. 3" Tensile Break-TD - 38 lbf ASTM-D882

   f. 3" Tensile Strength-TD - 3160 PSI ASTM-D882

   g. Elongation-MD - 530% ASTM-D882

   h. Elongation-TD - 660% ASTM-D822

   i. Puncture Propagation Tear (PPT) Resistance-MD - 12 lbf ASTM-D2582

   j. PPT Resistance-TD - 14 lbf ASTM-D2582

   k. Tear Strength-3" x 8"-MD - 24 lbf ASTM-D2261

   l. Tear Strength-3" x 8"-TD - 32 lbf ASTM-D2261

   m. Puncture Propagation Tear (PPT)

   n. Machine Direction/Transverse Direction (MD/TD)

5.2.6 Conduit Detection Wire

The conduit detection wire shall meet the following requirements:

1) Conduit detection wire shall be #10 AWG stranded copper orange-insulated THHN-THWN conductor.

5.2.7 Cable Markers

The Cable Markers shall meet the following requirements:

1) Shall be a six (6) foot cylindrical post with an 18” Cable Marker.

2) Shall have a cylindrical polymeric marker mounted on a 3.5” O.D. post and may be used for the identification of buried utility services. These markers may be used in road right-of-ways and installations requiring 360° visibility, good outdoor durability, and impact resistance.

3) The marker shall be comprised of polymer materials, which are resistant to impact (high Mean Time Between Failure (MTBF)), ultraviolet light, ozone, or hydrocarbon damage. The post and marker shall remain impact resistant in temperatures of -20°F to 140°F.

4) The marker shall be capable of permanent installation on a 3.5” O.D. tube and may utilize an anchor barb below ground level to prevent rotation and marker removal.

5) The marker shall have an outside diameter of 3.5 – 4.0 inches. The wall thickness shall be approximately 0.12 – 0.15 inches and the overall length shall be 18.00 inches.

6) The marker shall be orange in color and be pigmented throughout its entire cross section.

7) The graphics shall consist of a solvent-based ink that is abrasive and UV resistant and include the text, “City of Hendersonville Fiber Optic and Electrical Cable” “Call (615) 822-1016 Before Digging in this Area”.

8) The marker shall have a minimum tensile strength of 2700 pounds per square inch, as measured by ASTM D-638 (specimen type I with separation rate of two inches per minute.) Tensile strength shall not deviate more than 10 percent from the standard room temperature result when tested at both 140°F and 20°F after a minimum of two hours conditioning at the respective temperature.

9) A "Distance to Conduit" sticker or label shall also be provided. This label shall meet the following minimum requirements:

   a. Lettering shall be a minimum of 1 inch in height.

   b. Labels shall be manufactured from pre-coated adhesive backed reflective sheeting material meeting the minimum requirements of AASHTO M268 Type 1.

   c. The Label shall have the words "Distance to Conduit - - - Feet" pre-printed on the label. The distance numerals shall be added in the field and shall be manufactured from the same type of reflective sheetings. (See Plans for layout of label).

5.2.8 Pull Tape

The pull tape for cable installation shall meet the following requirements:

1) 1250 lb tensile strength

2) Flat, not round, construction

3) Printed sequential foot markings

4) Pre-lubricated for reduced pulling tension at start of cable pull

5.2.9 Low susceptibility to absorption of moisture; moisture resistant Duct Plugs

Duct plugs shall meet the following requirements:

1) Duct plugs intended for underground communications infrastructure shall be installed on conduits.

2) Duct plugs shall be sized to fit the conduits and cables with which they are used and shall be a split plug with a bushing assembly for sealing around the cable by mechanical compression.

3) Duct plugs shall provide watertight and airtight gasketed seals by use of mechanical expansion of the duct plug body and gasket. No sealants or caulks shall be used.

4) All metallic components of duct plugs shall be stainless steel.

5) Blank duct plugs are used to seal spare conduits and shall have inner rings to which pull tape can be tied.

5.3 Installation Requirements

5.3.1 General Requirements

1) All material installed shall follow the guidelines in the following sections.

2) Use blank duct plugs to seal the ends of all conduit immediately upon conduit placement. This includes but is not limited to intermediate/incomplete sections of conduit prior to conduit splicing or termination in pull boxes, and empty conduits in pull boxes prior to cable installation.

3) Conduit shall be installed in a straight line horizontal path between pull boxes except where shown otherwise in the plans.

5.3.2 Continuous Flexible Conduit (Conduit Duct Bank)

1) Install Conduit Duct Banks by configuring individual continuous flexible conduits into a continuous duct bank from termination point to termination point as shown in the Plans.

2) Continuous flexible conduit installation in earth shall be trenched, horizontal directional bored or drilled, or plowed at the Contractor's discretion, unless otherwise noted on the Plans, at a minimum depth of 24 inches from the top of the conduit. Unless identified as "bored" in the plans, the contractor shall be paid at the unit price bid for Conduit Bank (Type X), regardless of what installation method is used.

3) All continuous flexible conduit routes underneath asphalt or concrete roadways shall be horizontal directional bored or drilled at a minimum depth of 5 feet from the top of the conduit. No open trenching will be allowed in asphalt or concrete unless specified on Plan sheets. Separate encasement is not required for borings unless needed for proper installation due to poor soil conditions. All conduits underneath railroad tracks shall meet current specifications of the Railroad for boring under railroads. The contractor is required to attain and conform to the specifications of the Railroad for boring underneath a railroad. Any required steel casings or other materials needed to meet the railroad authority requirements shall be included in the cost of the conduit.

4) All conduit to be installed under streams shall be horizontal directional bored or drilled. No open trenching through an area deemed to be a current or wet weather stream will be allowed. All conduit bored under streams shall be a minimum depth of 5 feet below the streambed.

5) Bore logs will be required for each bore location. The Contractor shall submit a proposed bore log format to the Engineer for review and approval. Bore logs shall be turned over with as-built documentation at the conclusion of the project.

6) If a drainage or utility conflict arises, the Contractor shall submit a plan for resolving the conflict to the Engineer for review and approval.

7) Make every effort to minimize coupling. Couplings are permitted only with the Engineer's prior approval and will typically be approved where conduit types change or at locations where conduit reels end. Other locations will be on a case by case basis.

8) Conduit shall be placed in the straightest orientation possible, reducing bends, twists, rises, and waves. Conduits shall be held in place during backfilling when necessary to keep straight and at the proper depth. Where field conditions require the trench to change direction and bends are necessary, the bends shall be formed in the trench and should be smooth and even and shall not have less than a 4 foot radius (as measured to the inside surface of the conduit).

9) Test every conduit after the conduit is installed and before cable or pull tape is installed. Perform testing on all conduit types in this Technical Special Provision(TSP), including but not limited to each cell of multi-cell conduits, each conduit in a duct bank, and all other conduit installations. All testing shall be performed using the procedures and mandrel size recommended by the conduit manufacturer. Testing shall be performed in the presence of the Engineer. Payment for all testing is included in the cost of the conduit. Payment will not be made until all required pull tape has been installed and the installed conduit has been tested satisfactorily.

5.3.3 Rigid Galvanized Steel Conduit

1) Exposed conduit runs shall be 2 inch rigid galvanized steel unless otherwise required by the Plans.

2) All conduit runs on structures and poles shall be properly terminated into the respective device, or a weatherhead shall be installed so as to seal the conduit from moisture, insects, rodents and other foreign material. The costs of the galvanized steel conduit, weatherheads and all associated fittings shall be included in the cost of other items.

3) Bushings shall be installed in conduit at all exposed conduit terminations for protection of the conductors.

5.3.4 Marking Tape

1) As shown in the Plans Typical Details, install marking tape above all underground conduit installed by trenching or plowing.

2) Marking tape shall be installed in continuous manufactured lengths. No splicing or overlap is permitted.

3) Install a minimum of 4 feet of marking tape into pull boxes where trenched conduit is terminating. Marking tape shall enter under the lower edge of the pull box.

4) Marking tape is not required when conduit is bored.

5.3.5 Conduit Detection Wire

1) Install one (1) conduit detection wire with all conduits directly below or at the same level as the conduit. Conduit detection wire is required with all conduits installed by any installation method, including trenching, directional boring, or plowing.

2) Only one (1) conduit detection wire is required per installed conduit segment regardless of the number of conduits installed in that segment.

3) Conduit detection wire shall be installed outside of the conduit, except when boring conduit then the detection wire shall be placed in a spare conduit.

4) Conduit detection wire is not required for structure mounted conduit, except where underground segments of structure mounted conduit are greater than 20 feet in length.

5) Conduit detection wire is not required for conduit segments between pull boxes and pole/sign structure foundations, except where conduit segments are greater than 20 feet in length.

6) The conduit detection wire shall be continuous and unspliced between pull boxes and shall enter the pull boxes at the same location as the conduit with which it is installed.

7) Coil and secure 4 ft of conduit detection wire in each pull box or vault.

8) Testing:

   a. Perform a continuity or tone test after installation to confirm that a continuous run of conduit detection wire was installed between pull boxes or vaults.

   b. Submit a test plan at least fifteen (15) working days prior to the desired testing date. Testing shall not begin until the Engineer has approved the test plan, and all tests shall be conducted in the presence of the Engineer. Payment for installed conduit will not be made on a section of conduit until the detection wire has been tested satisfactorily.

5.3.6 Cable Markers

1) Install cable markers at the locations shown on the Plans.

2) All cable marker locations shall be approved by the Engineer prior to installation. The proposed schedule for installing the cable markers shall also be approved by the Engineer prior to installation.

3) After the cable markers are installed, the distance to conduit labels shall be applied.

5.3.7 Pull Tape

1) Install pull tape into each empty conduit and empty cell within a multi-cell conduit.

2) Install the pull tape after conduit testing has been completed.

3) Install and secure 5 feet of slacked pull tape in each empty conduit or cell at each pull box.

4) Secure the pull tape by tying it to the blank duct plug for the conduit in which it is installed.

5.3.8 Duct Plugs

1) Install blank duct plugs in each empty conduit that enters a pull box, ground-mounted cabinet, pole foundation, hub, or building entrance.

2) Install cable duct plugs in each conduit containing fiber optic or RDS communications cable that enters a pull box, ground-mounted cabinet, hub, or building entrance.

3) In lieu of cable duct plugs on conduits containing power service conductors, install duct seal around all conductors in pull box and cabinet conduit, so that the electrical conduit is sealed

5.3.9 Spare Conduits in Foundations

1) A minimum of one (1) 2 inch spare conduit shall be installed in all pole foundations and a minimum of two (2) 2 inch conduits shall be installed in the base of all ground mounted cabinets.

2) Spare conduits shall be sealed with blank duct plugs.

5.4 Measurement

5.4.1 General Requirements

1) All conduit material shall be measured following the guidelines in the following sections.

2) All conduit types shall be measured in linear feet per type to the nearest foot. All conduit types will measured along the conduit by the following:

   a. From center of pull box to center of pull box.

b. No additional measurement will be made for vertical conduit inside the pull box or structure.

c. No additional measurement will be made for conduit between a pull box and the nearby pole or structure.

5.4.2 Continuous Flexible Conduit (Conduit Duct Bank)

1) Unless otherwise specified in the Plans, all costs for materials, trenching, installing, backfilling trench, plowing, directional boring, restoration, marking tape, pull tape, duct plugs, fittings, conduit detection wire, testing, bore logs and other accessories and hardware necessary for installation of the conduit system shall be included in the overall cost of the conduit or conduit duct bank.

2) Continuous flexible conduit installation in earth shall be trenched, horizontal directional bored or drilled, or plowed at the Contractor's discretion, unless otherwise noted on the Plans.

3) All continuous flexible conduit routes underneath asphalt or concrete public roadways shall be horizontal directional bored or drilled at a minimum depth of 5 feet from the top of the conduit. No open trenching will be allowed in asphalt or concrete unless specified in the Plans.

4) All conduit to be installed under streams shall be horizontal directional bored or drilled. No open trenching through an area deemed to be a current or wet weather stream will be allowed.

5) Continuous Flexible Conduit (Conduit Duct Bank) will be measured by the linear foot for each type of conduit bank indicated after installation, as well as the type and number of conduit indicated below.

   a. Conduit Bank Type 1: One (1) 1 ¼" Continuous Flexible Conduit

   b. Conduit Bank Type 2 : Two (2) 1 ¼" Continuous Flexible Conduit

   c. 2" Conduit: One (1) 2" PVC Schedule 40 Conduit

   d. Conduit Bank Type 1 Bored: One (1) 1 ¼" Continuous Flexible Conduit

   e. Conduit Bank Type 2 Bored: Two (2) 1 ¼" Continuous Flexible Conduit

   f. 2" Conduit Bored: One (1) 2" PVC Schedule 80 Conduit

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

5.4.3 Rigid Galvanized Steel Conduit

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

5.4.4 PVC Schedule 40 Conduit

1) PVC Conduit will be measured by the linear foot.

5.4.5 Marking Tape

1) Marking Tape is included in the cost of the conduit and will not be measured separately.

5.4.6 Conduit Detection Wire

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

5.4.7 Cable Markers

1) Cable Markers will be measured per each and paid for at the contract price per each. The price bid shall include furnishing and installing the complete cable marker and distance sticker/label. This price shall be full compensation for all labor, tools, materials, equipment and incidentals necessary to complete the work.

5.4.8 Pull Tape

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

5.4.9 Duct Plugs

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

5.5 Payment

The contract unit price shall be full compensation for all work specified in this Section.

Payment will be made under:

Item No.	Description	Unit
725-22.21	Conduit Bank (Type 1)	LF
725-22.22	Conduit Bank (Type 2)	LF
730-12.02	Conduit 2” Diameter (PVC)	LF
725-22.61	Structure Conduit Bank (Type 1)	LF
725-22.31	Conduit Bank Bored (Type 1)	LF
725-22.32	Conduit Bank Bored (Type 2)	LF
730-12.13	Conduit 2” Diameter (Jack and Bored)	LF
725-03.60	Cable Marker	EACH

1) All Conduit will be paid per linear foot, as applicable, as follows:
    a. Stored Materials will be paid per TDOT Standard Specifications.
    b. Final Payment will be made after complete installation and testing.
2) Cable Markers will be paid per each, as applicable, as follows:
    a. Stored Materials will be paid per TDOT Standard Specifications.
    b. Final Payment will be made after complete installation and testing of the conduits.

SECTION 6

TRAFFIC OPERATIONS CENTER

6.1 Description

The City of Hendersonville (City) is constructing a Traffic Operations Center (TOC) in the Hendersonville City Hall located at 101 Maple Dr. N., Hendersonville, TN 37075. This section specifies the minimum requirements for a TOC furnished and installed on this project as shown in the plans.

6.2 Materials

6.2.1 Fiber Optic Termination Cabinet (FO Termination Cabinet)

1) Provide fiber optic termination cabinets in communications hubs and the Traffic Operation Center (TOC) as shown in the Plans for termination of seventy-two (72) fibers outside plant (OSP) cable. Fiber Optic Termination Cabinets as outlined in this TSP are also known as Fiber Distribution Centers or Modules.

2) Use termination cabinets that are fully compatible with all components of the fiber optic infrastructure as specified, including but not limited to fiber optic cable, fiber optic fusion splices, and fiber optic connectors.

3) Use rack-mount termination cabinets designed to fit standard 19-inch EIA equipment racks.

4) Provide all mounting hardware and supports to mount the termination cabinets in the locations shown in the Plans.

5) Use fiber optic termination cabinets providing 72 fiber connectors and capable of storing 72 fusion splices in splice trays.

6) Use termination cabinets that integrate the splice trays and connector modules into one (1) compartment within one (1) cabinet, or houses the splice trays and connector modules in separate compartments integrated into one cabinet.

7) Maximum dimensions of a complete termination cabinet shall be seven (7) rack units high (12.25 inches) by 16 inches deep.

8) Use fiber optic termination cabinets with fully enclosed metallic construction and with a protective hinged front cover for the connector ports.

9) Provide cable access on all sides of the enclosed area behind the connector port panel.

10) Provide sufficient splice trays for storing 72 fusion splices in 12 or 24 splice increments.

11) Provide termination cabinets with fiber optic connector modules in a 12 fiber configuration of six (6) rows of one (1) duplex connector couplers.

12) Connector modules shall mount vertically or horizontally in the termination cabinet front panel.

13) Connector modules shall include clearly legible and permanent labeling of each of the 12 fiber connector couplers, and shall be labeled and identified as shown in the Plans.

14) Provide factory-assembled 12 fiber termination interconnect cables (pigtail cables) to be fusion spliced to the outside plant cable and connected to the rear of the connector modules.

    a. Termination interconnect cables shall be all-dielectric single jacketed cable with high tensile strength yarn surrounding 12 individual 900 micron fibers following EIA/TIA-598B color identification with factory-installed connectors.

15) Provide all incidental and ancillary materials including but not limited to grommets, cable strain relief and routing hardware, blank connector panels, and labeling materials.

6.2.2 Network Switch (Type C)

See Section 3 of this TSP for specifications on Network Switch. This item is to be included in the cost of the TOC and shall not be paid for under another pay item.

6.2.3 Battery Backup

The Contractor shall provide a required battery backup and power conditioner (also referred to as uninterruptible power supply or UPS unit as per the guidelines stated in this Technical Special Provision (TSP). The UPS shall be a single rack mounted unit with batteries included in the UPS itself and shall be installed in the TOC. The contractor shall be responsible for conducting a performance design study and for designing the UPS that is shown on the Plans. The contractor shall submit all design calculations for the UPS unit to the Engineer for approval. The UPS shall be able to optimally operate the ITS devices it is intended for and maintain full site operation for the minimum time recommended by the software vendor.

1) Operation

   a. The UPS shall be capable of producing – simultaneously – fully regenerated and regulated, conditioned and pure sine wave power with continuous and hot standby AC output capability.

   b. The UPS inverter shall be on at all times to produce continuous, clean, regulated power to all loads. The inverter shall have a minimum operating efficiency of 92%. The continuous power output shall be provided for all equipment at the site up to the maximum load rating; also, a programmable digital delay timer shall be included for short-term battery run under full cycling operation.

   c. Upon loss of utility power the UPS shall utilize battery power in support of the system via a supplied Power Interface Module (PIM). In the normal operation, the UPS shall be operated in the real-time true on-line mode with the inverter supplying power to all cabinet loads, at all times. In addition, the UPS can be operated in hot standby mode with power transfer being accomplished in 100 msec or less. In the event of UPS failure and/or battery depletion, the PIM will ensure that the UPS will drop out and, upon return of utility power; the system will default to normal operating mode.

   d. The Power Interface Module shall enable removal and replacement of the UPS without shutting down the system (i.e. “hot swap” capability). Connectors shall be equipped with a “safety interlock” feature.

e. The UPS shall be capable of providing continuous, fully conditioned, regulated, pure sinusoidal (AC) power to all connected devices such as modems, switches, lights, communications hubs, NTCIP adapters and video equipment at all times.

f. The UPS shall be NTCIP capable with optional standard adapter.

g. The UPS shall contain two external serial ports located on the front panel of the UPS. The signal serial port shall provide the user the option to select alarm output functions. These functions shall be open collector type contact closures that the user can assign as signal utility interrupt, low battery and inverter active conditions or utility fail indicate. The RS232 Signal port provides an intelligent interface for connection to software systems for monitoring and control, including internet connections.

h. The UPS shall be fully power factor corrected under all operating conditions.

i. Each UPS shall be provided with a media containing Windows based configuration software.

2) Mounting/Configuration shall be of Universal Design.

a. Mounting method shall be 19” rack-mount.

3) Power Interface Module (PIM)

a. A PIM shall be required to safely insert utility power into the UPS system

b. The PIM shall contain a terminal strip for input and output power connections in addition to neutral and ground connections. In addition, the terminal strip shall also include open collector (relay type) connections for: on battery, low battery and digital flash timer.

c. The signal serial port on the PIM can be used to send open collector type contact closures that the user can assign as signal utility interrupt, low battery and inverter active conditions to the signal controller auxiliary alarm inputs.

4) Battery System

a. The batteries shall be internal batteries to the UPS that are included in the purchase of the UPS.

5) Electrical Specifications

   a. Nominal Input Voltage 120 VAC, Single Phase

   b. DC Battery Buss 36VDC

   c. Input Voltage Range 85 VAC to 140 VAC

   d. Input Frequency 60 Hz (+/-5%)

   e. Input Current (Max. draw) 10.4 amps

   f. Input Protection Input Fuse (15 amps)

   g. Nominal Output Voltage 120 VAC, Single Phase

   h. Power Rating 1.5KVA/1000W

   i. Output Voltage Regulation +/-5% in battery mode

   j. Output Frequency 60 Hz (+/-5%)

   k. Eight (8) 5-15R outlets

   l. Output Wave Form Pure sine wave

   m. Automatic shutdown

   n. Short circuit protection Current limit and automatic shutdown

   o. Efficiency 92% at full load

   p. Load Power Factor 0.7 lagging through unity to 0.7 leading

6) Physical Specifications, UPS Electronics Module shall be no greater than:

   a. Rack-mount: Width = 19”, Depth = 13”, Height = 3.5” (2U)

7) Environmental Specification

   a. The UPS system, including batteries, shall meet or exceed NEMA temperature standards from -40° C to +74° C (-40ºF to +165ºF).

   b. The UPS system, including batteries, shall be certified and field proven to meet or exceed NEMA temperature standards. A certificate of compliance, from an independent testing facility, shall be made available upon request.

8) Serviceability & Maintainability

a. MTTR (Mean-Time-To-Replace or Repair)

Electronics: Fifteen (15) minutes or less

Battery System: Fifteen (15) minutes or less

6.2.4 Workstation Computer

This project calls for furnishing and installing one (1) computer workstation in the TOC for operations of the system. The minimum requirements for the workstation computer are as follows:

1) Most current computer operating system (Windows, OS X, etc.) (32 Bit)

2) Computer central processing unit (CPU) at 3.20 GHz or better

3) 4GB RAM

4) 250GB of free hard drive space

5) Computer workstation shall be a laptop with docking station, dual monitors, keyboard and mouse.

Specification sheets are to be provided by the Contractor to the Engineer for approval before purchase and installation of equipment.

6.2.5 Environmental

The City of Hendersonville is to provide HVAC to the TOC room to provide for the server and equipment mounted in the server racks to operate within the manufacturer recommended temperature range.

6.2.6 Network Server

This project calls for furnishing and installing a Network Server in the TOC for operations of the system. All mounting hardware and the 19" standard racks to mount the Network Server and any subsequent equipment are to be provided by the Contractor and are to conform to the manufacturer's recommendations for rack mounting and hardware for those devices. The minimum requirements for the Network Server are as follows:

1) Most current operating system that is compatible with the workstation computer (32 Bit)

2) Computer central processing unit (CPU) at 3.20 GHz or better

3) 4GB RAM

4) 250GB of free hard drive space.

Specification sheets are to be provided by the Contractor to the Engineer for approval before purchase and installation of equipment.

6.3 Installation requirements

6.3.1 Fiber Termination Cabinet

This Fiber Termination Cabinet is to be installed and tested in the TOC as per the specifications for installment stated in section 4 of this TSP. This item is to be approved by the Engineer before installation.

6.3.2 Network Switch (Type C)

The Network Switch is to be installed and tested in the TOC as per the specifications for installment stated in section 3 of this TSP.

6.3.3 Battery Backup

The Contractor shall be responsible for all testing and documentation required for establishing approval and acceptance of the product. As a minimum, the following tests shall be conducted:

1) Perform field tests with various ITS devices as noted in design plans to verify that each device operates optimally

2) Verify Output (Amp- Hours)

3) Verify Daily load requirement (Amp-Hours)

4) Verify Loss of Load Probability (LOLP) of the designed power supply

5) Verify the Battery Reserve Days

6) Verify the Average Battery State of Charge

7) Verify the statistical Interval to Loss of Load

The battery backup unit shall be mounted in the 19” standard rack in the TOC.

6.3.4 Workstation Computer

The workstation computer is to be installed as per the manufacturer's recommendations and shall be connected into the monitoring system as the plans specify. Location and wiring shall be approved by the Engineer prior to installation.

Specification sheets are to be provided by the Contractor to the Engineer for approval before purchase and installation of equipment.

6.3.5 Environmental

The City of Hendersonville will provide HVAC to meet the requirements of the TOC room.

6.3.6 Network Server

The Network Server is to be installed by the Contractor per the manufacturer's recommendations and specifications in server racks that are to be provided, furnished, and installed by the Contractor. The server is to be installed and connected to the monitoring system as shown in the Plans. The location of the server rack and server is to be approved by the Engineer prior to installation.

Specification sheets are to be provided by the Contractor to the Engineer for approval before purchase and installation of equipment.

6.3.7 Server Rack Enclosure

The Server Rack Enclosure shall be a standard 19" rack and shall be large enough to accommodate all equipment that is to be mounted in this rack per the specifications in this section of this TSP.

6.3.8 Management Software

The traffic management software to be used on this project shall be compatible with the operating system of the central computer system that will be installed in the City's TOC, and the software will be compatible with all traffic signal controllers installed or purchased for this project. The software shall be installed as per the manufacturer's recommendations. A video card shall be installed to aid in the operation of the map. It shall meet the needs of the system and shall be approved by the Engineer prior to purchase and installation.

6.3.8.1 Software Requirements

The computer system and traffic management software shall be capable of:

1) storing a minimum of 15 signal timing plans per traffic signal within the system and maintenance records for all interconnected signals. Maintenance records shall include date and time of original service call, description of failure or requested preventive maintenance, date and time of service, disposition of maintenance activity, and comments for future consideration. (Order parts, repair communication cable, perform pest control, etc.)

2) utilizing existing City traffic detectors.

3) being accessed via the internet and by laptop from any location by the City's designated Public Work's staff. Log-in credentials shall be secure with password protection or acceptable biometric identifiers and shall include an administrative layer that conforms to the City's computer security policy. The software shall provide a security feature that logs the date, time, username, and user ID for every log in and log off. The System Administrator shall be able to access all functions within the system.

4) allowing the operator to select the appropriate timing plan, depending on the measured traffic conditions or according to a TOD schedule.

5) allowing the operator to define for each group of intersections the appropriate timing plan.

6) allowing the Traffic Signal System to change its operation according to the pre-defined daily/weekly schedule.

7) allowing the operator to decide if a phase is to be skipped, either through direct operator action or by the daily/weekly schedule.

8) operating an isolated intersection within a group or independently, depending on direct operator action or by the daily/weekly schedule

9) allowing system signals to be dropped completely from system control to operate freely, but to continue being monitored by the system.

10) allowing small groups of intersections, which the operator defines as being critical, to be operated in a synchronized fashion using double the cycle length in the parent grouping, or half the cycle length in the parent grouping.

11) a fallback state that allows individual intersections to operate in a TOD, coordinated mode in the event of failures of the system software or hardware, detectors or communication. System communications shall be used to facilitate this fallback operation.

12) allowing a coordinated group to be able to include more than one coordinated route, such as two crossing arterials. The system will be able to maintain coordination along both roads.

13) allowing all field system devices to be connected to the Traffic Signal System server which can be remotely accessed from workstations within the City's computer network. System operators, traffic engineering, and maintenance staff will be assigned different levels of authority and be granted access to equipment for which they are authorized, based on their roles and responsibilities.

14) using the following complex coordination and controller features:

    a. the ability to repeat a phase per cycle
    b. the ability to operate different phase sequences based on different traffic conditions or by the daily/weekly schedule
    c. the ability to omit a phase under some traffic conditions or based on external input to allow a shorter cycle length to operate, or to provide additional time to other phases
    d. the ability to coordinate using the beginning of main street yellow or the beginning of main street green

15) adding future traffic signals and ITS devices to its system network, and that functionality be available to accommodate video cameras and variable message signs.

16) adhering to the Nashville Area Regional ITS Architecture to achieve the goal of inter-agency communication and operations.

17) monitoring and controlling a minimum of 100 traffic signals.

18) monitoring and controlling a minimum of 50 future ITS devices, which may be variable message signs, weather monitoring stations, traffic counting stations, CCTVs providing live video feeds, or other ITS devices.

19) allowing the operator to control the intersections in groups that are defined by the operator. A group of intersections may be comprised of simply one traffic signal, but may include many more signals. Signal grouping shall be defined by the operator and shall have the capability to be changed manually, by day of week, or by time of day/week.

20) providing a means for the City's workstation to update Individual controllers with new timing plan information.

21) loading plans developed by signal timing software packages into the system by file transfer.

22) downloading any controller's timing information, including all timing plans, and controller settings such as minimum green, extension/passage, yellow, all red, maximum green, and pedestrian timings.

23) providing for multiple ways to change cycle length, and should accomplish transitions between timing plans within three cycle lengths.

24) communicating with field devices over any combination of single-mode fiber optic cable, wireless radios, cellular telephone modems, or third party communication line connections.

25) supporting IP-addressable communications and shall communicate with field devices using National Transportation Communications for ITS Protocol (NTCIP) protocols.

26) providing a graphical user interface to allow real-time monitoring of signalized intersections located within the City's traffic signal system.

27) supporting populating the database through uploads from other computers connected to the City's communication network.

28) accessing online help for the user.

29) saving reports and signal timings (cycle, offsets, splits, etc.) to a file in standard word processing and spreadsheet formats for development of signal timing plans.

30) interfacing with Synchro signal timing software.

31) providing all necessary utilities for producing local intersection and systems graphics. All graphic displays shall be in color.

32) allowing users of the software the ability to change signal timing plans from the TOC and anywhere else via the internet.

33) creating a call ticket to the City's signal system manager(s) via e-mail and mobile phone text message for any signal hardware failures such as signal bulb burn-outs and failed detector loops.

34) creating a routine maintenance notice via e-mail on a semi-annual basis to perform preventive maintenance on traffic signals for each corridor in the City's traffic signal system.

35) tracking all maintenance calls and routine maintenance performed within the City's signal system.

36) keeping records of changes to timing plans, controller settings, and maintenance calls for a period of at least five years before archiving. The software shall keep records of maintenance activities by date and time, including changes to signal timings.

6.3.8.2 Mapping System

The mapping system will be run using GIS mapping. The Contractor will provide a broad signal system map display as well as individual intersection displays that match the real time events happening at each of these intersections. A list of intersections will be provided to the Contractor upon request to the City for an intersection list. Information such as traffic signal states, detector states,

pedestrian states, and up to six (6) “alarms” (to be defined by the City) shall be transmitted back to the TOC via the Ethernet system to be viewed in real time on the map featured in the traffic management software.

6.3.8.3 Video Card

A video card shall be installed to aid in the operation of the map. It shall meet the needs of the system and shall be approved by the Engineer prior to purchase and installation.

6.3.8.4 Maintenance

Maintenance and technical support of the traffic management software shall be included in the price bid for the project for the first year following the date of acceptance of the project. After one (1) year from the date of acceptance, software and support fees will become the responsibility of the City. (Should the City choose not to pay the maintenance fees, then the City will no longer receive software and firmware updates.)

6.3.8.5 Warranty

The TOC equipment shall be warranted to be free of manufacturer defects in materials and workmanship for a period of five (5) years from the date of Final Acceptance. Equipment covered by the manufacturer’s warranties shall have the registration of that component placed in the City’s name prior to Final Inspection. The Contractor is responsible for ensuring that the vendors and/or manufacturers supplying the components and providing the equipment warranties recognize the City as the original purchaser and owner/end user of the components from new. During the warranty period, the supplier shall repair or replace with new or refurbished material, at no additional cost to the City, any product containing a warranty defect, provided the product is returned postage-paid by the City to the supplier's factory or authorized warranty site. Products repaired or replaced under warranty by the supplier shall be returned prepaid by the supplier.

During the warranty period, technical support shall be available from the supplier via telephone within four (4) hours of the time a call is made by the City, and this support shall be available from factory certified personnel. During the warranty period, updates and corrections to control unit software shall be made available to the City by the supplier at no additional cost.

6.4 Testing Requirements

1) All test results shall confirm physical and performance compliance with this TSP. The Engineer is to field verify that all equipment is in the location that the Engineer approved for installation and all wiring is wired in such a way as to not be a hazard or safety issue as approved by the Engineer.

2) All equipment in the TOC shall be tested and approved by the Engineer. The Contractor shall provide testing documents to the Engineer no later than fourteen (14) days after the test to be reviewed by the Engineer for all devices installed in the TOC.

3) The Contractor shall submit documentation and proof of manufacturer-recommended training and certification for the installation and configuration of any equipment to be installed in the TOC.

6.5 Training and Integration

6.5.1 Training

Unless otherwise specified in the specific ITS device sections, prior to Conditional System Acceptance, the Contractor shall provide two (2) non-consecutive four (4) hours training sessions to describe the configuration and operation of all electronic equipment and ITS devices, including network switches, wireless communications equipment, electrical services, fiber optic cable network, and TOC equipment. The Contractor shall contact the City to verify the devices to be trained on and the content of the training sessions.

The training shall be provided at a location provided by the City for at least six (6) personnel with individual copies of all training materials and manuals provided to each participant. The Contractor shall also provide this information in electronic form. The training must include a complete demonstration of the configuration, operation and capabilities of each component in the system. The training should also consist of a hands-on demonstration of all software configuration and functionality where applicable.

The training sessions shall include a mixture of classroom style training in equipment operation, hands-on operator training, and question and answer sessions. The Contractor shall submit the trainers' qualifications to the Engineer for approval prior to scheduling the training. The qualifications of the trainers must meet, at a minimum, the recommended qualifications of the equipment manufacturer. If qualified and certified personnel are not on the Contractor's staff, a representative of the manufacturer shall provide the training.

The Contractor shall submit to the Engineer for approval a detailed training plan, training session outline, including course agendas, detailed description of functions to be demonstrated and a proposed schedule. The training plan and training session outline must be submitted not less than sixty (60) days prior to the proposed schedule. If the documents are not approved thirty (30) days prior to the scheduled training the schedule shall be adjusted.

Upon notification of the City during the burn-in period, the Contractor shall also provide a one (1) day training session on the maintenance of the overall system. This is separate from the above training requirement, and is specific to the maintenance of the devices and the system. The requirement for a training plan and training session outline of the maintenance session are the same as stated above. The training shall be provided for at least six (6) personnel with individual copies of all training materials provided to each participant. The training must include both classroom style training and hands-on training in the field of the maintenance and troubleshooting procedures required for each component.

All Training shall be recorded and provided to the Engineer on Media approved by the Engineer.

6.5.2 Integration

As part of, and prior to performing the Conditional System Acceptance Testing, all devices shall be fully integrated into the TOC central software applications and database. While the Contractor can test device connectivity from the TOC with manufacturer software in order to verify communications of those devices over the fiber optic network, the integration effort shall employ specific coordination between Central Software Developers and the Contractor. The Contractor shall contact the Central Software Developers for integration of the devices into their respective software at the TOC, or the Contractor shall be fully certified in that software application in order to integrate and add the devices to that software, as approved by the Central Software Developers. Contact shall be made with the Central Software Developers a minimum of sixty (60) days prior to needing their assistance onsite, as necessary and as required. The Contractor may also ask for their integration assistance remotely, as approved by the Engineer. If problems or issues arise that cannot be handled remotely, the Central Software Developer shall be required to be onsite to address such issues. The Contractor shall coordinate all integration activities with the TOC operations personnel, prior to commencement of the TOC integration. This item is to be paid for under system integration and shall include providing all integration necessary to provide a completely operational system to the Engineer’s satisfaction.

6.6 Measurement

The Traffic Operations Center (TOC) will be measured in units of each and paid for at the contract price Lump Sum. The price bid shall include furnishing, installing, configuration, integration and testing of all equipment listed in this section of this TSP to accomplish a complete and operational TOC including all chassis, modules, power cables, power supplies, software, license, fiber termination cabinets, fiber optic patch cords, fiber optic attenuator patch cords, Network Switches, Network Server, battery backup, Cat 6 patch cords, workstation Computer, media converters (if needed), and all incidental components, attachment hardware, mounting shelf and hardware, testing and training requirements, and all work, equipment and appurtenances as required to provide a fully functional switch ready TOC for use. The price bid shall also include all configuration and control software, system documentation including: shop drawings, operations and maintenance manuals, wiring diagrams, block diagrams, and other material necessary to document the operation of the switch and network. This price shall be full compensation for all labor, tools, materials, equipment and incidentals necessary to complete the work.

6.7 Payment

Item No.	Description	Unit
730-30.01	Traffic Operations Center Computer System	Lump Sum
725-24.51	Traffic Operations Center System Integration	Lump Sum
725-24.61	Traffic Operations Center Training	Lump Sum

1) All TOC equipment described in this section of this TSP will be paid as follows:

   a. Stored Materials will be paid per TDOT Standard Specifications.

   b. Final Payment will be made after complete installation and testing.

2) System integration will be paid for in full after completion and testing to the satisfaction of the Engineer.

3) Training shall be paid in full after the class has been held and completed.

SECTION 7

TRAFFIC ACTUATED CONTROLLERS

7.1 Traffic Actuated Controllers

The traffic controllers for this project shall be eight-phase actuated, and these controllers shall meet or exceed the current NEMA Traffic Signal Systems Standard. Standard A, B, C, and D Connectors are to be provided as well as built in 10 Base-T Ethernet with a minimum of 4 RJ-45 connectors. The Controllers shall support NTCIP communications protocol as defined in NEMA Standards Publication TS 2-2003 (R2008) or most current NEMA Standard. The vendor shall submit private laboratory certification that the proposed unit is in complete compliance with the NEMA standards in effect at the time of the advertisement for bids. The controller shall have all timing values entered via a front panel mounted keyboard. This keyboard shall be an integral part of the controller unit. Each controller shall have all operating timing parameters as specified in NEMA on a per phase basis, including all Volume/Density features. Each phase shall have a defeatable Last Car Passage feature wherein the last vehicle receiving the Phase Green shall receive at least one second. The controller shall have all of the following keyboard entered values or parameters:

1) Start on condition of the controller where the user can select via the keyboard the following:
    a. Phases to start in.
    b. Phase display to be on.
    c. Overlap display start-on condition.
    d. Normal start-up display shall be main street green phase(s), with concurrent overlaps green.
2) Phase recall functions.
    a. Non-lock detector.
    b. Lock detector Call.
    c. Minimum recall.
    d. Maximum recall.
    e. Pedestrian recall.

f. Non-actuated phase.

g. Phase not active, phase omitted.

h. Pedestrian phase omitted.

3) All phase interval timing values except the Phase Yellow Clearance shall be as per NEMA. Each controller phase Yellow Clearance Interval is 3.0 seconds as a minimum. The controller shall have a back-lit liquid crystal display for each ring of the controller to provide an English language menu for programming with displays for programming or reading all controller features. The dynamic displays for real-time operation shall be able to display the following values for each ring or phase(s) concurrently:

a. Per Phase Display:

i. Phase Vehicle Call.

ii. Phase Pedestrian Call.

iii. Phase is Next in Service.

iv. Phase is In Service.

v. Phase Pedestrian Intervals in Service.

b. Per Ring Display:

i. Ring Gapped Out.

ii. Ring Maximum Green Termination.

iii. Ring was Force Off Terminated.

iv. Ring Maximum Green II in effect.

v. Ring Phase in Service Operating:

- Lock Call.
- Non-Lock Call.
- Minimum Recall.
- Maximum Recall.
- Pedestrian Recall.
- Non-Actuated Mode.

c. Per Ring Display of Timing Values (Real Time). The following values shall be select displayed and shall display the current value in a real time mode.

i. Minimum Green Interval.

ii. Passage Timer.

iii. Pedestrian Interval Timing.

iv. Maximum Green Timer.

v. Time Before Reduction Timer.

vi. Time to Reduce Timer.

It shall be possible to inspect and alter any currently programmed value while the controller is in operation without affecting the field operation. The controller shall continue to operate the intersection as values are inspected or altered. All operator entered data shall be stored in EEPROM devices which require no battery to support value storage. No internal components of circuitry shall require battery support. The timer shall have a front-panel mounted RS-232 connector to allow the user to print a hard copy of all programmed data to a standard serial printer. The printer shall use a standard RS-232 connecting cable. The printer shall be supplied by others.

7.2 Installation Requirements

7.2.1 Traffic Actuated Controller

All traffic controllers are to be installed to the satisfaction of the Engineer and shall be installed per manufacturer's recommendations. There will be eight (8) controllers that will not be installed under this contract but will be purchased under this contract and

delivered to the City of Hendersonville (two (2) spare controllers and six (6) are to be provided to the Contractor of the SR 258 [New Shackle Island Rd.] Construction job).

7.2.2 Cabinet Modifications

All modifications needed to be made to the cabinet to ensure proper function of the controller in conjunction with all equipment shall be approved by the Engineer and all specifications and codes are to be followed to ensure a proper and safe installation. These modifications are to include any back panel modifications or cabinet wiring that is needed to be done in order for these controllers to be complete and functional in these cabinets.

7.2.3 Warranty

The traffic controllers shall be warranted to be free of manufacturer defects in materials and workmanship for a period of one (1) year from the date of Final Acceptance. Equipment covered by the manufacturer's warranties shall have the registration of that component placed in the City's name prior to Final Inspection. The Contractor is responsible for ensuring that the vendors and/or manufacturers supplying the components and providing the equipment warranties recognize the City as the original purchaser and owner/end user of the components from new. During the warranty period, the supplier shall repair or replace with new or refurbished material, at no additional cost to the City, any product containing a warranty defect, provided the product is returned postage-paid by the City to the supplier's factory or authorized warranty site. Products repaired or replaced under warranty by the supplier shall be returned prepaid by the supplier.

During the warranty period, technical support shall be available from the supplier via telephone within four (4) hours of the time a call is made by the City, and this support shall be available from factory certified personnel. During the warranty period, updates and corrections to control unit software shall be made available to the City by the supplier at no additional cost.

7.3 Measurement

7.3.1 Traffic Actuated Controller

Controllers will be measured in units of each and paid for at the contract price per each. The price bid shall include furnishing and installing (with the exception of the installation cost for the eight (8) controllers being delivered to the City) the Controllers, and all related material and equipment, to include controller configuration, signal timings, and any modifications to the back panel or cabinet wiring, specified in the Plans and this Technical Special Provision (TSP), and all labor, system integration, testing, system

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

7.4 Payment

The contract unit price shall be full compensation for all work specified in this Section.

Payment will be made under:

Item No.	Description	Unit
730-16.02	Eight Phase Actuated Controller	EACH

Controller will be paid per each as follows:

1) 40% of the contract unit price for delivery of the Controllers.

2) Additional 40% of the contract unit price for complete installation of Controller and all modifications necessary.

3) Additional 10% of the contract unit price for completion of Stand Alone Site Test.

4) Final 10% of the contract unit price upon Final System Acceptance.

SECTION 8

CABINET MODIFICATION

8.1 Description

Cabinet modification is to include all necessary modifications to the existing traffic cabinets to provide a completely operational cabinet system with the proposed devices stated in this Technical Special Provision (TSP) and on the Plans. All incidental parts which are not shown on the Plans or specified in this TSP and which are necessary to complete the cabinet modifications shall be furnished and installed as though such parts were shown on the Plans or specified in this TSP. The work performed shall be complete and shall operate to the satisfaction of the Engineer at the time of completion. This work shall also include furnishing and installation of outlet power strips where required, door switches where required, and any fiber/conduit entrances into the existing cabinets. All work pertaining to fiber entrances into an existing cabinet shall be done to TDOT standard specifications.

8.2 Method of Measurement

ITS Equipment Cabinet modifications, complete in place, tested, and accepted, will be measured per each installation. Such measurement shall be inclusive of all materials, mounting hardware, fiber splicing necessary for each cabinet being modified to provide a completely operational cabinet system.

8.3 Payment

Equipment Cabinet Modifications, measured as prescribed above, will be paid for at the contract unit price per each, which shall be full compensation for the labor, tools, materials, equipment and incidentals necessary to complete the work.

Payment will be made under:

Item Number	Description	Unit
730-15.11	MODIFY CABINET (INSTALL ALT. ENTRANCE)	EACH

1) 60% of the contract unit price will be paid for completed modification to include all modifications necessary to provide a completely operational cabinet system and testing to the satisfaction of the Engineer.

2) An additional 30% of the contract unit price will be paid for completion of the Stand Alone Site Test of all field devices housed or connected to the equipment cabinet.

3) The final 10% of the contract unit price will be paid upon Final System Acceptance.

SECTION 9

TESTING AND VERIFICATION

9.1 SYSTEM TESTING PROCESS

All systems, components, installation, and any associated workmanship or materials are required to be reviewed, tested, and accepted by factory authorized representatives prior to turnover to the City.

Acceptance Testing shall be divided into four distinct phases as follows:

1) Individual Device Testing
2) Individual Subsystem Testing
3) System Integration Testing
4) System Acceptance Testing verified in each testing phase.

The Contractor shall prepare and submit a Comprehensive Acceptance Test Plan that describes all the activities and tasks associated with testing. At a minimum, the Comprehensive Acceptance Test Plan shall contain the following elements:

1) Summary of each test phase
2) A schedule for the accomplishment of each test and identification of the interim milestones
3) Identification of all components, including the number and type of field devices, to be used during the test
4) Schematic drawings showing interconnection and types of equipment employed
5) A description of the hardware and software involved and/or required for the test
6) A description of the purpose and goal of each test case and the method of testing
7) A full step-by-step description of the tests performed including test conditions at the start and end of each test, expected test results with Pass/Fail criteria, and actual test results
8) A description of the conditions that shall exist at the start of the test, the action and or function to be tested, and the conditions/results expected to exist at the conclusion of the test

9) A description of the reports, database listings, statistical analyses, tables, charts, etc. to be used to document the test results
10) A description of the procedures to be used to control and resolve all failures encountered during the performance of each test
11) A plan and schedule to conduct the next iteration of the test phase or a statement that the phase was completed successfully
12) Each test procedure shall include a sheet for sign off and date by both the person performing the test and the test witness. Space for tester and witness comments shall also be included
13) System acceptance criteria

9.2 SYSTEM TESTING PROCEDURES

The City of Hendersonville will be responsible for monitoring and certifying all system testing. The Contractor shall provide notice of system testing to the City and TDOT at least 30 calendar days prior to beginning any test.

The Contractor shall prepare comprehensive written test procedures and submit to the City at least seven calendar days prior to each stage of testing. These procedures shall clearly describe what actions are to be taken, what attributes are being tested, which system requirements are being verified, and what responses shall be received in order to pass the test. Procedures shall be sufficiently thorough to test all devices, subsystems, or integrated system attributes.

Vendor representatives shall be present during all testing in order to provide guidance and assistance to the City and the Contractor. All testing shall be held in the presence of a City representative unless otherwise authorized in advance, in writing.

For each test, the Contractor will document the test procedures and the test results. Any failure or lack of performance to meet the stated system requirements shall be immediately recorded and the Contractor shall prepare a report stating the cause of failure and a solution to resolve the deficiency. The report shall be submitted to the City within 7 days of the failure. The Vendor shall coordinate with the Contractor to correct and retest items where deficiencies were noted. The testing procedure will be repeated until all the deficiencies are corrected, at which time the Contractor and the City will approve the test report. Copies of all testing will be forwarded to TDOT upon request.

Upon completion of all required verification testing, the Contractor shall prepare a final Verification Report which will contain all critical information regarding testing conducted including both failures and successes. Resolution of the cause of failures shall also be

detailed. A list of all hardware, software and special equipment utilized in the testing shall be provided.

9.2.1 Individual Device Testing

This testing is conducted to demonstrate that the individual devices at each location are fully operational. The purpose is to verify that each individual field device can function as specified without damage during shipment and that the device has been properly installed.

The individual devices to be tested shall include, but not limited to:

1) Wiring and Cabling (Wiring and cable testing shall be performed as specified in TDOT Standard Specification for Road and Bridge Construction Section 701.03.15.D, before performing any other system testing. The results of the testing shall be recorded on standard forms within 5 days of completing the testing, and submitted to the City for approval.)
2) Traffic Controllers
3) Communication Devices (Ethernet Switch, Wireless Communication Antenna and Transceiver, etc.)
4) Servers and Workstations

9.2.2 Individual Subsystem Testing

This testing shall be conducted only after all device testing has been completed. Each subsystem shall be tested individually in its operational configuration, demonstrating complete compliance with all subsystem components between and including the operations center and the field elements.

Typical subsystems to be tested include:

1) Communication Subsystem: Demonstrate that communications are operational at each location
2) Signal Control Subsystem: Demonstrate that the system software is fully capable of controlling each traffic signal controller, manually and through timing plan changes.

The Contractor may divide the Individual System Testing into multiple submittals, one for each subsystem as they are being installed and commissioned.

Conditional Acceptance may be granted after successful completion of all subsystem testing.

9.2.3 System Integration Testing

The System Integration Test includes all components in the signal system and demonstrates that the system is totally functional as a complete system and capable of altering traffic signal timings through manual commands or a schedule.

It may be necessary to simulate varying levels of traffic demand in order to complete System Verification testing. Documentation that thoroughly describes the devices or software used to simulate traffic volumes shall be submitted to the City 30 days before testing may begin.

9.2.4 System Acceptance Testing

The System Acceptance Test demonstrates that the whole system will operate as specified and support operations for an extended period of time, not less than 30 working days. The Test also provides a controlled burn-in period for all the installed equipment.

The System Acceptance Test shall commence following notification by the City that the results of the System Integration Testing are satisfactory and following receipt of the Contractor's certification that the system is ready for System Acceptance Testing.

During the 30-working day period, the City will operate the system as specified using the fully configured software and hardware and all applicable manuals, printed guides and procedures submitted by the Contractor. The Contractor shall correct any major failure or malfunction as it occurs during this period. After correction, the test shall continue until the System has operated continuously for 30 days without significant malfunction or fatal software error.

9.3 CERTIFIED COMPLETED TEST REPORTS

Following the completion of each test phase, the Contractor will prepare and submit a Test Report that describes the results of the test phase and the next steps to be taken. The City will review the report and respond, indicating its approval or noting changes required either in the performance of the work or in the report. The Contractor shall make changes or perform additional work as the City may direct prior to the start of the

next test phase. No test phase shall be considered complete, nor may the Contractor proceed to the next phase of testing until the City has approved, in writing, the Contractor's test report for the previous phase. The report shall contain, but not be limited to:

1) Summary of the test period results including a statistical analysis of test results
2) Descriptive narrative of individual test objective(s)
3) Data dictionary of test database
4) System status prior to testing and after testing
5) Expected test results
6) Actual test results
7) Exception condition report (when applicable)
8) Explanation of exception conditions and Contractor corrections
9) Before and after database listings
10) All applicable screen printouts, reports, interim processing dumps and other audit trail physical evidence to validate the test activity for each iteration of the test conducted
11) Completed tester Sign Off sheets

9.4 VALIDATION METHOD

9.4.1 Pre-implementation evaluation

Prior to the field deployment, traffic simulation models (e.g., VISSIM) can be used to evaluate the existing timing plans by measuring arterial performance under existing conditions and comparing expected Levels of Service from proposed coordinated signal timing plans.

9.4.2 Post-implementation evaluation

After the field deployment, an On/Off study may be conducted to compare Levels of Service when the system is operated and when it is turned off.