SP-157076
(New)

SPECIAL PROVISIONS
FOR
ADAPTIVE TRAFFIC SIGNALS AND FIBER OPTICS COMMUNICATIONS

Black Hawk County
STP-A-8155(743)--86-07

Effective Date
April 17, 2018

THE STANDARD SPECIFICATIONS, SERIES 2015, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

1. GENERAL

1.1 These Special Provisions include the furnishing and installing of all material and equipment necessary to complete, in place and operational, an adaptive signal control technology, a traffic signal interconnect fiber optic system, and an upgrade of non-adaptive traffic signal controllers, as described in the Project plans.

1.2 The installation of the traffic control signals and accessories shall be in conformance with the Manual on Uniform Traffic Control Devices, latest edition at the time of advertising the bids.

1.3 Upon notice by the City Traffic Operations Department, the Contractor shall be responsible for ONE-CALL locates of the fiber cables installed under this Project until acceptance of the Project by the City.

1.4 Wiring Diagrams- Fiber optic wiring (Splicing and Terminations) diagrams are provided to define the fiber optic wiring of all traffic cabinets, hubs, and facilities. Discrepancies of any wiring diagrams shall be resolved with the Engineer prior to installation. Changes to the wiring diagrams may occur during the Project, based on user demand and other projects interacting with this Project. The Contractor shall maintain accurate quantities of splices and termination at each location during the Project.

1.5 At the completion of the Project, the Contractor shall provide the Engineer with field red-line plan indicating changes to original plans, including wiring-diagrams, to assist in preparation of the As-Built drawings.

2. SYSTEM INTEGRATION

2.1 The Contractor shall install, program, network, connect, and test the complete communication

system including all network switches, and any other component of the complete and functional system.

3. EQUIPMENT AND MATERIALS

3.1 Fabrication and assembly process materials shall comply with the applicable parts of Section 2523 of the Standard Specifications with the additions as stated herein.

3.2 Equipment and materials shall be of new stock. Contractor shall submit a completed list of materials and equipment to the Engineer for written approval before any equipment or materials are ordered.

3.3 A PDF file of catalog cuts and manufacturer's specifications shall be furnished for all standard "off-the-shelf" items or items manufactured specifically for this Project.

3.4 Engineer's review of shop drawings and catalog cuts shall not relieve the Contractor for any responsibility under the contract documents.

3.5 All electrical equipment shall conform to the standards of the National Electrical Manufacturer's Association (NEMA), and all material and work shall conform to the requirements of the National Electrical Code (NEC), the Standards of the American Society for Testing Materials (ASTM), the American National Standards Institute (ANSI), and local ordinances. Miscellaneous electrical equipment and materials shall be UL approved.

3.6 Wherever reference is made, in these special provisions or in the standard specifications, to the code, the safety orders, the general order, or the standards mentioned above, the reference shall be construed to mean the code, order, or standard that is in effect on the date of advertising for bids for this Project.

3.7 Certification from the manufacturers of all electrical equipment, conduit, and cable shall be supplied by the Contractor stating said materials comply with these Specifications.

3.8 Any existing equipment designated to be removed on the Project shall remain the property of the City of Waterloo. The Contractor shall contact the City Traffic Operations Department (319-291-4440) to coordinate pick-up of equipment by City forces.

4. TESTING AND MAINTENANCE OF SIGNAL EQUIPMENT

4.1 The Contractor shall notify the Engineer of the date the signal or communication system will be ready for testing once the Project is ready to implement and/or open to traffic.

4.2 Upon authorization by the Engineer, the Contractor shall place the signal or communication system in operation for a consecutive 30 day test period. The signal(s) and communication network shall not be placed into operation without prior notification and authorization of the Engineer. Any failure or malfunction of the equipment furnished by the Contractor, exclusive of minor malfunctions (such as lamp burnouts or power outages) occurring during the test period, shall be corrected at the Contractor's expense, after which the signal or communication system shall be tested for an additional 30 consecutive day period. This procedure shall be repeated until all installed equipment has operated satisfactorily for 30 consecutive days.

4.3 A representative from the manufacturer and/or supplier of signal controller shall be at the Project site when the signal controllers are ready to be turned on to provide technical assistance including, as a minimum, programming of all necessary input data. All required signal timing data will be provided by the Engineer.

4.4 After signal turn on and prior to the final acceptance of the completed traffic signal system, the

Contractor shall respond, within 24 hours, to perform maintenance or repair of any failure or malfunction reported.

5. WARRANTY

5.1 The Contractor shall transfer all required equipment warranties to the City on the date of final Project acceptance.

6. FIBER OPTIC CABLE AND CONNECTIONS

6.1 All designed interconnect systems shall use single-mode fiber optic interconnect cable. All fiber optic components required to provide proper communication with the City traffic signal network shall be furnished and installed as part of this item. The work shall consist of furnishing and installing a fiber optic cable of the type, size, and number of fibers specified. All fiber optic materials and equipment procured and installed as part of this specification shall be OFS, Corning, or General Cable brand.

6.2 General Requirements

6.2.1 Materials and Equipment
Materials and equipment shall be standard products of a manufacturer regularly engaged in the manufacture of the products. All materials and equipment furnished shall be completely free from defects and shall be of good quality. The cable shall be rated for gigabyte data bandwidth. All fiber shall be loose tube construction for both indoor and outdoor installation. Indoor cabling shall use plenum rated conduit to within less than 50 feet of point of termination eliminating the requirement to convert to indoor cable.

6.2.2 Contractor Qualifications
Trained and experienced personnel shall supervise the fiber optic cable installation. Qualified technicians shall make the cable terminations and splices. The technicians performing terminations and splices shall be IMSA Fiber Optic Level 2 Certified, be a FOA (Fiber Optic Association) Certified Fiber Optic Technician, hold an approved equal certification, or have proven experience installing fiber optic equipment. The Contractor upon request of the Engineer shall provide documentation of qualifications and experience for fiber optic equipment installations.

6.2.3 Codes Requirements
The fiber optic cable installation shall be in accordance with or exceed all minimal requirements of State Codes, National Codes, and manufacturer codes as applicable.

6.2.4 Miscellaneous Equipment
The Contractor shall furnish and install all necessary miscellaneous connectors and equipment to make a complete and operating installation in accordance with the plans, standard sheets, standard specifications, special provisions, and accepted good practice of the industry.

6.2.5 General Considerations
The cable shall meet all requirements stated within this specification. The cable shall be new, unused, and of current design and manufacture.

6.3 Fiber Characteristics
All Fibers in the cable must be usable fibers and meet required specifications.

6.3.1 Single-Mode Fiber
Typical core diameter: 8.3um
Cladding Diameter: 125 +1.0um by fiber end measurement

Core-to-cladding offset: <1.0um
Coating Diameter: 250 +15um
Attenuation uniformity: No point discontinuity shall be greater than 0.1 dB, except terminations or patch cords, at either 1310nm or 1550nm. The coating shall be a layered UV cured acrylate applied by the fiber manufacturer. The coating shall be mechanically or chemically removable without damaging the fiber.

Factory cable rating shall be 0.35 dB/KM at 1310nm and 0.25 dB/KM at 1550nm. Installed tolerance shall be less than 0.44 dB/KM at 1310nm and less than 0.33 dB/KM at 1550nm, testing tolerance.

All fiber cables shall be Gigabyte rated, i.e. single mode shall be 28 KM for 1310nm and 40 KM for 1550nm based on a 10-dB power budget.

All Single mode fiber shall be rated for multi-frequency, four frequencies, equivalent to the AllWave OFS specification and shall be rated to withstand extended aging under water impregnation conditions.

6.4 Fiber Specification Parameters

6.4.1 All fibers in the cable shall meet the requirements of this specification. The testing tolerance attenuation specification shall be the maximum attenuation for each fiber over the entire operating temperature range of the cable when installed.

6.4.2 The change in attenuation at extreme operational temperatures for single-mode fibers shall not be greater than 0.20 dB/km at 1550nm, with 80% of the measured values no greater than 0.10 dB/km at 1550nm.

6.4.3 Optical fibers shall be placed inside a loose buffer tube, with 12 fibers per tube.

6.4.4 The buffer tubes shall meet EIA/TIA-598, “Color coding of fiber optic cables.”

6.4.5 Fillers shall be included in the cable core to lend symmetry to the cable cross-section where needed.

6.4.6 The central anti-buckling member shall consist of a glass reinforced plastic rod. The purpose of the central member is to prevent buckling of the cable.

6.4.7 The cable shall use a completely dry cable design without the use of gels or filling compounds. Dry water blocking material shall be used around the buffer tubes as well as internal to the tubes. Water blocking gels shall not be acceptable on this Project.

6.4.8 Buffer tubes shall be stranded around a central member. Acceptable techniques include the use of the reverse oscillation, or “SZ”, stranding process.

6.4.9 All dielectric cables (with no armoring) shall be sheathed with medium density polyethylene. The minimum nominal jacket thickness shall be 1.4 mm. Jacketing material shall be applied directly over the tensile strength members and flooding compound. Cable jacketing shall utilize the newer designs to provide maximum flexibility without loss or appreciable dB attenuation. Cable diameter shall not exceed 0.50 inch.

6.4.10 The jacket or sheath shall be marked with the manufacturer’s name, the words “optical cable”, the year of manufacture, number of fibers, type of fiber (SM) and sequential feet or meter marks. The markings shall be repeated every on-meter or three feet. The actual length of the cable shall be within -0/+1% of the length marking. The marking shall be in contrasting color to the cable jacket. The height of the marking shall be

approximately 2.5 mm. A copy of the manufacturer fiber definition and shipping sheet identifying all tests, results and fiber indexes shall be provided to the Engineer on delivery of cable to the City or shall be included with the Contractor's list of places of installation, when installed by the Contractor.

6.4.11 The maximum pulling tension shall be 600 pounds during installation.

6.4.12 Two, four, six, or twelve buffer tubes with twelve fibers each, or subsets specified, shall be provided and designated as follows:

Buffer Tube/Fiber	Tube/Fiber Color
#1, 1st tube or fiber	blue
#2, 2nd tube or fiber	orange
#3, 3rd tube or fiber	green
#4, 4th tube or fiber	brown
#5, 5th tube or fiber	slate
#6, 6th tube or fiber	white
#7, 7th tube or fiber	red
#8, 8th tube or fiber	black
#9, 9th tube or fiber	yellow
#10, 10th tube or fiber	violet
#11, 11th tube or fiber	rose
#12, 12th tube or fiber	aqua

6.5 Quality Assurance Provisions

6.5.1 All optical fibers shall be proof tested by the fiber manufacturer at a minimum load of 100 kpsi.

6.5.2 All optical fibers shall be 100% attenuation tested by the manufacturer. The attenuation of each fiber shall be provided with each cable reel. The measured attenuation shall be for both 1310 and 1550 frequency. This documentation shall be provided with each spool. The Contractor shall designate on the Plans and document the location where each spool has been installed and provide this data to the Engineer.

6.6 Cable Installed in Ducts and Conduits

6.6.1 A suitable cable feeder guide shall be used between the cable reel and the face of the duct and conduit to protect the cable and guide it into the duct/conduit off the reel. It shall be carefully inspected for jacket defects. If defects are noticed, the pulling operation shall be stopped immediately and the Engineer notified. Precautions shall be taken during installation to prevent the cable from being "kinked" or "crushed". A pulling eye shall be attached to the cable and used to pull the cable through the duct and conduit system. A pulling swivel shall be used to eliminate twisting of the cable. As the cable is rolled off the reel into the cable feeder guide, it shall be sufficiently lubricated with a type of lubricant recommended by the cable manufacturer. Dynamometers or breakaway pulling swings shall be used to ensure that the pulling line tension does not exceed the installation tension value specified by the cable manufacturer. The mechanical stress placed on the cable during installation shall not be such that the cable is twisted or stretched. The pulling of cable shall be had assisted at each controller cabinet. The cable shall not be crushed, kinked, or forced around a sharp corner. If lubricant is used it shall be of water based type and approved by the cable manufacturer. Sufficient slack shall be left at each end of cable to allow for proper cable termination or splicing, minimum of 30 feet. This slack shall be in addition to installation slack as specified. Additional slack cable shall be left in each hub cabinet and handhole. Excess slack at hub cabinets shall be re-pulled into the nearest handhole to provide a neat and orderly

installation. The slack amounts to be stored in each handhole are as noted in the plans.

6.6.2 Storage of minimum slack cable in controller cabinets and additional slack at pull boxes shall be coiled. The slack coils shall be bound at a minimum of three points around the coil perimeter and supported in their static storage positions. If stored in a handhole, fiber shall be stored along the outer most walls to allow unabated ingress and egress. The binding material and installation shall not bind or kink the cable. Storage of additional slack cable adjacent to conduit risers and support poles shall be as visibly marked/tagged as "CAUTION – FIBER OPTIC CABLE". Maximum length of cable pulling tensions shall not exceed the cable manufacturer's recommendations. Along with the fiber optic cable, on No. 10 AWG THHN, 600 volt single conductor cable (trace wire), orange in color, shall be pulled with 10 feet of slack in each pull box or handhole. All fiber cables shall be marked with a metallic or preapproved identifier in the handhole adjacent to the traffic signal cabinet or hub cabinet and on the cable in the hub cabinet at point of termination. The identifier, both in the cabinet and in the handhole, shall indicate the direction the cable is going, cable contents (SM), and the abbreviated location for the other end destination.

6.7 Minimum Bend Radius

For static storage, the cable shall not be bent at any location to less than ten times the outside diameter of the cable or as recommended by the manufacturer. During installation, the cable shall not be bent at any location to less than twenty times the outside diameter of the cable or as recommended by the manufacturer.

6.8 After the Fiber Optic Cable Installation

6.8.1 Each section of the cable shall be tested for continuity and attenuation as a minimum. If the attenuation is found not to be within the acceptable nominal values, the Contractor shall use an optical time domain reflectometer (OTDR) to locate points of localized loss caused by bends or kinks. If this is not successful, the Contractor shall replace the damaged section of cable with no additional payment. Splices will not be allowed to repair the damaged section. After all fiber is installed, all fibers, whether terminated or non-terminated, shall be tested with an OTDR. All fibers terminated shall be tested with a power meter. Each OTDR trace, for documented test result submittal shall be displayed individually and not be combined with other fiber traces as overlays. Single mode fiber shall be tested at 1310 nm. The results of the OTDR test shall be provided on an electronic media (disk) and paper printout. The OTDR wave, pictorial diagram of dB loss over the length of fiber tested, shall be provided along with the measured data values. The printout shall contain the manufacturer's fiber optic Index of Refraction to the third decimal point for the fiber provided. The Contractor shall provide the Engineer with a written report showing all the values measured compared to the calculated values for length and coupler/connector losses at the completion of these tests.

6.8.2 Documentation provided to the Engineer shall include written indication of every splice termination, patch cord, etc. for cable being measured. Power meter measurement recordings shall indicate the exact measured distance (OTDR or field measurement with cross reference for oscillation multiplier) on the sheet showing the power meter readings. Any deviations between fiber readings in the same tube shall be notated for OTDR graphs as well as deviations greater than 5% on power meter readings. Rated values for acceptable installation shall be based on the following parameters:

Patch cords/Pigtails	0.15 dB each (SM)
Terminations	1.0 dB set of two (In and Out)
Splices	0.08 dB each

1 KM = 0.3077 KF where KF is 1000 feet

6.8.3 Data documentation for each test between buildings, hubs, or cabinets shall include, the length of fiber as measured by OTDR, frequency used in test on OTDR by each fiber type, distance to each splice, termination, or patch cord jumper, dB loss rating by manufacture from spool documentation index of refraction by type of fiber in section, and the dB loss of each section as measured in the final test for each fiber. A special test shall be made on all continuous spliced fiber from start to end that includes the total dB loss measured and the OTDR plot on electronic disk. Splice points shall be identified on the trace.

6.9 Fiber Optic Termination

6.9.1 Terminations shall be made using the method recommended by the connector manufacturer.

6.9.2 All fibers shall utilize a fan-out kit of the size and type recommended by the manufacturer and of the number of fibers provided in each fiber tube.

6.9.3 All fibers terminated shall utilize a ceramic ferrule (outdoor connections), ST, mechanical termination with a wide temperature (-40°F to +170°F) epoxy. Heat cured or epoxy type connections meeting the full temperature ratings are acceptable for this Project, including factory manufactured pigtails.

6.9.4 The Contractor shall be required to provide proof of purchase of sufficient quantities of ceramic terminations for outdoor terminations to verify ceramic connector usage or temperature ratings on epoxy or heat cured processes prior to terminating any fibers.

6.9.5 The Contractor may terminate fibers by splicing factory pigtails to the fiber ends and then connecting the pigtail to the fiber coupler in the fiber tray. When splicing pigtails to terminate, all splices shall be provided with metal reinforced shrink tube protector.

6.9.6 All termination couplers shall be rated for SM fiber application.

6.10 Fiber Termination Panels

6.10.1 The Contractor shall provide and install termination panels with 12 and 24 position capacity as indicated in the Tabulation of Equipment at each traffic signal cabinet or fiber hub.

6.10.2 The Fiber Termination Panel shall include all required equipment to provide a fully functional panel; this includes breakout kits, fiber distribution units, housing, etc.

6.10.3 The breakout kits, fiber distribution units, or termination boxes used to terminate each fiber cable in the cabinet shall provide for the separation and protection of the individual fibers with the buffer tubing and jacketing materials.

6.10.4 The termination housing shall be installed within a wall interconnect housing, which shall provide for storing fibers, ample room for feed through cables, strain relief for multiple cables within the unit, and accommodate SC compatible connectors.

6.10.5 All fiber pigtails shall be terminated through ST connectors on the wall interconnect panel. All terminations shall be either ST type, ceramic core (outdoor connections).

6.10.6 Splices to pigtail fiber, where used shall utilize fan out kit protection to the fiber, heat shrink tubing with metal bar reinforcement and 900 micron rated pigtail insulation. Splices to factory pigtails shall use pigtails that are rated for a minimum temperature range of 0°F to +150°F. In the absence of pigtails meeting this temperature rating, fibers

shall utilize loose tube fiber in fan-out kit tubes and SC connectors.

6.11 Connectors

Connectors shall be either SC (ceramic ferrule-outdoor connections) type, field installable, and self-aligning and centering or factory fabricated pigtails. Fiber optic equipment used for terminating fibers shall be rated for the type of connectors used. Connectors shall be NEMA temperature rated epoxy type or Engineer approved equal.

6.12 Duplex Patch Cords

Patch cords shall have connectors on each end and shall contain a pair of fibers per cord (Duplex). The patch cords shall be factory made, buffered, and strengthened with aramid yarn to reduce the possibility that accidental mishandling will damage the fibers or connection. The patch cords shall be yellow. The connectors on each end shall be of the same type as indicated in Sec 6.11 of this provision, except where the second connector is required to be different for compatibility with the equipment to which the patch cord connects. Length of the patch cord shall suffice to provide approximately 5 feet of slack after installation. Patch cords to be installed in the Fiber Hub cabinets and other locations where the fiber terminations already exist, shall be supplied and installed by the City as indicated in the plans.

6.13 Splice Enclosure (In-Ground)

6.13.1 Splice Enclosures shall provide capacity of 144 fiber splices.

6.13.2 The Enclosure shall be: suitable for outdoor applications with a temperature range of -22°F to 140°F, protect splices from moisture and damage, non-reactive and not support galvanic cell action, waterproof, re-enterable, sealed with a gasket, permit selective splicing to allow one or more fiber strands to be cut and spliced without disrupting other fibers, equipped with a basket to accommodate the slack from all fibers routed into the enclosure, capable of holding splice trays from various manufacturers, input/output capacity of four 18 mm cables, equipped with a termination block to terminate the central strength members of the fiber optic cables.

6.13.3 Splice trays shall be: compatible with fiber splices and splice enclosure, equipped with polyethylene tubes to protect exposed individual fibers within the enclosure, stackable within the splice enclosure. Vinyl markers shall be supplied to identify each fiber to be spliced. Each splice shall be individually mounted and mechanically protected on the splice tray. Loose tube buffers shall be secured with a tube guide or channel snap. Slack fiber shall be placed in an oval shape along an inside wall of the tray.

6.14 Fiber Optic Fusion Splice

Splice all optical fibers as shown in the plans or as directed by the Engineer.

6.14.1 Make all splices using a fusion splicer that automatically positions the fibers using either the Light Injection and Detection (LID) system or the High-resolution Direct Core Mounting (HDCM) system. Provide all equipment and consumable supplies.

6.14.2 Secure each spliced fiber in a protective groove. Completely re-coat bare fibers with a protective room temperature vulcanizing (RTV) coating, gel, or similar substance, prior to insertion in the groove, to protect the fiber from scoring, dirt or micro bending.

6.14.3 Prior to splicing to fiber installed by others, measure and record the optical loss over that fiber. Utilize the same methods as shown in Sec 6.8 of this provision.

6.14.4 Use a different splice tray for each buffer tube color. If an enclosure contains multiple buffer tubes of the same color, but none of the tubes are spliced to fibers in the other tubes of the same color, use a separate splice tray for that tube.

6.14.5 All splices shall be nominally 0.03 to 0.05 dB loss but shall be less than a 0.08 dB loss.

6.15 Light Source and Power Meter

6.15.1 An LED light source with a wavelength that is the system wavelength, 1310 and 1550 nm for single mode shall be used. The LED shall be stable within 0.1 dB in intensity over a time period sufficiently long to perform measurement. The output of the LED shall overfill the input end of the launch fiber/cable in both numerical apertures (NA) and core diameter. The accuracy of the combined light source and power meter shall be less than 0.05 dB and be temperature compensated stabilized to 0.01 dB over the operating range of the meter(s).

6.15.2 The Contractor shall provide one each Light Source and Power Meter and/or one each 650 nM visible light source, to the Fiber Optic Coordinator or City technician complete with all attachments for measuring individual fibers of single mode at both 1310 and 1550 nm for spot testing/inspecting of installed and terminated fibers. This test kit shall include one each 200X power zoom scope for observing fiber ends for smoothness and fractures. AC power adapters shall be provided with all light and power meters as well as battery operation. This test kit shall remain the property of the Contractor. This test kit shall be made available from the beginning to completion of the Project and be on-site at all times.

6.15.3 Power Meter
The detector in the power meter shall have an effective numerical aperture and active region that is larger than the receive reference cable and/or the fiber under test. The power meter shall have a minimum range from +3 DBMS to -40 DBMS. The power meter shall have an accuracy of +/- 0.5 dB through the operating temperature and minimum resolution of 0.1 dB.

6.16 Launch Reference Attenuator

6.16.1 The launch attenuator, two for single mode fiber testing, shall be utilized for all OTDR tests such that one launch cable shall be at the beginning of the fiber being tested and the second launch cable shall be on the end of the fiber being tested past the final connector. Only one launch cable shall be required when testing non-terminated fiber. The launch attenuator(s) shall be of the same fiber core size and type as the fiber under test. The attenuator shall emulate 900-foot fiber length, minimum, for single mode fiber or as specified by the OTDR manufacturer for stabilization of the pulse generation. Launch cables shall be of identical length for incoming and outgoing light during tests. SC/LC connectors shall be utilized with each attenuator to connect the device to the test device, OTDR. One launch cable shall be installed on the start of the fiber being tested and one launch cable shall be installed on the end of each terminated to view the dB loss of the final connector.

6.16.2 The OTDR shall have the Threshold Loss set at a value to show each splice or termination junction of a single fiber in each tube without showing the extraneous noise caused by handhole coils or turs into the cabinets. This level is normally a value (Threshold Loss) between 0.3 and 0.8 on the OTDR. This trace shall be provided for one fiber in each tube tested and each “event” shall be marked as splice, jumper or patch cord. The Threshold Loss shall then be set to a value of 0.10 for single mode fiber tests. The test of each fiber installed shall be conducted and any recorded events above the threshold shall be identified, such as jumper or patch cord. Events that are in excess of the provided values shall be corrected prior to documentation submittal, such as terminations in excess of the rated value or bends in the fiber at the point of a splice entering or leaving a splice tray (See Testing). For measured values recorded in excess of the above (0.10 for SM) listed values, refer to the fiber parameters specification as

hereinbefore defined. The Engineer reserves the right to spot test fiber terminations, splices, or re-testing of all fibers in a section to insure proper quality assurance both during and after installation and testing. Deviations from Engineer testing and report documentation shall be reviewed and the Contractor shall be able to retest any or all challenged measurements to verify a valid test. Inconsistent test results, in the sole opinion of the Engineer, shall cause the Contractor to retest the entire fiber installation.

6.17 Testing

6.17.1 General

The Contractor shall provide all personnel, equipment, instrumentation, and supplies necessary to perform all testing and is considered incidental to the Project. All testing shall be performed in the accepted manner and in accordance with the testing equipment manufacturer's recommendations. All data shall be recorded and submitted to the Engineer as hereinbefore specified. The Contractor shall provide one copy of operating software to read and view all OTDR traces.

6.17.2 Attenuation

The end-to-end attenuation shall be measured for each fiber for each link after installation and termination. A patch cord jumper cable shall be connected to both the light source and the receive cable to the power meter by the use of a connector (barrel). The two reference cables shall then be connected via a termination coupler and power meter "zeroed" to eliminate the line loss. This process results in a reading of the actual line loss (dB) of the input connector, fiber cable, exiting connector, and any other splices or jumpers installed in the measured test link. The calculated "loss" shall not include the input or departing cables in the loss calculation. The calculated fiber loss measured shall list the number of terminations, including the input and departing connectors, the number of splices and the number of patch cords used to jumper the link(s) into the measured final link. The measured values for each terminated fiber in each tube shall include the Tube number, fiber number, number of feet in the link, the number of splices, the number of patch cords, and the number of connectors, if any. The length of the optical cable shall be as measured by the OTDR rather than the fiber cable jacket as the fiber is in reverse oscillation process resulting in a greater optical distance than the fiber cable jacket. The value for both the OTDR length and the cable jacket length shall be provided in the recorded documentation for each link distance. All distances shall be recorded in feet rather than meters for both recorded lengths.

Fibers that are not continuous from beginning of the link to the end of the link shall be noted in the documentation; otherwise all fibers in a single tube may be listed in a single data entry for all required data listed above for all fibers in the tube. The fiber documentation for each fiber shall identify the fiber being tested by either fiber number or fiber coating color and be recorded by complete tube, Tube 1 through Tube 12, fiber 1 through fiber 12. The direction of the test shall be recorded for information purposes only to resolve discrepancies in replicating the test during inspections of the final installation. The power meter reading recordings shall log total dB loss over the length of the fiber measured, equivalent to the dB loss budget.

The output power levels at the network hardware transmitters or receivers shall be measured and recorded for system documentation. The power meter shall be connected to the transmitter side do the equipment with a system jumper. The transmit power level shall then be read and recorded.

Each tube of the cable shall be in the same file divider where the tube cover OTDR page shows the overview of all splices, patch cords, terminations from start to end. The second section shall include all Power Meter readings and the mandated documentation to show the calculated line loss (losses). The third section shall contain all OTDR traces,

one trace per screen. The fourth section shall include the spool sheet for the fiber installed on the test section. An “explanation” sheet may be included where required to clarify an unusual reading that is valid but difficult to be explained through traditional data presentation, such as a video feed fiber that is attached to a jumper to provide continuous feed from the start to end of the tube length where other fibers in the same tube are simply spliced. The above format shall be repeated for each tube of the cable.

6.17.3 Continuity

Continuity tests shall be used to determine whether a test or system jumper does or does not pass light. A continuity test shall also be used to assure the fibers have not been crossed over in the jumper and that the transmit fiber goes to the receiver fiber. The visible light tester shall be utilized to illuminate faulty terminations or fibers with excessive bends failing to pass light.

To perform continuity test, a high-intensity red light (Visible Fault Identifier (VFL)) light source shall be aimed into the connector at one end, while an observer watches for a flicker of light at the other end. One each 650 nm red VFL light source shall be furnished to the Engineer by the Contractor on request during the testing of the fiber by the Contractor for spot testing. This device shall be made available during testing of continuity to the Engineer to assist in verifying fault locations and connector bleeding.

6.17.4 OTDR Testing

An OTDR shall be used to evaluate the quality and length of cable reels prior to their use on the Project. A minimum of one fiber per tube per reel shall be tested if payment for stored goods is requested. The fiber loss in dB/km and the length of each reel shall be recorded in the documentation. The maximum attenuation of the cable shall be as hereinbefore specified. This test does not require an electronic document; but is provided to ensure that the fiber has been received in useable quality without shipment damage. The test results of the Contractor OTDR tests of received spools shall be provided to the Engineer, in a minimum of hard copy print, prior to receiving payment for stored goods.

An OTDR shall be used to evaluate the quality and length of cable installed on the Project. This test shall be conducted on all fibers, terminated and not terminated, and shall be conducted after all termination on the fibers for a link have been completed. The fiber loss in dB/km and length of each reel shall be recorded in the documentation. The index of refraction, minimum of three decimal points, provided by the manufacturer on the spool documentation shall be used for the test on the OTDR. The maximum attenuation of the cable shall be as hereinbefore specified. A hard copy of OTDR signature traces, electronically and in printed form, for all fiber links shall be made and provided in the documentation as specified. The data provided shall be in easy to understand format and of sufficient detail to verify the results. Fiber testing shall include only one fiber trace per graph. One copy of the operating system software to view the fiber graphs shall be provided with the final documentation.

6.17.5 Documentation

The result of all testing shall be recorded along with date of test, name of person performing test, brand name, model number, serial number of equipment used during testing, and any other pertinent information and data. The Contractor shall be responsible to provide input to the Engineer reviewing the recorded data documentation to resolve all questions or data discrepancies. A copy of the evaluation calculation equations to be used may be obtained by the Contractor by request and by supplying an electronic copy. (The evaluation FO Calculator is an EXCEL program worksheet that calculates design dB Loss based on required inputs.) Documentation shall be considered incidental to bid items and no additional compensation shall be provided. Fiber optic cable test results shall be provided to the Engineer, and the City of Waterloo

Public Works Director.

6.18 Basis of Payment
Measurement and payment for items covered by these special provisions include the documentation and acceptance testing, in addition to all materials and equipment necessary for a fully operational system. Payment will be made as follows:

Bid Item Fiber – 12 ct SM, measured per linear foot.

Bid Item Fiber – 24 ct SM, measured per linear foot.

Bid Item Fiber – 72 ct SM, measured per linear foot.

Bid Item Fiber Optic Fusion Splice, measured per each.

Bid Item Fiber Optic Termination, measured per each.

Bid Item Duplex Patch Cord, measured per each.

Bid Item Fiber Termination Panel – 12-Position, measured per each.

Bid Item Fiber Termination Panel – 24-Position, measured per each.

Bid Item Fiber Splice Enclosure (In-Ground), measured per each.

7. Ethernet Communication System

7.1 This specification sets forth the minimum requirements for an Ethernet-based traffic signal interconnect and communications system. All equipment and materials to provide a properly functioning Ethernet communications system is included.

7.2 The Contractor shall furnish and install all Ethernet Communication System switches, SFPs, and system integrator for this Project.

7.3 The fiber optic Ethernet communications equipment shall include:

7.3.1 Harsh environment Layer 2 Switch shall be configured with minimum of four Gigabit Ethernet RJ45/SFP combo uplink ports and twelve 10/100-TX RJ-45 fast Ethernet ports and power supply. The Ethernet switch shall be Cisco IE-4000-16T4G-E, Comtrol ES8520-XT, EtherWAN EX73900 Series, Ruggedcom RSG920P, SEG520-4SFP-T, or KY03120DM and meet the following minimum requirements or equivalent approved by the Engineer.

i. Store-and-Forward, minimum of 11 Gbps switching bandwidth

ii. 16K Unicast MAC addresses, and IGMPv1,v2,v3 snooping

iii. Management via console CLI, Web, ACL, SNMP, RMON, TFTP, HTTPS, and SSH

iv. Operating temperature -40°F to 167°F for extreme environment, 10% to 95% non-condensing and NEMA TS2 certified

v. VLAN (802.1Q), IPv4/IPv6, GVRP, QoS, LACP, RSTP (sub-50ms topology recovery time), LLDP, NTP, RADIUS, SNMPv1-3, Port-Security, Storm Control

vi. Event notification by e-mail, SNMP trap, syslog, digital input and relay output, standard/private MIB for SNMP monitoring software interface.

vii. The switch shall include four Single Mode (SM) SFP transceivers for 1000Base-LX/LH (LC), support EXT temperature, 1310nm 10KM distance. The provided SFP transceivers shall be Cisco compatible and shall support Digital Monitoring (DoM) or equivalent tested and approved by the Engineer.

viii. The switch shall include a standard AC power cable, DIN rail and panel mount kits.

ix. Dual power inputs with terminal block for a 24vDC power supply. An included external power supply shall be NEMA TS2 certified.

7.3.2 Single Mode (SM) SFP transceivers
The provided SFP transceivers shall operate on any Layer 2 switch model and manufacturer in the traffic signal cabinets or uplink to an existing Layer 3. The SFP transceivers are considered subsidiary to the Layer 2 switches, and no direct payment will be made. The provided SFP shall meet the following minimum requirements or equivalent approved by the Engineer:

i. 1000Base-LX/LH (LC connector) Single Mode (SM) SFP transceivers shall support EXT Temperature, Cisco compatible, and Digital Monitoring (DoM), 1310 nm wavelength, TX Power range from 0-5 dBm, RX range from -32 dBm to -40 dBm. It shall support the 1310 nm wavelength and 10 KM distance.

7.4 The system shall be primarily fiber optic based. The system shall also include interface equipment and cabling for CAT5e or CAT6 communications, except cable installed in conduit external to a controller cabinet shall be CAT5e or CAT6 FTP, Outdoor, UV Rated, and Shielded Dry Gel-type cable with anti-crosstalk divider, drain wire, and rip cord.

7.5 All equipment, terminations, connectors, terminal blocks, and any other hardware to construct the system shall be designed for outdoor use in typical traffic signal system conditions. All equipment shall include mounting brackets to secure the equipment in the cabinet.

7.6 Basis of Payment
Payment shall be made upon network equipment delivery, installation, and successful operational testing. Measurement and payment for items covered by this specification are as follows:

Bid Item Ethernet Switch, Harsh Environment Layer 2, Managed, Furnish and Install, measured per each.

8. Replacing Damaged Improvements/Site Restoration

8.1 The Contractor is to restore to its original condition any disturbed areas at sites including, but not limited to; pull box/handhole, conduit, pole base installations, and relocated signs. Restoration shall be accomplished by placing material equivalent to that of the adjacent undisturbed area. Disturbed unpaved areas shall be fertilized, seeded, and mulched.

8.2 The Contractor shall take special care to minimize the disturbance of the existing ground.

8.3 Improvements such as sidewalks, curbs, driveways, roadway pavement, and any other improvements removed, broke, or damaged by the Contractor shall be replaced or reconstructed with the same kind of materials found on the work or with materials of equal quality. The new work shall be left in serviceable condition satisfactory to the Engineer. Whenever a part of a square or slab of existing concrete sidewalk, driveway, or pavement is broken or damaged, the

entire square or slab shall be removed and the concrete reconstructed.

8.4 Basis of Payment
The cost of replacing damaged improvements and/or restoration of disturbed areas, including erosion control during construction, will be incidental to the bid items of the Project. No direct payment will be made for any materials or labor, which is performed under this provision.

9. Traffic Signal Controller

9.1 Furnish and Install
Traffic controller hardware shall be upgraded or replaced to meet and exceed the current ATC, NEMA and NTCIP standardization requirements. The modernized controller hardware shall provide traffic operations with a robust, industry leading, and open architecture hardware platform. A controller hardware upgrade shall be equipped with NEMA TS-2, ATC, NTCIP 1201 and 1202 communication protocol standard. It shall be fully-loaded with open source Linux Operating System, color touch screen, serial and high-speed Ethernet and wireless communication interfaces, USP port for flash drive, and support live software upgrades. All traffic signal controllers shall have the capability to fully communicate with MaxView by Intelight central management software.

Adaptive Signal Control Technology (ASCT) Controller: All ASCT traffic signal controllers shall be an Intelight X-3 ATC Lite controller. Included with each of these controllers shall be a license to fully communicate with the MaxView central management software.

New Non-ASCT Controller: Traffic signal controller without adaptive signal control technology (ASCT) shall be fully NTCIP ready and shall be compatible with the City's MaxView central management software by Intelight and capable of communication, including capability to fully upload and download data. Included with each of these controllers shall be a license to fully communicate with the MaxView central management software.

9.1.1 The controller equipment furnished shall be new, of the latest model, fabricated in a first-class quality manner from good quality material. The manufacturer shall replace free of charge to the Contractor and/or City of Waterloo any part that fails in any manner because of defective material or quality within a period of 12 months from the date the equipment was placed into operation following installation.

9.1.2 Certification of the manufacturer's controller assembly by an independent testing laboratory shall be provided to the Engineer. This certification shall indicate that the manufacturer's controller assembly is in accordance with the test procedures as specified in the NEMA Standard No. TS1-1983. Certification to NEMA Standard No. TS-2, current edition at the time of bid shall be acceptable.

9.1.3 All components shall be amply de-rated with regard to heat dissipating capacity and rated voltage so that, with maximum ambient temperatures and maximum applied voltage, a material shortening of life or shift in values shall not occur.

9.2 Basis of Payment
Measurement and payment for items covered by this specification are as follows:

Bid Item Traffic Signal Controller, ASCT, Furnish and Install, measured per each.

Bid Item Traffic Signal Controller, Non-ASCT, Furnish and Install, measured per each.

10. MaxView by Intelight Central Management Software License for Existing Traffic Signal Controller

10.1 Furnish Only
A license for communicating with the MaxView central management software shall be acquired and provided to the City for each existing Econolite ASC/3 traffic signal controller in the Project that is to remain in place and be connected to the central management system.

10.2 Basis of Payment
Measurement and payment for items covered by this specification are as follows:

Bid Item Maxview Software License for Existing Traffic Signal Controller, Furnish Only, measured per each.