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USACE / NAVFAC / AFCEC / NASA **UFGS-27 13 23.00 40 (February 2023)**

Preparing Activity: NASA **Superseding**
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UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2023
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DIVISION 27 - COMMUNICATIONS

SECTION 27 13 23.00 40

COMMUNICATIONS OPTICAL BACKBONE CABLING

02/23

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SECTION 27 13 23.00 40

COMMUNICATIONS OPTICAL BACKBONE CABLING
02/23

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NOTE: This guide specification covers the requirements for requirements for fiber optic cable systems.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

****

PART 1 GENERAL

1.1 REFERENCES

****

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM C338	(1993; R 2013) Standard Test Method Softening Point of Glass
ASTM D4976	(2012a) Standard Specification for Polyethylene Plastics Molding and Extrusion Materials

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C2	(2023) National Electrical Safety Code

INSULATED CABLE ENGINEERS ASSOCIATION (ICEA)

ICEA S-87-640	(2023) Optical Fiber Outside Plant Communications Cable; 4th Edition

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA RN 1	(2005; R 2013) Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit
NEMA TC 2	(2020) Standard for Electrical Polyvinyl Chloride (PVC) Conduit
NEMA TC 3	(2021) Polyvinyl Chloride (PVC) Fittings for Use With Rigid PVC Conduit and Tubing
NEMA TC 6 & 8	(2020) Standard for Polyvinyl Chloride (PVC) Plastic Utilities Duct for Underground Installations
NEMA TC 9	(2020) Standard for Fittings for Polyvinyl Chloride (PVC) Plastic Utilities Duct for Underground Installation

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2023) National Electrical Code

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

SAE AMS-STD-595A	(2017) Colors used in Government

Procurement

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)

TIA-472D000	(2007b) Fiber Optic Communications Cable for Outside Plant Use
TIA-492CAAB	(2005) Detail Specification for Class Iva Dispersion-Unshifted Single-Mode Optical Fibers with Low Water Peak
TIA-526-7	(2015a; R 2022) Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant, Adoption of IEC 61280-4-2 edition 2: Fibre-Optic Communications Subsystem Test Procedures - Part 4-2: Installed Cable Plant - Single-Mode Attenuation and Optical Return Loss Measurement
TIA-526-14	(2023d) OFSTP-14A Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant
TIA-568.1	(2020e) Commercial Building Telecommunications Infrastructure Standard
TIA-568.3	(2022e) Optical Fiber Cabling Components Standard
TIA-569	(2019e; Add 1 2022) Telecommunications Pathways and Spaces
TIA-590	(1997a) Standard for Physical Location and Protection of Below Ground Fiber Optic Cable Plant
TIA/EIA-598	(2014D; Add 2 2018) Optical Fiber Cable Color Coding
TIA/EIA-604-3	(2004b; R 2014) Fiber Optic Connector Intermateability Standard (FOCIS), Type SC and SC-APC, FOCIS-3

U.S. DEPARTMENT OF AGRICULTURE (USDA)

RUS Bull 1753F-601a	(2009) Minimum Performance Specification for Fiber Optic Cables (For Backbone, Feeder and Distribution Plant) (PE-90a)

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-STD-2042	(2002; Rev B; Notice 1 2007) Fiber Optic Cable Topology Installation Standard Methods for Naval Ships

1.2 DEFINITIONS

References in this section to cable refer to fiber optic ("FO") cable.

Fiber optic cable consists of optical fibers, strength member[s], and jacketing. Associated components include optical fiber connectors, optical patch panels, terminal bay cabinets, and splice closures as indicated.

1.3 ADMINISTRATIVE REQUIREMENTS

1.3.1 Pre-Installation Meetings

Within [30] [_____] calendar days after [date of award] [date of receipt by him of notice of award], submit for the approval of the Contracting Officer [six (6)] [_____] copies of outline drawings of all equipment to be furnished under this contract, together with pre-construction and installation drawings and documents. Ensure drawings show the general arrangement and overall dimensions of the cable installation, control centers, space requirements, details of any hidden floor supports or ceiling systems and provisions for conduits for external cables. Submit the following for review and approval:

a. Fiber Optic System Contract Drawings

b. Detailed Shop Drawings

c. Qualifications

d. Quality Assurance Plan

Submit a quality assurance plan for fiber optic cable systems consisting of detailed procedures defining methods to ensure compliance to contract drawings and specifications by drawing control, inspection and procurement records, and test plan showing when and how each system will be tested, material testing, and certification records. Submit test plan to the Technical Representative for approval at least [30] [_____] calendar days prior to the start of testing.

Submit manufacturer's product data for the following items. Ensure data includes a complete list of parts, special tools, and supplies with current unit prices and source of supply:

a. Optical Fibers

b. Fiber Optic Cable Design

c. Splice Organizers

d. Pre-Connected Cable Assembly

e. Fiber Optic Terminal Cabinets

f. Optical Patch Panel Assemblies

g. Fiber Optic Media Types

h. Fiber Optic Terminations and Connectors

i. Fiber Optic Enclosures

j. Fiber Optic Cable Installer and Splicer Qualifications

k. Manufacturer's Qualifications

1.4 SUBMITTALS

****

NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Qualifications[; G[, [____]]]

Quality Assurance Plan[; G[, [____]]]

SD-02 Shop Drawings

Fiber Optic System Contract Drawings[; G[, [____]]]

Detailed Shop Drawings[; G[, [____]]]

Record (As-Built) Drawings[; G[, [____]]]

SD-03 Product Data

Optical Fibers[; G[, [____]]]

Fiber Optic Cable Design[; G[, [____]]]

Splice Organizers[; G[, [____]]]

Pre-Connected Cable Assembly[; G[, [____]]]

Fiber Optic Terminal Cabinets[; G[, [____]]]

Optical Patch Panel Assemblies[; G[, [____]]]

Fiber Optic Media Types[; G[, [____]]]

Fiber Optic Terminations and Connectors[; G[, [____]]]

Fiber Optic Enclosures[; G[, [____]]]

SD-06 Test Reports

Single and Multi-Mode OTDR Test[; G[, [____]]]

Fiber Optic Field Tests Plan[; G[, [____]]]

SD-07 Certificates

Fiber Optic Cable Installer and Splicer Qualifications[; G[, [____]]]

Manufacturer's Qualifications[; G[, [____]]]

SD-08 Manufacturer's Instructions

1.5 QUALITY CONTROL

1.5.1 Fiber Optic Cable Installer and Splicer Qualifications

Provide technicians installing FO media, splices and performing system tests who are certified and trained in accordance with an approved manufacturers training program, with a minimum of 3 years FO experience in installing equivalent FO systems. Submit data for approval to the [____] Contracting Officer. Submit FO technician qualifications for approval 30 days before splices are to be made on the cable. Certification includes the training, and experience of the individual on specific type and classification of FO media to be provided under this contract.

1.5.2 Quality Assurance Plan

Prepare a quality assurance plan which provides a detailed outline of all testing to be accomplished. Quality assurance plan includes, as a minimum, a schedule of when tests will be performed relative to installation milestones, specific test procedure that will be used, a list of test equipment that will be used including manufacturer, model number, range, resolution accuracy and conformance to the specified requirements.

1.5.3 Manufacturer's Qualifications

Ensure FO media manufacturer has a minimum of 3 years experience in the manufacturing, assembly, and factory testing of FO media which comply with RUS Bull 1753F-601a. Ensure manufacturer provides a list of customers with 3 years of maintenance logs documenting experience with government customers.

1.5.4 Fiber Optic Field Tests Plan

Prepare and provide technicians and test equipment for field tests of FO media. Perform OTDR and end to end tests of all installed media. Conduct tests on single mode fiber in accordance with TIA-526-7 for single mode fiber and TIA-526-14 for multi mode fiber.

1.6 DELIVERY, STORAGE, AND HANDLING

Ship media to job site on factory reels in [____] m [____]-ft lengths or in factory cartons. Provide a reel drum radius no smaller than the minimum bend radius recommended by the manufacturer for the media. Attach a permanent label on each reel showing length, media, identification number, and date of manufacture. Provide water resistant label and ink on the labels. Apply end seals to each end of the media to prevent moisture from entering the cable while stored at the job site. Ensure reels are suitable for outside storage conditions when temperature ranges from minus 40 degrees C to plus 65 degrees Cminus 40 degrees F to plus 150 degrees F, with relative humidity from zero to 100 percent. Store equipment, other than FO media, delivered and placed in storage with protection from weather, humidity and temperature variation, dirt and dust, or other contaminants.

1.7 PROJECT/SITE CONDITIONS

Ensure that the buried cable is fed through the plow into the ground at zero tension. Do not allow tension to develop in the cable.

Whenever the plow is stopped, unreel sufficient cable to guard against sudden jerks when the plow is started.

Exercise caution to ensure that the plow is not backed up while the blade is in the ground. Cable can be severely damaged by the plow backing up even a slight amount. During the plowing operation, the plow may strike a buried object or rock that would stop the equipment and necessitate removal of the plow from the ground. When this occurs, remove the plow carefully without backing up. When it is necessary to back the plow, uncover the cable a sufficient distance back from the plow for inspection by the Contracting Officer to determine if there is any damage. Immediately report any damage to the Contracting Officer. Repair or replace damages as directed by the Contracting Officer.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

Provide fiber optic cables for the duct in the existing cable duct and manhole system and/or directly buried to the facility. Provide modifications as design located within the fiber optic terminal in existing facility buildings.

Provide installation methods and procedures for installing the FO media and pathway system. Include methods and procedures for installing FO media, pathway, splices, and associated hardware. Submit installation procedures and equipment list to the Contracting Officer.

****

NOTE: Verify design drawings provide physical location details for aerial poles, underground media routes, maintenance holes, handholes, ducts, duct banks, pathways, cable markers, and related hardware. Show telecommunications rooms, closets, and backboards on drawings. Provide a telecommunications media schedule on the drawings with FO pair, counts, media length and pathway length. Perform pathway fill, (max 40 percent), and media tension calculations for all runs. Ensure materials are listed as RUS certified for the application http://www.usda.gov/rus/telecom/materials/material.htm

Ensure design drawings provide details for installation of the FO cable in accordance with EIA/TIA-590.

****

Provide detailed drawings for the fiber optic cable and pathway system. Provide single line schematic details of the fiber optic and pathway media, splices, and associated construction materials. Ensure drawings are in AUTOCAD.DXF or compatible format. Provide Registered Communications Distribution Designer (RCDD) approved drawings of the fiber optic system. Include drawing details of fiber optic terminations in equipment rooms. Show final configuration, including location, fiber pair count, pathway innerduct arrangement, and pathway assignment of outside plant.[Design Pier FO systems for compatibility with MIL-STD-2042 and NAVSEA drawings.]

2.1.1 Fiber Optic Cable Design

2.1.1.1 Fiber Optic Media Types

Verify FO media meets all performance requirements of TIA-568.1, TIA-568.3 and the physical requirements of ICEA S-87-640 and TIA/EIA-598.

****

NOTE: Specify requirements for Fiber Optic media from the following selections:

Fiber Optic Media Type:
(single mode) (multi mode) (hybrid)

Fiber Count: [12][24][48][ ][216]

Media Optic Characteristics:
Fiber core diameter: [50]mmf [62.5]mmf or [ ]smf
Bandwidth 850nm mHz/km: [500]50$_{\mu}$m [160] 62.5$_{\mu}$m
Bandwidth 1300nm mHz/km: [500]50$_{\mu}$m [500]62.5$_{\mu}$m
Attenuation 850nm dB: [2.5]50$_{\mu}$m [3.0]62.5$_{\mu}$m
Attenuation 1300nm dB: [0.8]50$_{\mu}$m [0.7]62.5$_{\mu}$m

Bending Radius mm: [30]50µm [30]62.6µm [30]smf
****

a. Multi Mode Fiber Media

Provide FO media with outer sheath jacket,[strength member,] ripcords, water blocking material,[optional steel shield,] core tube, and core fibers as installed in a permanent underground pathway system as shown on the construction drawings. Provide FO media with an all glass, graded index material with a nominal core diameter of 50 microns. Provide a cladding material for the fiber which is compatible with the core. Center media transmission window at 850 and 1300 nanometer wavelengths, with attenuation at 1300 nanometers less than or equal to 1.5 dB per kilometer, and minimum bandwidth of 500 mHz-Km. Verify FO media complies with TIA-568.3.

****

NOTE: Specify the number of fiber strands. The minimum number of fiber to a facility or building is 12 plus 25 percent spare capacity. Specify loose tube or tight tube design. In general use gelatin filled media unless tight tube is required to interface with customer terminal equipment. The loose tube construction is more appropriate where media is subject to numerous bends along the cable route. This includes aerial and long distance runs (over one Km). Tight tube design may be used for exterior direct burial in ducts below the frost line. For Navy projects the preferred underground installation is within a pathway system compliant with EIA/TIA-569. Ensure direct burial installations comply with EIA/TIA-590. Media for Defense Information System Agency (DISA) equipment connection should comply with Mil-Std-188-176. 62.5 micron fiber should only be used for passive extension of existing fiber systems. New system fiber connected to electronics should be 50 micron.
****

b. Single Mode Fiber Media

Provide FO single mode media with outer sheath jacket,[strength member,] ripcords, water blocking material,[optional steel shield,] core tube, and core fibers as installed in a permanent underground pathway system as shown on the construction drawings. Provide media with all glass, dual window, graded index material with a core diameter of [____][8.7] microns. Coat fiber with a cladding material which is concentric with the core. Ensure fiber cladding diameter is a nominal 125 microns, and media has a transmission window centered at 1300 and 1550 nanometer wavelengths. Attenuation at 1550 nanometers is less than 0.4 dB per kilometer. Verify FO media complies with TIA-568.3, and TIA-492CAAB (OS2).

2.1.1.2 Cable Length

Ensure cable is manufactured continuous with no factory splices.

2.1.1.3 Construction

a. Number of Fibers Per Tube Per Cable

36-fiber cable and 72-fiber cable are required as follows:

(1) Provide 36-fiber cable containing multimode and single mode fibers, with cable core configuration comprised of six loose buffer tubes, each containing six fibers. Color code six fibers in each loose buffer tube using the first colors of the standard Munsell color code, Blue, Orange, Green, Brown, Slate, and White. Color code loose buffer tubes using the standard Munsell color code, Blue, Orange, Green, Brown and Slate. Ensure sixth buffer tube is Pink. Consider single mode fibers last in configuration.

(2) Provide 72-fiber cable containing multimode and single mode fibers, with cable core configuration comprised of 12 loose buffer tubes, each containing six fibers. Color code six fibers in each loose buffer tube using the first colors of the standard Munsell color code, Blue, Orange, Green, Brown, Slate and White. Color code loose buffer tubes using the standard Munsell color code, Blue, Orange, Green, Brown, Slate, Red, Black, Yellow, and Violet. Ensure eleventh and twelfth buffer tubes are Blue/White and Orange/White, respectively. Consider single mode fibers last in configuration.

b. Inner Jacket

Locate buffer tubes concentrically around the cable central core member and covered with a polyethylene inner jacket. Ensure inner jacket is [high] [medium] density polyethylene in accordance with ASTM D4976. Fill space between the buffer tubes and inner jacket with a gel compound to prevent air, moisture, or water intrusion in the inner jacket.

c. Pulling Strength Member

Use a ramid type material as pulling strength members in the cable to provide pulling strength of at least [1800] [_____] newton [400] [_____] pounds for the cable during installation.

d. Cable Outer Jacket

Apply black [high] [medium] density, high-molecular weight, polyethylene materials in accordance with ASTM D4976 longitudinally over all the inner jacket and sheathing strength member to form the cable outer jacket. Ensure outer jacket is smooth, concentric, non-nutrient to fungus, and free from holes, splits, blisters, or other imperfections. Overall outside cable diameter cannot exceed [19] [_____] millimeter [0.75] [_____]-inch.

e. Metallic Armor

Provide a metallic armor shield for direct buried cable for additional tensile strength, rodent protection, and high crush and moisture resistance. Provide metallic armoring of metallic tube or steel corrugation-coated with anti-corrosion material, sealed at the longitudinal overlap.

2.1.2 Cable Identification

A single line of the cable ID indicates multi-mode or single mode fibers, the cable number and the fiber count. A hybrid cable will show both on

the same line.

Example:

FM05 : 61-120	Identifies Multi-Mode Fiber Cable 05 with MM Fibers 61 through 120.
FS05 : 13-24	Identifies Single Mode Fiber Cable 05 with SM Fibers 13 through 24.

2.1.3 Temperature Environment

Provide fiber optical cable compliant with the mechanical performance requirements herein while used in duct applications where the temperature varies from minus 8 degrees C to plus 38 degrees C 17.6 degrees F to 100 F. Ensure optical performance degradation is less than [five] [_____] percent of the optical performance requirements in the temperature range of minus 20 degrees C to plus 60 degrees C 4 degrees F to 140 degrees F. Do not damage fiber optical cable in storage where the temperature may vary from minus 40 degrees C to plus 65 degrees C 40 degrees F to 149 degrees F.

2.2 EQUIPMENT

2.2.1 Splice Organizers

Provide fusion spliced single mode or multi-mode fibers with a protective sleeve covering, stored in an organizer with a minimum of 450 millimeter 18-inches spare coiled buffer tubing or ribbon.

2.2.2 Pre-Connected Cable Assembly

Provide factory assembled pre-connectorized cable assembly to interface with the patch panel bulkhead feed-through receptacle. Provide dust caps for all terminated fibers.

Ensure multi-mode fiber optic cable assembly is comprised of a single fiber connector, terminated on [three (3)] [_____] meter length of single fiber, multi-mode cable. Verify single fiber cable contains a buffered optical fiber the same as that provided in the multi-fiber cable.

Ensure single fiber optic cable assembly is comprised of a single fiber connector terminated on the [three (3)] [_____] meter length of single fiber, single mode cable. Single fiber cable contains a buffered optical fiber, the same as that provided in the multi-fiber cable. Ensure return loss for single mode connectors is a minimum of [minus 30dB] [_____].

Provide connector/cable interface on both the single and multi-mode cable assemblies able to withstand a tensile force of [110] [_____] newton [25] [_____] pounds without detrimental effects on the connector loss characteristics.

Verify each connectorized cable assembly has a loss of less than or equal to [0.5 dB] [_____].

2.2.3 Optical Patch Panel Assemblies

Provide all cable terminations in optical patch panel assemblies, with patch panel assemblies of the pre-assembled chassis type with associated rack-mounting hardware.

To facilitate the transition between outside plant cable and the preconnectorized cable assemblies, ensure the fibers are [fusion] [mechanical] spliced and housed in a splice tray. Position splice tray in the optical patch panel assembly as indicated. Ensure splice attenuation does not exceed [0.2] [_____] db. Cover splice with a protective sleeve.

2.2.4 Fiber Optic Terminal Cabinets

Provide front recess only FOT cabinets. Cabinet's frame consists of vertical and horizontal tubular aluminum extrusions with a minimum wall thickness of [3.81] [_____] millimeter [.150] [_____]-inches. Ensure front to rear aluminum extruded corners are at least [3.18] [_____] millimeter [.125] [_____]-inches thick, and rear door, top panel, and side panels are a minimum of [1.3] [_____] millimeter [18] [_____]-gage steel. Provide cabinet with [1.9] [_____] millimeter [14] [_____] gage steel, [7.14] [_____] millimeter [.281] [_____] inches punched panel/chassis mounting rails permitting recessed installation of equipment. Place cable entry and exit holes as indicated. Verify dimensions of cabinet and associated cabinet hardware are as indicated.

Provide gray color cabinet in accordance with SAE AMS-STD-595A.

2.2.5 Fiber Optic Enclosures

Provide metallic enclosures for fiber optic data transmission equipment. NEMA 250, type 4 enclosure. Protect the spliced fibers from moisture and physical damage. Splice closure provides strain relief for the cable and the fibers at splice points. Provide full documentation citing conformance to structural parameters.

2.2.6 Fiber Optic Terminations And Connectors

FO connectors to comply with TIA-568.3 and TIA/EIA-604-3.

2.2.7 Fiber Optic Pathway System

Provide an FO pathway system including raceway conduit, duct system, and maintenance manholes and handholes as shown on the drawings. Provide pathway materials compliant with TIA-569, and the following commercial standards for construction materials, NEMA RN 1 (PVC), NEMA TC 2 (PVC), NEMA TC 3 (PVC), NEMA TC 6 & 8, and NEMA TC 9.

2.2.7.1 Conduit

****
NOTE: Delete the following paragraph and specify the specific conduit requirements for small projects in this section.
****

[Provide conduit as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.

]2.2.8 FO Media Tags

Provide stainless steel, 41.25 mm 1 5/8-inches in diameter 1.58 mm 1/16-inch thick, and circular in shape.

2.2.9 Buried Warning and Identification Tape

Provide color, type and depth of tape as specified in paragraph "Buried Warning and Identification Tape" in Section 31 00 00 EARTHWORK. Ensure FO media is marked and protected as required by TIA-590.

2.2.10 Grounding Braid

Provide low electrical impedance connections grounding braid from flat tin-plated copper for dependable shield bonding.

2.3 MATERIALS

Verify all materials used within a given cable are compatible with all other materials used in the same cable when such materials come into intimate contact. Ensure all cable components used have no adverse affect on optical transmission or on the mechanical integrity characteristics of the fiber placed in the cable, and all materials used are non-toxic, non-corrosive, and present no dermal hazard.

Minimum required material components applied to fiber optic cable construction are: central core member, ribbon fiber bundle, color-coded optical fiber, color-coded loose tube buffer with gel-filling, gel-filling around loose tube, inner jacket, pulling strength members, and outer jacket. Variations in sequence and construction structural components will be considered when necessary.

2.3.1 Central Core Member

As applicable, include a central core member to serve as a cable core foundation to reduce strain on the fibers but not to serve as a pulling strength member. Ensure material of the central core member is non-metallic.

2.3.2 Optical Fibers

Provide two types of optical fibers, single-mode fiber and multi-mode fiber, within the cable as follows:

2.3.2.1 Single-Mode (SM) Fiber

Provide Single-Mode (SM) fiber of equivalent [step] [graded] index optical glass, with a fiber core diameter of approximately 8.7 micrometer. Cladding diameter is 125 plus or minus 3 micrometer with core cladding offset less than 1 micrometer. Ensure minimum tensile strength of the fiber after primary protective coating is greater than 350,000 kilopascal 50,000 psi.

2.3.2.2 Multi-Mode (MM) Fiber

Provide Multi-Mode (MM) fiber of the [graded] [step] index optical glass type, with a core diameter of [50] [62.5] plus or minus 3 micrometers. Cladding diameter is 125 plus or minus 3 micrometers. Ensure the core-cladding offset is less than 3 micrometer, and the minimum tensile strength of the fiber after primary protective coating is greater than 350,000 kilopascal 50,000 psi.

Softening point of the optical fiber clad material is 1630 degrees C plus or minus 50 degrees C in accordance with ASTM C338, or the optical fiber

meets the requirements in paragraph SPLICE COMPATIBILITY TEST.

2.3.3 Fiber Primary Protective Coating

Coat optical fiber with suitable material to preserve the intrinsic high tensile strength of the glass fiber. Ensure outside diameter of the coated optical fiber is 250 (plus or minus 15) micrometer. Provide coating material which is readily removable, mechanically or chemically, without damaging the optical fibers when the removal is desired.

2.3.4 Optical Fiber Color-Code Coating

Coat primary protective coated SM and MM fibers with a color-code coating for individual fiber identification. Maximum outside diameter of color-code coated fiber is less than 300 micrometer.

2.3.5 Loose Tube Buffering

Surround color-code coated fiber[s] with a loose tube buffering for protection from external mechanical and environmental influences. Fill interior of the tube with a suitable gel-fitting compound to prevent water migration. Color code loose tube buffering for the tube identification. Ensure material of the buffering tube is [PVC] [mylar] [nylon] [_____].

2.3.6 Optical Fiber Ribbons

A ribbon is a planar array of optical fibers typically with a count of 12 or 24 comprising one unit and within a cable multiple units shall be appropriately identified and constructed, per TIA-472D000.

2.3.7 Colorants

Verify color concentrates or inks used to color code the optical fibers and the loose buffer tube are not susceptible to migration and chemical reaction with gel filling compound.

2.3.8 Filling Compound

Ensure inner jacket interior, loose tube buffer or ribbon fiber bundle cavity contains a gel-type filling compound, of suitable viscosity so that it protects the optical fibers against the ingress of water and/or soluble chemicals, and not flow at the temperature of up to 65 degrees C 149 degrees F. Verify gel filling compound is electrically non-conducting, inert gel-type, waterproof compound, non-toxic, with no dermal hazards, and compatible chemically and mechanically with all cable components and associated splice hardware materials to which it may make contact. Ensure gel filling compound is removable, as required, using commercially available products under field-type conditions.

PART 3 EXECUTION

3.1 INSTALLATION

Install and test the FO media in accordance with contract drawings, specifications, [IEEE C2,] NFPA 70, and TIA-590. Provide all necessary power, utility services, technicians, test equipment, calibration equipment as required to perform final acceptance tests of the media. Replace media which fails the final acceptance field tests and re-test at the contractors expense.

3.1.1 Fiber Splices

Splices are not permitted unless shown on the construction drawings.

Test splices to demonstrate a maximum 0.2 dB loss. Provide [fusion] [mechanical] type outside plant fiber splices along the fiber route. Make all splice measurements at 1300 nm, plus or minus 5 nm. Mount all splices in trays. Do not increase number of splices.

Protect media ends of unspliced FO media during splicing operations. Cover completed splice with a protective sleeve heat shrink type to restore the protective properties of the fiber coating and buffering. Deviations to the splice, location and pulling plan will be permitted, upon approval by the Contracting Officer, at no additional cost to the Government.

Ensure all fiber colors are continuous from end to end. No switching or staggering of color scheme within the cable at splice points is allowed. Splice fibers in order with multi-mode fibers identified first and single mode fibers at the end.

Bring cables out of the manhole in a controlled environment to perform the fiber fusion splice operation. Complete splice by returning the cable to the manhole such that the excess cable does not impede future entrance and utilization. Secure cable at regular intervals.

3.1.2 Contractor Damage

Promptly repair indicated utility and communications lines or systems damaged during site preparation and construction. When Contractor is advised in writing of the location of a non-indicated line or system, such notice provides that portion of the line or system with "indicated" status in determining liability for damages. In every event, immediately notify the Contracting Officer of damage.

3.1.3 Buried Cable and/or Inner-Duct for Blown Fiber Optic Cable

3.1.3.1 Location

****

NOTE: Buried cable installation refers to the placement of cables directly in the ground without protection other than their own outer coverage (jackets). The overall buried cable installation may include manholes and hand holes, for splicing, terminating and pull-through purposes.

****

Verify location of the cable splice overlaps as indicated. Ensure that all cable ends are sufficiently long before cutting.

3.1.3.2 Field Staking

When staking the cable plow or trench line, place stakes at least every 30 meter 100-feet in level country and more frequently in rolling country or in dense vegetation, so that the construction force can sight at least two successive stakes at all times. Place stakes at changes in direction. The beginning and end of all turns should be staked clearly. Where

existing buried cable is encountered within [600] [_____] millimeter [2] [_____]-feet of the proposed line, decrease the distance between stakes to a minimum of [3] [_____] meter [10] [_____]-feet. When possible, stakes should project above the vegetation along the line. When a road or other crossings are involved, Place stakes at both extremes of the right-of-way.

A stake, with the appropriate number or explanation noted on it, should be used to show the location of each caution point, such as underground utility crossings and culverts; miscellaneous points, such as physical cable protection; and buried cable warning sign locations.

3.1.3.3 Method of Cable Placement

****

NOTE: Method used in placing the cable depends on the exact location of the route, obstructions encountered, soil conditions, and topography of the route. Use method which best suits the local conditions and which produces the least amount of disturbance or damage to existing utilities and surrounding areas should be used. Under certain conditions, combinations of placing methods may be advantageous.

****

Place a warning tape above all direct buried cable and inner-duct.

Ensure depth of buried cable and inner-duct in soil measured from the top of the cable or inner-duct to the surface of the ground is a minimum of [800] [_____] millimeter [30] [_____]-inches. When existing utilities are crossed, use hand excavation at a distance of no less than [1.3] [_____] meter [four] [_____]-feet on each side of the utility.

a. Open Trench Method

(1) Ensure trench is free of all rock and debris.

(2) Pull cable or inner-duct from cable reel truck or dolly and place in the trench by hand.

(3) Place cable or inner-duct in trench as soon as practical and backfill immediately to avoid cave-in, and ensure safe operational conditions.

(4) Provide inspection closely behind the cable reel dolly and ensure that the cable or inner-duct lies flat on the trench bottom, and is placed at the required minimum depth.

(5) Pull cable or inner-duct by hand on each end simultaneously, to remove excess slack, prior to backfilling.

(6) Backfill trench in [150] [_____] millimeter [six] [_____]-inch lifts to ensure proper fill. Compact each backfill lift with hand tamp tools. Hand tamp first lift prior to placing the cable.

b. Direct Plow Method

(1) Ensure plow is clear of any obstruction which may damage cable or inner-duct and that all rollers on the tractor and on the plow

turn freely and are properly located.

(2) Hand feed cable or inner-duct off the reel at all times to ensure that no damage is done to the cable due to excess tension.

(3) Closely inspect the cable or inner-duct for any blemish or damage, and ensure a free and continuous flow of the cable or inner-duct from the reel to the plow. Ensure that the cable or inner-duct is plowed at the minimum required depth.

3.1.3.4 Compaction

****
NOTE: The following method of compaction is recommended: Run the tractor track or tire along and immediately adjacent to both sides of the plow slot; fill in any ground depressions which may develop with earth to form a mound over the center of the plow slot; and then run the tractor tire over the center slot. Different soil conditions may warrant that other methods of compaction be employed.
****

Compact the plow slot following the plowing or trenching of wire or cable.

3.1.4 Underground Cable Pulling in Ducts or Inner-Ducts

Provide inner duct assignment of individual cables as indicated. Do not place cables in ducts other than those specified.

Exercise adequate care when handling and storing reels of cable to prevent damage to the cable. Do not install cable with dents, flat spots, or other sheath distortions.

3.1.4.1 Securing Cable

Immediately after cable placement, attach a permanent identification tag as indicated to visible cable sections. Check cables to ensure that the markings are intact.

Support and secure cables and equipment as indicated. Where the specific method of support is not shown, use supports and fasteners to secure cables and equipment in position. Provide metallic supports and fasteners with a corrosion resistant finish. Rout all cables along the interior sides of manholes.

Provide two or more cable hooks per manhole.

Use clamps and straps as necessary to properly secure the cable.

3.1.4.2 Bending

Use caution when bending cable to avoid kinks or other damage to the sheath. Bend radius is as large as possible with a minimum of [250] [_____] millimeter [10] [_____]-inches. Increase minimum radius when necessary to meet cable manufacturer's recommendation. Do not rest cables against any sharp edges.

Pull and splice cable in the manner and at the locations shown.

3.1.4.3 Pulling

Attach pulling lines to both cable ends when cable is destined for bi-directional pull, and fitted with factory-installed pulling eyes. Pull cables not equipped with a pulling eye using a pulling line attached to the cable end by means of a cable grip. Do not use core hitches.

Locate and align cable reels so that the cable is paid out from the top of the reel into the duct or conduit in a long, smooth bend without twisting. Do not pull cable from the bottom of the reel. Use a cable feeder guide of proper dimensions at the mouth to guide the cable into the duct or conduit.

Set up rigging at the pulling end so that the pulling line and cable exit on a line parallel with the duct or conduit to prevent either from rubbing against the edge or mouth. Do not pull cable ends around sheave wheels. When the sheave or pulley cannot be positioned to obtain sufficient cable end slack for proper racking and splicing with the pulling line attached to the end of the cable, a split cable grip may be used to obtain the necessary slack.

3.1.4.4 Lubricant

Use pulling lubricant to minimize pulling tension and prevent sheath damage when pulling cables into ducts and conduits. Apply lubricant to the cable sheath with a lubricator. When pulling has been completed, wipe the exposed cable ends clean of lubricant.

Ensure lubricants are compatible with and intended for use with plastic-sheathed cables. Do not allow soap and grease type lubricants.

Check all equipment and the pulling set to minimize interruptions once pulling begins. Pull cable without stopping until the required amount of the cable has been placed. When the pulling operation is halted before the pull is completed, do not release the tension of the pulling line. When pulling is resumed, overcome the inertia of the cable by increasing the tension in small steps a few seconds apart until the cable is in motion. Feed the cable from the top of the reel by rotating the reel in the feed direction at the rate of pull. Do not strip cable off the reel by pulling.

3.1.4.5 Damage and Defects

Use a tension monitoring device to ensure that the maximum pulling tension that may be applied to the cable to be pulled into a conduit section is not exceeded. Any damage to the cable due to exceeding the maximum tension will require a new cable furnished by the Contractor.

Carefully inspect cable for sheath defects or other irregularities as it is paid out form the reel. When defects are detected, stop pulling immediately and repair or replace the cable section at the discretion of the Contracting Officer. Maintain a system of communications between pulling and feed locations so that pulling can be stopped instantly, when required.

Hand guide cable through intermediate manholes and into the next duct section when making pull-throughs. Use proper rigging in the intermediate manhole to keep the pulling line and cable aligned with the exit duct to

prevent the line or cable from rubbing against the edge of the duct. Set up cables in pull-through manholes and rack before the cable ends in adjacent manholes are set up and racked.

Tie cable ends pulled into manholes, vaults, or terminal locations that are not to be racked or otherwise permanently positioned immediately, in fixed positions to prevent damage to the cables and provide adequate working space.

3.1.4.6 Seal

Seal ducts or innerduct in which cable is placed with urethane foam duct seal. Insert this material between the cable and the duct or innerduct of which it is in, between the innerduct and the duct, and in all unused innerduct, in order to prevent damage to the cable sheath and to prevent the entrance of dirt or water into the manhole or vault.

Provide cables in continuous lengths as required to accomplish the required installation without splices from termination to termination, except where field splices are specifically shown.

3.1.5 Underground Air-Blown Fiber Installation in Inner-Ducts

The blowing method is preferred over traditional pulling method due to savings in manpower, installation time and reduced stress on the fiber optic cable and provides additional protection by the inner duct. Longer runs can be achieved blowing, especially in runs with multiple bends and undulations. This method begins with pre-installed smooth-wall plastic inner-ducts varying in size from 1, 1.25, or 1.5 inches in diameter and color. Corrugated inner ducts are not to be used for blowing. Smooth-wall inner ducts are joined with mechanical splices for continuous blowing operations. Extra inner-ducts of different colors should be installed as applicable for future use in direct buried operations and to fill exiting duct space between maintenance holes and when removing large abandon cable with a risk of a duct collapse. Future use inner-ducts shall be mechanically spliced at junction points and the ends capped to prevent debris from entering. Trench or direct bury applications shall include a ground wire for future locates.

High-speed air flow combined with mechanical pushing is called "blowing or jetting". Compressed air is injected in the inner duct inlet after few hundred feet of cable is pushed into the duct. Compressed air flows at high speed through the inner duct and along the cable. The pushing force is applied mainly near the cable inlet by a pushing device. Standard optical fiber optic cables are blown down the inner duct assisted by air pressure, which pushes and floats the cable along the path up to 6,000 feet or more. The pushing device, better known as the "Blowing Machine" basically captures the cable between two belts, sandwiched and pushed forward by hydraulic or air assisted drive to control the cables forward speed as it's combined with high-speed air.

Air blown fiber installation equipment usually includes the blowing machine, air compressor, water separator, hydraulic pump, and cable spool.

3.1.6 Cable Installation in Cable Trays

Do not install communication cables in the same cable tray with ac power cables.

Install cables placed in cable trays in a neat and orderly manner and not crossed or interlaced with other cables except at breakout points.

Individually retain cables in vertical trays with straps at a maximum of [1800] [_____] millimeter [6] [_____]-feet on center.

3.1.7 Grounding Systems

Ground cables at each termination point or as indicated.

3.1.8 Direct Burial System

****
NOTE: Specify the depth of media placement. Designer may specify air blown fiber installed in new or existing underground duct pending the approval of the media manufacturer. Air blown fiber installation and construction materials require approval by the contracting officer.
****

Verify installation is in accordance with TIA-590. Under railroad tracks, paved areas, and roadways install cable in conduit encased in concrete. Slope ducts to drain. Excavate trenches by hand or mechanical trenching equipment. Provide a minimum cable cover of 610 mm 24-inches below finished grade. Ensure trenches are not less than 155 mm 6-inches wide and in straight lines between cable markers. Do not use cable plows. Provide bends in trenches with a radius of not less than [915][_____] mm [36][_____]-inches. Where two or more cables are laid parallel in the same trench, space laterally at least 75 mm 3-inches apart. When rock is encountered, remove it to a depth of at least 75 mm 3-inches below the cable and fill the space with sand or clean earth free from particles larger than 6 mm 1/4-inch. Do not unreel and pull cables into the trench from one end. Cable may be unreeled on grade and lifted into position. Provide color, type and depth of warning tape as specified in Section 31 00 00 EARTHWORK.

3.1.8.1 Media Placement

a. Separate FO media crossing other cables or metal piping from the other cables or pipe by not less than [75][_____] mm [3][_____]-inches of well tamped earth. Do not install FO media under or above traffic signal loops.

b. Provide media in one continuous length without splices except where splices are shown on the drawings.

c. Do not allow bends in media which exceed the manufacturers minimum recommended radii. Do not bend media to a radius less than 10 times the outside diameter of the media.

d. Leave a horizontal slack of approximately 915 mm 3 feet in the ground on each end of cable runs, on each side of connection boxes, and at points where connections are brought above ground. Where cable is brought above ground, leave additional slack to make necessary connections.

3.1.8.2 Identification Slabs (Markers)

Provide a marker at each change of direction of the cable, over the ends of ducts or conduits which are installed under paved areas and roadways and over each splice. Provide concrete identification markers, approximately 500 mm 20-inches square by 150 mm 6-inches thick and stake mounted warnings meeting the requirements of REA.

3.1.9 Underground Ducts

Construct underground duct as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION. Encase in concrete any ducts under roads, paved areas, or railroad tracks.

3.1.9.1 Connections to Existing Maintenance Holes [and Handholes]

For duct line connections to existing structures, break the structure wall out to the dimensions required and preserve the steel in the structure wall. Cut the steel and the duct line envelope.

3.1.9.2 Connections to Concrete Pads

For duct line connections to concrete pads, break an opening in the pad out to the dimensions required and preserve the steel in the pad. Cut the steel and extend it out to tie into the reinforcing of the duct line envelope. Chip out the opening in the pad to form a key for the duct line envelope.

3.1.9.3 Connections to Existing Ducts

Where connections to existing duct lines are indicated, excavate the lines to the maximum depth required. Cut off lines and remove loose concrete from the conduits before new concrete encased ducts are installed. Provide reinforced concrete collar, poured monolithically with the new duct line to take the shear at the joint of the duct lines.

3.1.10 Reconditioning of Surfaces

3.1.10.1 Unpaved Surface Treatment

Restore unpaved surfaces disturbed during the installation of duct or direct burial cable to their original elevation and condition. Carefully preserve existing sod and topsoil and replace after the back-filling is completed. Replace damaged sod with sod of quality equal to that removed. Where the surface is disturbed in a newly seeded area, re-seed the restored surface with the same quantity and formula of seed as that used in the original seeding.

3.1.10.2 Paving Repairs

****
NOTE: Choose one of the following options.
****

[a. Where trenches, pits, or other excavations are made in existing roadways and in other areas of pavement where surface treatment of any kind exists, restore such surface treatment or pavement to the same thickness and to the same kind as previously existed. Ensure surface treatment or pavement matches and ties into the adjacent and surrounding

existing surfaces.
]

****
NOTE: Insert appropriate Section number and title in the blank below using format per UFC 1-300-02 UNIFIED FACILITIES GUIDE SPECIFICATIONS (UFGS) FORMAT STANDARD**.**
****

[b. Make paving repairs as specified in [_____].

]3.1.11 Cable Pulling

Test duct lines with a mandrel and swab out to remove foreign material before the pulling of FO media. Avoid damage to cables in setting up pulling apparatus or in placing tools or hardware. Do not step on media when entering or leaving the maintenance holes. Do not place media in ducts other than those shown without prior written approval of the Contracting Officer. Roll cable reels in the direction indicated by the arrows painted on the reel flanges. Set up media reels on the same side of the maintenance hole as the pathway section in which the media is to be placed. Level the reel and bring into proper alignment with the pathway section so that the media pays off from the top of the reel in a long smooth bend into the duct without twisting. Do not, under any circumstances roll the media off from the bottom of the reel. Check the equipment set up prior to beginning the media cable pulling to avoid an interruption once pulling has started. Use a cable feeder guide of suitable dimensions between media reel and face of duct to protect media and guide cable into the duct as it is rolled off the reel. As media is rolled off the reel, lubricate and inspect media for sheath defects. When defects are noticed, stop pulling operations and notify the Contracting Officer to determine required corrective action. Stop media pulling if reel binds or does not roll off freely. Rectify cause of binding before resuming pulling operations. Provide media lubricants recommended by the cable manufacturer. Provide 1 meter 3.3-feet of spare media in all manholes and enclosures for final termination and testing.

3.1.11.1 FO Media Tensions

Install FO media as shown on construction drawings. Provide devices to monitor media tension during installation. Do not exceed manufacturers recommended maximum FO tensions and bending radii during installation.

3.1.11.2 Pulling Eyes

Equip media 30 mm 1-1/4-inches in diameter and larger with cable manufacturer's factory installed pulling-in eyes. Provide media with diameter smaller than 30 mm 1-1/4-inches with heat shrinkable type end caps or seals on cable ends when using cable pulling grips. Do not beat rings to prevent grip from slipping into the cable sheath. Use a swivel grip of 19 mm 3/4-inch links between pulling-in eyes or grips and pulling strand.

3.1.11.3 Media in Maintenance Manholes, Handholes, and Vaults

Do not install media utilizing the shortest route, but route along those walls providing the longest route and the maximum spare cable lengths. Form cables to closely parallel walls, not to interfere with duct entrances. Support media on brackets and cable insulators at a maximum of

1220 mm 4-feet. In existing maintenance manholes, handholes, and vaults where new ducts are to be terminated, or where new media are to be installed, modify the existing installation of media, cable supports, and grounding as required with cables arranged and supported as specified for new media.

3.1.12 Aerial Media

****
NOTE: Include tensioning and sag data on drawings in tabular form.
****

Provide pole installation as specified in Section 33 71 01 OVERHEAD TRANSMISSION AND DISTRIBUTION. Where physical obstructions make it necessary to pull distribution wire along the line from a stationary reel, use cable stringing blocks to support wire during placing and tensioning operations. Do not place ladders, cable coils, and other equipment on or against the distribution wire. Sag the wire in accordance with the data shown.

3.1.12.1 Aerial FO Media

Keep media ends sealed at all times using cable end caps. Take media from reel only as it is placed. During placing operations, do not bend in a radius less than 10 times the outside diameter of media. Place temporary supports sufficiently close together, and properly tension the media where necessary, to prevent excessive bending. In those instances where spiraling of media is involved, accomplish mounting of enclosures for purposes of loading, splicing, and distribution after the spiraling operation has been completed.

3.1.13 Grounding

****
NOTE: Verify the existence of grounding facilities. It is essential that all grounding facilities, new and existing, conform with IEEE C2, NFPA 70, MIL-HDBK-419, and MIL-STD-188-124.
****

Ground exposed non current carrying metallic parts of telephone equipment, media sheaths, media splices, and terminals.

3.2 FIELD QUALITY CONTROL

3.2.1 Test Requirements

Ensure test equipment used for verifying installation testing is calibrated by a certified testing company within [3] [_____] weeks of use.

3.2.1.1 Single and Multi-Mode OTDR Test

Ensure the Optical Time Domain Reflectometer (OTDR) conforms to the following minimum requirements:

a. Operating wavelengths: [1,300] [_____] plus or minus 20 nanometers and 1,550 [_____] plus or minus 10 nanometers.

b. Attenuation Range (one way): minimum [15] [_____] dB at 1,300 nm and attenuation at 1,550 nm less than the attenuation at 1,300 nm.

c. Maximum Optical Return Loss: [30] [_____] dB

d. Attenuation Resolution: [0.01] [_____] dB

e. Accuracy: plus [0.5] [_____] dB

Use OTDRs with digital readout capability and a means of providing a permanent record in the form of a [strip chart] [photograph] [_____].

As a minimum, test each fiber cable after installation for any faults or attenuations using an Optical Time Domain Reflectometer (OTDR).

Clearly state all test equipment, test procedures, and testing techniques in the quality assurance plan. Conduct tests in accordance with the approved Quality Assurance Plan. Ensure all field tests are witnessed by the Contracting Officer. Give Contracting Officer at least [20] [_____] calendar days notice prior to performing each test.

Provide each test sheet with a sign-off blank or cover page for both Contractor and the Contracting Officer. Deliver copies of the completed test forms and test results as indicated.

Record sequential cable markings along the cable on the sequential cable form, prior to and after each end of splice point, and submit for approval.

Maintain an accurate test record during all field tests.

3.2.2 Final Acceptance Tests

Perform end-to-end tests including power meter light source and OTDR tests. Perform OTDR measurements as required by TIA-568.1 and TIA-568.3. Test single mode fiber in accordance with TIA-526-7 (Optical Power Loss). Test multi mode fiber in accordance with TIA-526-14(Optical Power Loss).

3.2.2.1 Test Results

Provide results of final acceptance tests (OTDR traces, etc.), to the Contracting Officer within [5][_____] working days after completion of tests.

3.3 CLOSEOUT ACTIVITIES

Submit [_____] copies of the Record (As-Built) Drawings to the Contracting Officer.

-- End of Section --