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Preparing Activity: USACE Superseding
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UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2007

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SECTION TABLE OF CONTENTS

DIVISION 27 - COMMUNICATIONS

SECTION 27 21 10.00 10

FIBER OPTIC DATA TRANSMISSION SYSTEM

07/06

PART 1 GENERAL

- 1.1 REFERENCES
- 1.2 SUBMITTALS
- 1.3 SYSTEM DESCRIPTION
 - 1.3.1 General
 - 1.3.2 Environmental Requirements
 - 1.3.3 Hazardous Environment
 - 1.3.4 Electrical Requirements
 - 1.3.5 Input Line Surge Protection
 - 1.3.6 Power Line Surge Protection
 - 1.3.7 Spare Parts
- 1.4 DELIVERY OF TECHNICAL DATA
 - 1.4.1 Group I Technical Data Package
 - 1.4.1.1 System Drawings
 - 1.4.1.2 Equipment Data
 - 1.4.1.3 Data Transmission System Description and Analyses
 - 1.4.1.4 System Overall Reliability Calculations
 - 1.4.1.5 Certifications
 - 1.4.1.6 Key Control Plan
 - 1.4.2 Group II Technical Data Package
 - 1.4.3 Group III Technical Data Package
 - 1.4.4 Group IV Technical Data Package
 - 1.4.4.1 Performance Verification and Endurance Testing Data
 - 1.4.4.2 Operation and Maintenance Data
 - 1.4.4.3 Training Data
 - 1.4.5 Group V Technical Data Package
 - 1.4.5.1 Functional Design Manual
 - 1.4.5.2 Hardware Manual
 - 1.4.5.3 Maintenance Manual
 - 1.4.5.4 Operator's Manual
 - 1.4.6 Group VI Technical Data Package

PART 2 PRODUCTS

- 2.1 FO MODEMS
 - 2.1.1 FO Modem Operating Wavelength
 - 2.1.2 FO Modem Inputs and Outputs
- 2.2 FO TRANSMITTER AND RECEIVER MODULES
 - 2.2.1 Analog FO Transmitter and Receiver Modules
 - 2.2.2 Digital FO Transmitter and Receiver Modules
 - 2.2.3 FO Transmitter Module
 - 2.2.4 FO Receiver Module
- 2.3 FO DIGITAL REPEATERS
- 2.4 FO ANALOG REPEATERS
- 2.5 TRANSCEIVERS FOR VIDEO APPLICATIONS
- 2.6 TRANSCEIVERS FOR LAN APPLICATIONS
- 2.7 FO SWITCHES
- 2.8 FO SPLITTER/COMBINER
- 2.9 FIBER OPTIC DIGITAL REPEATERS (FODR)
- 2.10 DATA TRANSMISSION CONVERTER
- 2.11 ENCLOSURES
 - 2.11.1 Interior
 - 2.11.2 Exterior
 - 2.11.3 Corrosive Environment
 - 2.11.4 Hazardous Environment
- 2.12 TAMPER AND PHYSICAL PROTECTION PROVISIONS
 - 2.12.1 Enclosure Covers
 - 2.12.2 Conduit-Enclosure Connections
 - 2.12.3 Locks and Key-Lock-Operated Switches
 - 2.12.3.1 Locks
 - 2.12.3.2 Key-Lock-Operated Switches
- 2.13 SYSTEM REQUIREMENTS
 - 2.13.1 Signal Transmission Format Code
 - 2.13.2 Flux Budget/Gain Margin
 - 2.13.3 Receiver Dynamic Range
- 2.14 OPTICAL FIBERS
 - 2.14.1 General
 - 2.14.2 50 Micron Multimode Fibers
 - 2.14.3 62.5 Micron Multimode Fibers
 - 2.14.4 8.3 Micron Single-Mode Fibers
- 2.15 CROSS-CONNECTS
 - 2.15.1 Patch Panels
 - 2.15.2 Patch Cords
- 2.16 CABLE CONSTRUCTION
 - 2.16.1 General
 - 2.16.2 Exterior Cable
 - 2.16.2.1 Aerial Cable
 - 2.16.2.2 Duct Cable
 - 2.16.2.3 Direct Burial Cable
 - 2.16.3 Interior Cable
 - 2.16.4 Pigtail Cables
- 2.17 FO CONNECTORS
- 2.18 MECHANICAL SPLICES
- 2.19 FUSION SPLICES
- 2.20 CONDUIT, FITTINGS AND ENCLOSURES
- 2.21 FAN-OUT KITS

PART 3 EXECUTION

- 3.1 INSTALLATION
 - 3.1.1 Interior Work

- 3.1.2 Exterior Work, Aerial
- 3.1.3 Exterior Work Underground
- 3.1.4 Service Loops
- 3.1.5 Metallic Sheath Grounding
- 3.1.6 Splices
 - 3.1.6.1 General
 - 3.1.6.2 Mechanical Splices
- 3.1.7 Connectors
- 3.1.8 Identification and Labeling
- 3.1.9 Enclosure Sizing and Cable
- 3.1.10 Enclosure Penetrations
- 3.2 TESTING
 - 3.2.1 General
 - 3.2.2 Contractor's Field Test
 - 3.2.2.1 Optical Time Domain Reflectometer Tests
 - 3.2.2.2 Power Attenuation Test
 - 3.2.2.3 Gain Margin Test
 - 3.2.2.4 Analog Video Signal Test
 - 3.2.2.5 Digital Video Signal Test
 - 3.2.2.6 Performance Verification Test and Endurance Test
- 3.3 TRAINING
 - 3.3.1 General
 - 3.3.2 System Maintenance Course

-- End of Section Table of Contents --

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SECTION 27 21 10.00 10

FIBER OPTIC DATA TRANSMISSION SYSTEM 07/06

NOTE: This guide specification covers the requirements for fiber optics data transmission systems.

Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

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

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

PART 1 GENERAL

NOTE: There are two ways the designer can require the submission of data concerning fiber optic equipment. The most common way is through the use of submittals. However, the Federal Acquisition Regulations apply special constraints on some types of technical data that fall under the Data Requirements Clause. Generally, the technical data associated with fiber optic data transmission systems do not fall under the special Data Requirements Clause. However, if other systems such as EMCS, UMCS, IDS, ESS, and CCTV, interconnected by

FO systems do fall within the special category, the associated FO technical data should be acquired in the same manner. Therefore, if some systems used with this specification fall under the special Data Requirements Clause, use sub-paragraph a. below for guidance.

a. The acquisition of all technical data, data bases and computer software items that are identified herein will be accomplished strictly in accordance with the Federal Acquisition Regulation (FAR) and the Department of Defense Federal Acquisition Regulation Supplement (DOD FARS). Those regulations, as well as the Army and Corps of Engineers implementations thereof, should also be consulted to ensure that a delivery of critical items of technical data is not inadvertently lost. Specifically, the Rights in Technical Data Non-commercial, DOD FARS 52.227-7013, and DOD FARS 52.227-7031 [Reserved], as well as any requisite software licensing agreements will be made a part of the CONTRACT CLAUSES or SPECIAL CONTRACT REQUIREMENTS of the contract. In addition, the appropriate DD Form 1423, Contract Data Requirements List, will be filled out for each distinct deliverable item and made a part of the contract. Where necessary, a DD Form 1664, Data Item Description, shall be used to explain and more fully identify the data items listed on the DD Form 1423. It is to be noted that all of these clauses and forms are required to assure the delivery of the data in question and that such data is obtained with the requisite rights to use by the Government. Include with the request for proposals a completed DD Form 1423, Contract Data Requirements List. This form is essential to obtain delivery of all documentation. Each deliverable will be clearly specified, both description and quantity being required.

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 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.

CONSUMER ELECTRONICS ASSOCIATION (CEA)

CEA 170 (1957) Electrical Performance Standards -
Monochrome Television Studio Facilities

CEA-310-E (2005) Racks, Panels, and Associated
Equipment

ELECTRONIC INDUSTRIES ALLIANCE (EIA)

EIA/TIA-455-170 (1989) FOTP-170 Cable Cutoff Wavelength of
Single-Mode Fiber by Transmitted Power

EIA/TIA-455-30B (1991) FOTP-30 Frequency Domain
Measurement of Multimode Optical Fiber
Information Transmission Capacity

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C2 (2005) National Electrical Safety Code

IEEE C62.41 (1991; R 1995) Recommended Practice for
Surge Voltages in Low-Voltage AC Power
Circuits

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250 (2003) Enclosures for Electrical Equipment
(1000 Volts Maximum)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2005; TIA 2005) National Electrical Code

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)

TIA-232-F (1997; R 2002) Interface Between Data
Terminal Equipment and Data
Circuit-Terminating Equipment Employing
Serial Binary Data Interchange

TIA-455-104-A (1993; R 2005) Standard for FOTP-104 Fiber
Optic Cable Cyclic Flexing Test

TIA-455-13-A (1996; R 2002) FOTP-13 Visual and
Mechanical Inspection of Fiber Optic
Components, Devices, and Assemblies

TIA-455-177-B (2003) FOTP-177 IEC-60793-1-43 Optical
Fibres - Part 1-43: Measurement Methods

	and Test Procedures - Numerical Aperture
TIA-455-46A	(1990) FOTP-46 Spectral Attenuation Measurement for Long-Length, Graded-Index Optical Fibers
TIA-455-47B	(1992) FOTP-47 Output Far Field Radiation Pattern Measurement
TIA-455-58-B	(2001) FOTP-58 Core Diameter Measurement of Graded-Index Optical Fibers
TIA-455-78-B	(2002) FOTP-78 Optical Fibres - Part 1-40: Measurement Methods and Test Procedures - Attenuation
TIA-455-82B	(1992) FOTP-82 Fluid Penetration Test for Fluid-Blocked Fiber Optic Cable
TIA-455-91	(1986; R 1996) FOTP-91 Fiber Optic Cable Twist-Bend Test
TIA-485-A	(1998; R 2003) Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint System
TIA/EIA-455-171-A	(2001) FOTP-171 Attenuation by Substitution Measurement for Short-Length Multimode Graded-Index and Single-Mode Optical Fiber Cable Assemblies
TIA/EIA-455-25C	(2002) FOTP-25 Impact Testing of Optical Fiber Cables
TIA/EIA-455-41A	(1993; R 2001) FOTP-41 Compressive Loading Resistance of Fiber Optic Cables
TIA/EIA-455-81B	(2000) FOTP-81 Compound Flow (Drip) Test for Filled Fiber Optic Cable
TIA/EIA-455-88	(2001) FOTP-88 Fiber Optic Cable Bend Test
TIA/EIA-606-A	(2002) Administration Standard for the Telecommunications Infrastructure

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

47 CFR 15 Radio Frequency Devices

UNDERWRITERS LABORATORIES (UL)

UL 1666 (2000; Rev thru Jul 2002) Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts

1.2 SUBMITTALS

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation 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.

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" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Fiber Optic System[; G][; G, [____]]
Installation[; G][; G, [____]]

Detail drawings including a complete list of equipment and material, including manufacturer's descriptive and technical literature, performance charts and curves, catalog cuts, and installation instructions. Detail drawings shall contain complete cabling, wiring and schematic diagrams and any other details required to demonstrate that the system has been coordinated and will properly function with its associated subsystems as well as other systems. Drawings shall show proposed layout and anchorage of equipment and appurtenances, and equipment relationship to other parts of the work including clearance for maintenance and operations. System drawings shall show proposed configuration, including location, type and termination of both interior and exterior fiber optics and showing the location, duct and innerduct arrangement, and fiber assignment. The ac power consumption and

heat dissipation shall be shown under both normal and maximum operating conditions.

SD-03 Product Data

Fiber Optic System

Equipment calculations for flux budgets and gain margins.

Spare Parts

Data lists of spare parts, tools, and test equipment, as specified.

Manufacturer's Instructions[; G][; G, [_____]]

Where installation procedures, or any part thereof, are required to be in accordance with the recommendations of the manufacturer of the material being installed, printed copies of these recommendations shall be submitted prior to installation. Installation of the item will not be allowed to proceed until the recommendations are received and approved.

Test Procedures and Reports[; G][; G, [_____]]

Test plans shall define test procedures and tests required to ensure that the system meets technical, operational, and performance specifications. The test plans shall define milestones for the tests, equipment, personnel, facilities, and supplies required. The test plans shall identify the capabilities and functions to be tested.

SD-06 Test Reports

Test Procedures and Reports[; G][; G, [_____]]

Test reports, in booklet form showing field test procedures and field tests performed to adjust each component and field tests performed to prove compliance with the specified performance criteria, upon completion and testing of the installed system.

SD-07 Certificates

Fiber Optic System

Manufacturer's certificate indicating compliance with transmission and reliability requirements. Where equipment or materials are specified to conform to the standards or publications and requirements of CFR, ANSI, IEEE, NEMA, NFPA, EIA, or UL, certificates attesting that the items furnished under this section of the specification conform to the specified requirements.

SD-10 Operation and Maintenance Data

System Maintenance Course

[Six] [_____] copies of operating instructions outlining the step-by-step procedures required for system operation including description of each subsystem in its operating mode. Instructions

shall include the manufacturer's name, service manual, parts list, and a brief description of equipment, components, and their basic operating features. [Six] [_____] copies of the maintenance instructions listing regular maintenance procedures, possible system failures, a troubleshooting guide for repairs, and simplified diagrams for the system as installed. A video describing operating and maintenance instructions may be included.

1.3 SYSTEM DESCRIPTION

1.3.1 General

NOTE: Show on drawings the data transmission media required between each sub-assembly of the system or systems to be interconnected. Give consideration to compliance with NEC for supports, raceways, etc.

A fiber optics (FO) data transmission system (DTS) shall be provided. The data transmission system shall consist of fiber optic transmission media, transmitter and receiver modules, modems, transceiver modules, repeaters, cable and power line surge protection, terminal devices (such as connectors, patch panels and breakout boxes) and power supplies for operating active components. The data transmission system shall interconnect system components as shown. Computing devices, as defined in 47 CFR 15, shall be certified to comply with the requirements for Class A computing devices and labeled as set forth in 47 CFR 15.

1.3.2 Environmental Requirements

NOTE: Select equipment and cable temperature rating within ambient temperature conditions at project location. State additional requirements when ambient conditions are more extreme than manufacturers' equipment ratings (e.g., conformal coating for 100% relative humidity or condensing atmospheres, enclosure heaters or enclosure coolers.)

Equipment and cable to be utilized indoors shall be rated for continuous operation under ambient environmental conditions of 0 to 50 degrees C 32 to 122 degrees F dry bulb and 10 to 95 percent relative humidity, non-condensing. Equipment and cables to be used outdoors shall be rated for continuous operation under ambient environmental conditions of [minus 40] [minus [____]] to plus [75] [____] degrees C [minus 40] [minus [____]] to plus [166] [____] and humidity of up to 100 percent condensing or as normally encountered for the installed location. All equipment and cable shall be rated for continuous operation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified or normally encountered for the installed location. Cables installed in ducts, plenums, and other air-handling spaces shall be installed per NFPA 70. Cables installed in plenums shall be plenum-rated cables listed for the use. Cables installed in risers shall be riser-rated cables listed for the use, unless the installed cable is identified as a permitted substitution for the required riser-rated cable type.

1.3.3 Hazardous Environment

NOTE: Designer will show hazardous (classified) environment area(s), type of hazard(s), and hazard classification (Class I, II, or III, or combinations; Divisions 1 or 2; Groups A, B, C, D, E, F, or G or combinations; and operating temperatures) on the drawings. Whenever possible, avoid placement of the FO DTS equipment and cables within the hazardous location to reduce installation costs, and to simplify maintenance.

System components and wiring located in areas where fire or explosion hazards may exist because of flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings shall be rated for Classes, Divisions, Groups and suitable for the operating temperatures and shall be installed according to Chapter 5 of NFPA 70 and as shown.

1.3.4 Electrical Requirements

The equipment shall operate from a voltage source as shown, plus or minus 10 percent, and 60 Hz, plus or minus 2 percent.

1.3.5 Input Line Surge Protection

Inputs and outputs shall be protected against surges induced on wiring and cables including wiring and cables installed outdoors. Surge protection devices shall be selected based on voltages and current ratings of components to be protected. Communications equipment shall be protected against surges induced on any communications circuit. Cables and conductors (except non-conductive fiber optic cables which serve as communications circuits from consoles to field equipment and between field equipment), shall have surge protection circuits installed at each end. Protection shall be furnished at equipment, and additional triple electrode gas surge protectors rated for the application on each conductive wire line and coaxial circuit shall be installed within 1 meter 3 feet of the building cable entrance. Surge protection devices shall be selected based on voltages and current ratings of components to be protected. Fuses shall not be used for surge protection. The inputs and outputs shall be tested in both normal mode and common mode using the following two waveforms:

- a. A 10 microsecond rise time by 1000 microsecond pulse width waveform with a peak voltage of 1500 volts and a peak current of 60 amperes.
- b. An 8 microsecond rise time by 20 microsecond pulse width waveform with a peak voltage of 1000 volts and a peak current of 500 amperes.

1.3.6 Power Line Surge Protection

Equipment connected to AC circuits shall be protected from power line surges. Surge protection devices shall be selected based on voltages and current ratings of components to be protected. Equipment shall meet the requirements of IEEE C62.41. Fuses shall not be used for surge protection.

1.3.7 Spare Parts

The Contractor shall submit spare parts data for each different item of

material and equipment specified and furnished, after approval of detail drawings not later than [_____] months prior to the date of beneficial occupancy. The data shall include a list of parts and supplies, with current unit prices and source of supply, and a list of the parts recommended by the manufacturer to be replaced after [1 year] [3 years] of service.

1.4 DELIVERY OF TECHNICAL DATA

NOTE: Insert the Section title of the appropriate additional specifications: Section 28 23 23.00 10 CLOSED CIRCUIT TELEVISION SYSTEMS; Section 28 16 00.00 20 BASIC INTRUSION DETECTION SYSTEMS (IDS); Section 28 20 00.00 20 COMMERCIAL INTRUSION DETECTION SYSTEMS (IDS); Section 28 20 01.00 10 ELECTRONIC SECURITY SYSTEM; Section 28 16 01.00 10 SMALL INTRUSION DETECTION SYSTEM; Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEMS (UMCS).

For UMCS, IDS, ESS and similar systems requiring head-end computers and software, designer shall use the paragraph DELIVERY OF TECHNICAL DATA and delete paragraph SUBMITTALS. In no case will both paragraphs be retained.

Computer software and technical data (including technical data which relates to computer software), which are specifically identified in this specification shall be delivered strictly in accordance with the CONTRACT CLAUSES, SPECIAL CONTRACT REQUIREMENTS, and in accordance with the Contract Data Requirements List (CDRL), DD Form 1423, which is attached to and thereby made a part of this contract. All data delivered shall be identified by reference to the particular specification paragraph against which it is furnished. If the DTS is being installed in conjunction with another system such as an intrusion detection system, electronic SECURITY system, closed circuit television system, or utility monitoring and control system, the Technical Data Packages shall be submitted as part of the Technical Data Package for Section [____]; [____] hard copies and [____] electronic copies (DC-ROM or DVD-R) of the Technical Data Package(s) shall be submitted.

1.4.1 Group I Technical Data Package

1.4.1.1 System Drawings

The package shall include the following:

- a. Communications system block diagram.
- b. FO receivers, transmitters, transceivers, multiplexers, and FO modem installation, block diagrams, and wiring and cabling diagrams.
- c. FO receivers, transmitters, transceivers, multiplexers, and FO modem physical layout and schematics.
- d. Details of interfaces with other systems.
- e. Details of connections to power sources, including grounding.

- f. Details of surge protection device installations.
- g. Details of cable splicing and connector installations.
- h. Details of aerial cable and messenger installation on poles, cable entrance to buildings, and termination inside enclosures.
- i. Details of underground cable and duct installation, cable entrance into buildings, and terminations inside enclosures.

Drawings shall show proposed layout and anchorage of equipment and appurtenances, and equipment relationship to other parts of the work including clearance for maintenance and operations. System drawings shall show proposed configuration, including location, type and termination of both interior and exterior fiber optics and showing the location, duct and innerduct arrangement, and fiber assignment. The ac power consumption and heat dissipation shall be shown under both normal and maximum operating conditions.

1.4.1.2 Equipment Data

A complete data package shall be delivered for all material, including field and system equipment.

1.4.1.3 Data Transmission System Description and Analyses

The data package shall include complete system description, and analyses and calculations used in sizing equipment required by these specifications. Descriptions and calculations shall show how the equipment will operate as a system to meet the specified performance. The data package shall include the following:

- a. FO receivers, transmitters, transceivers, multiplexers, FO modem transmit and receive levels, and losses in decibels (dB) on each communication link.
- b. Digital transmitter and receiver communication speed and protocol description.
- c. Analog signal transmission method and bandwidth of the transmitter and receiver.
- d. Data transmission system expansion capability and method of implementation.
- e. FO system signal-to-noise ratio calculation for each communication link.
- f. Flux-budget and gain margin calculation for each communication link.

1.4.1.4 System Overall Reliability Calculations

NOTE: The designer must insert the section that describes the system configuration.

The data package shall include manufacturers' reliability data and

calculations required to show compliance with the specified reliability. The calculations shall be based on the configuration specified in Section [_____] and as shown.

1.4.1.5 Certifications

Specified manufacturers' certifications shall be included with the data package.

1.4.1.6 Key Control Plan

NOTE: The designer will specify the Section in which a key control plan is found, when this specification is used with IDS, ESS, or CCTV:
Section 28 16 00.00 20 BASIC INTRUSION DETECTION SYSTEMS (IDS); Section 28 20 00.00 20 COMMERCIAL INTRUSION DETECTION SYSTEMS (IDS); Section 28 20 01.00 10 ELECTRONIC SECURITY SYSTEM; Section 28 16 01.00 10 SMALL INTRUSION DETECTION SYSTEM; Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEMS (UMCS); Section 28 23 23.00 10 CLOSED CIRCUIT TELEVISION SYSTEMS.

1.4.2 Group II Technical Data Package

NOTE: If the designer has specified site condition investigation in other sections, the first bracketed sentence, with the proper section number inserted, may be substituted in lieu of the second set of bracketed sentences.

[The Group II technical data package is specified in Section [_____] .] [The Contractor shall verify that site conditions are in agreement with the design package. The Contractor shall submit a report to the Government documenting changes to the site, or differing conditions that affect performance of the system to be installed. For those changes or conditions which affect system installation or performance, specification sheets shall be provided (with the report), or written functional requirements to support the findings, and a cost estimate to correct the deficiency shall be provided with the report. The Contractor shall not correct any deficiency without written permission from the Government.]

1.4.3 Group III Technical Data Package

NOTE: Insert section number and title for the UMCS, IDS, ESS or CCTV specifications.

The Contractor shall prepare [test procedures and reports](#) for the factory test. A test plan and test procedures shall be prepared in accordance with Section [_____] and this specification. The test procedures shall describe the applicable tests to be performed, and other pertinent information such as specialized test equipment required, length of test, and location of the test. The procedures shall explain in detail, step-by-step actions and

expected results to demonstrate compliance with the requirements of this specification, and the methods for simulating the necessary conditions of operation to demonstrate performance of the system. The test report shall describe the results of testing to include the date, time, location and system component designations of material and equipment tested. Testing action shall be recorded whether successful or not. Reasons for termination of testing shall be described. Testing work sheets, printouts, strip charts, oscilloscope or optical time domain reflectometer (OTDR) printouts/photographs, raw and analyzed data, and testing conclusions shall be included in the report. The Contractor shall deliver the factory test procedures to the Government for approval. After receipt by the Contractor of written approval of the test procedures, the Contractor may schedule the factory test. The Contractor shall provide written notice of the test to the Government at least 2 weeks prior to the scheduled start. The final test report shall be delivered within 15 days after completion of the test.

1.4.4 Group IV Technical Data Package

1.4.4.1 Performance Verification and Endurance Testing Data

**NOTE: Insert section number and title for the UMCS,
IDS, ESS or CCTV specification.**

The Contractor shall prepare procedures and reports for the performance verification test and endurance test. Test procedures shall be prepared in accordance with Section [_____] and this specification. Testing shall be performed on an installed system as approved by the Government. Where required and approved by the Government, the Contractor shall simulate conditions of operation to demonstrate the performance of the system. The test plan shall describe the applicable tests to be performed, other pertinent information such as specialized test equipment required, length of performance verification test and endurance test, and location of the performance verification test and endurance test. The procedures shall explain in detail, step-by-step actions and expected results to demonstrate compliance with the requirements of this specification, and the methods for simulating the necessary conditions of operation to demonstrate performance of the system. The test report shall describe the results of testing to include the date, time, location and system component designations of material and equipment tested. Testing action shall be recorded whether successful or not. Reasons for termination of testing for any reason shall be recorded in the report. Testing work sheets, printouts, strip charts, oscilloscope or OTDR printouts/photographs, raw data, analyzed data and testing conclusions shall be included in the report. The Contractor shall deliver the performance verification test and endurance test procedures to the Government for review and approval. After receipt of written approval of test procedures, the Contractor may schedule the performance verification and endurance tests. The Contractor shall provide written notice of the performance verification test and the endurance test to the Government at least 2 weeks prior to the scheduled start of the test. The final performance verification test and endurance test report shall be delivered 30 days after completion of testing.

1.4.4.2 Operation and Maintenance Data

A draft copy of the operation and maintenance data, in manual format, as specified for the Group V technical data package, shall be delivered to the Government prior to beginning the performance verification test for use

during site testing.

1.4.4.3 Training Data

Lesson plans and training manuals, including type of training to be provided, with a list of reference material shall be delivered for approval by the Government prior to starting any training.

1.4.5 Group V Technical Data Package

NOTE: Specify the correct number of manuals on DD Form 1423. Adjust the quantities below to fill special local requirements. Coordinate O&M manual requirements with those of the performing district.

Generally, FO systems do not include controls or functions under the control of system operators. Therefore, an operator's manual is not needed. Include an operator's manual if such controls are provided.

The Group V package consists of the operation and maintenance data, in manual format. Final copies of the manuals bound in hardback, loose-leaf binders, shall be delivered to the Government within 30 days after completing the endurance test. The draft copy used during site testing shall be updated with any changes required prior to final delivery of the manuals. Each manual's contents shall be identified on the cover. The manuals shall include the names, addresses, and telephone numbers of each subcontractor installing equipment and systems, and of the nearest service representative for each item of equipment and each system. The manuals shall have a table of contents and tab sheets. Tab sheets shall be placed at the beginning of each chapter or section and at the beginning of each appendix. The final copies delivered after completion of the endurance test shall include all modifications made during installation, checkout, and acceptance. Manuals delivered shall include:

- a. Functional Design Manual: [two] [____] copies [____] hard copies [1] [____] CD-ROM(s).
- b. Hardware Manual: [two] [____] copies [____] hard copies [1] [____] CD-ROM(s).
- c. Maintenance Manuals: [two] [____] copies. [____] hard copies [1] [____] CD-ROM(s).
- d. Operator's Manual: [six] [____] copies [____] hard copies [1] [____] CD-ROM(s).

1.4.5.1 Functional Design Manual

The functional design manual shall identify the operational requirements for the data transmission system and explain the theory of operation, design philosophy, and specific functions. A description of hardware functions, interfaces, and requirements shall be included for all system operating modes.

1.4.5.2 Hardware Manual

A manual describing all equipment and devices specified and under Part 2 PRODUCTS shall be furnished. The following information shall be included:

- a. General description and specifications.
- b. Installation and checkout procedures.
- c. Equipment electrical schematics and layout drawings.
- d. Data transmission systems schematics.
- e. Alignment and calibration procedures.
- f. Manufacturer's repair parts list indicating sources of supply.
- g. Interface definition.

1.4.5.3 Maintenance Manual

The maintenance manual shall include descriptions of maintenance for all equipment including inspection, periodic preventative maintenance, fault diagnosis, and repair or replacement of defective components.

1.4.5.4 Operator's Manual

The operator's manual shall fully explain procedures and instructions for operation of the system. This shall include an operator's manual for any fiber optic systems in which system operators control any function of the system.

1.4.6 Group VI Technical Data Package

The Group VI Technical Data Package shall consist of the as-built drawings revised to include system revisions and modifications. Copies of the updated as-built drawings shall be delivered to the Government following approval of the PVT and endurance test.

PART 2 PRODUCTS

**NOTE: All of the products listed in this section
may not be required for every project. Keep the
products required and delete the others.**

2.1 FO MODEMS

FO modems shall be selected to meet FO system requirements. The modems shall allow full duplex, asynchronous, point-to-point digital communication for the system being installed.

2.1.1 FO Modem Operating Wavelength

**NOTE: Select the required operating wavelength:
Typically 850 and 1300 wavelengths are used with
multimode fibers and 1300 and 1550 wavelengths are**

used with single-mode fibers. Generally, longer wavelengths should be used for cable lengths over 3 km (1.75 miles) because longer wavelengths exhibit less attenuation than shorter wavelengths. Dense Wave Division Multiplexing (DWDM) and Coarse Wave Division Multiplexing (CWDM) transmitters use multiple wavelengths; the flux budget should be based on the wavelength with the greatest attenuation.

The operating wavelength shall be centered on [850] [1300] [1550] nanometers (nm).

2.1.2 FO Modem Inputs and Outputs

NOTE: Match the input and output configurations to the equipment to be interconnected. The data rate of the FO modem must exceed the data rate of the devices served.

FO modems shall accept inputs and provide outputs compatible with [TIA-232-F] [TIA-485-A] [20 mA current loop] [T1] [10 Base-F]. Digital data rates through each link shall be [9.6 KBPS] [19.2 KBPS] [38.4 KBPS] [1.54 MBPS] [10 MBPS].

2.2 FO TRANSMITTER AND RECEIVER MODULES

NOTE: There are several ways fiber optic transmitters and receivers can be implemented such as:

a. The transmitter and receiver can be mounted on a logic board. The transmitter and receiver are then an integral part of the system at the logic level.

b. The transmitter and receiver can be individual modules which are mounted external to the logic boards. They can be powered by their own power supplies and can communicate with the serial data ports of the logic boards at logic levels.

c. The fiber optics transmitter and receiver can be combined with interface and control logic to form a fiber optic modem. The system field equipment can thus communicate with the modem over a EIA 232-F serial data port.

The designer must determine where FO communication devices will be located. In many systems, FO transmitters and receivers or modems are located in the field equipment enclosures of the systems being supported by the FO system. Often, these FO devices are physically mounted on circuit cards or modules. In other cases, FO devices will have to be installed in separate enclosures provided with the FO system.

This is often the case for FO repeaters and active star units.

FO transmitter/receiver pairs shall have signal-to-noise power ratio of 40 dB or better after photo detection at the receiver. Transmitter power output and receiver sensitivity shall not drift more than plus or minus 2 dB over their operational life.

2.2.1 Analog FO Transmitter and Receiver Modules

FO transmitter/receiver pairs used to pass analog video signals shall accept inputs and provide outputs that comply with [CEA 170](#) and shall have a bandwidth of 6 MHz or greater.

2.2.2 Digital FO Transmitter and Receiver Modules

FO transmitter/receiver pairs used to pass digital signals shall accept inputs and provide outputs compatible with [[TIA-232-F](#)] [[TIA-485-A](#)] [20 mA current loop] [T1] [10 Base-F]. Digital data rates through each link shall be [9.6 KBPS] [19.2 KBPS] [38.4 KBPS] [1.54 MBPS] [10 MBPS]. FO transmitter and receiver modules shall be housed [in field equipment enclosures where possible] [in new enclosures] [as shown]. FO transmitter and receiver modules shall be compatible with each other, the FO cable, and connectors.

2.2.3 FO Transmitter Module

The FO transmitter module shall accept electronic signals and shall modulate a light source. The light source shall be coupled into an FO cable. The operating wavelength shall be centered on [850] [1300] [1550] [850 and 1300] [1300 and 1550] nanometers.

2.2.4 FO Receiver Module

The FO receiver module shall receive light from the FO cable and shall convert this light into an electronic signal identical to the electronic signal applied to the FO transmitter module. The operating wavelength shall be the same as the transmitter.

2.3 FO DIGITAL REPEATERS

FO digital repeaters shall be used to extend the range of the FO data transmission system when necessary to meet the requirements of paragraph SYSTEM REQUIREMENTS. For simplex circuits, the repeater shall consist of an FO receiver connected to an FO transmitter. For Duplex circuits, the repeater shall consist of a pair of FO receivers that are connected to a pair of FO transmitters. The FO receivers shall receive the optical signal and drive the transmitters. The transmitters shall regenerate the optical signal at the transmission rate specified. The FO repeater shall be mechanically and optically compatible with the remainder of the FO system.

2.4 FO ANALOG REPEATERS

FO analog repeaters shall be used to extend the range of the FO data transmission system when necessary to meet the requirements of the paragraph SYSTEM REQUIREMENTS. For simplex circuits, the repeater shall consist of an FO receiver connected to an FO transmitter. For duplex circuits, the repeater shall consist of a pair of FO receivers that are

connected to a pair of FO transmitters. The FO receivers shall receive the optical signal and drive the transmitters. The transmitters shall regenerate the optical signal in compliance with CEA 170. The FO repeater shall be mechanically and optically compatible with the remainder of the FO system.

2.5 TRANSCEIVERS FOR VIDEO APPLICATIONS

FO Transceivers shall allow bi-directional signal transmission on a single fiber. The operating wavelength in one direction shall be 1300/850 nanometers, while in the opposite direction it shall be 850/1300 nanometers. Crosstalk attenuation between channels shall be 40 dB or greater. FO transceivers shall be selected to match or exceed the highest data rate of attached input devices. The FO transceiver shall be mechanically and optically compatible with the remainder of the FO system.

2.6 TRANSCEIVERS FOR LAN APPLICATIONS

**NOTE: Designer will use the transceivers for ESS or
UMCS systems which use a LAN topology for
communication.**

Transceivers for FO LAN applications shall be active units, compatible with the LAN cards, modems and repeaters used in the system. Indicators provided shall be for power, collision detection, receive, transmit, and status. Power for transceivers shall be derived from the Attachment Unit Interface (AUI) port of LAN equipment or from a dedicated power supply. Transceiver loss characteristics shall be less than 1.0 db. Connectors shall be low loss and compatible with LAN equipment. Circuitry shall be included so when a device is disconnected, other devices on the LAN continue to operate without any disruption.

2.7 FO SWITCHES

**NOTE: Designer will show FO switches and designate
latching or nonlatching on contract drawings.**

FO switches shall be single pole, double throw. Switching speed shall be less than 15 milliseconds. Insertion loss shall be less than 1.5 dB. Crosstalk attenuation between FO outputs shall be 40 dB or greater. FO switches shall be latching or nonlatching as shown.

2.8 FO SPLITTER/COMBINER

FO splitter/combiner units shall provide full-duplex communications in a multi-point configuration. Each unit shall have one input port module and up to four output port modules. FO splitter/combiner units shall be mechanically and optically compatible with the remainder of the FO system. The splitter/combiner shall allow a mixed configuration of port module operating wavelengths and single-mode or multimode FO cables. Each port module shall have a separate FO cable input and output. Port modules shall be connected using an electronic data bus. Port module FO transmitters shall regenerate the optical signal at the transmission rate specified. Port modules shall be rack-mounted in a 483 mm 19 inch rack complying with CEA-310-E. The total propagation delay through the splitter/combiner shall

be less than 100 nanoseconds.

2.9 FIBER OPTIC DIGITAL REPEATERS (FODR)

FODRs shall combine the features specified for Fiber Optic Digital Repeaters and Local Area Network (LAN) transceivers. FODRs shall regenerate the optical signal at the transmission rate specified. The FODRs shall be mechanically and optically compatible with the remainder of the [Fiber Optic System](#). FODRs shall restore the optical signals amplitude, timing and waveform. The FODR shall provide an electrical interface to the transmission media. The electrical interface shall be identical to all other network interfaces as specified.

2.10 DATA TRANSMISSION CONVERTER

Data transmission converters shall be used to connect equipment using [TIA-485-A](#) data transmission when necessary and as shown. Converters shall operate full duplex and support two wire circuits at speeds up to 2 megabytes per second and have a built in 120 Ohm terminating resistor. Converters shall be mechanically, electrically, and optically compatible with the system.

2.11 ENCLOSURES

NOTE: If all FO devices will be located in enclosures of other systems, then paragraph ENCLOSURES can be deleted. Otherwise, paragraph ENCLOSURES must remain and enclosure locations must be shown on the drawings.

Enclosures shall conform to the requirements of [NEMA 250](#) for the types specified. Finish color shall be the manufacturer's standard, unless otherwise indicated. Damaged surfaces shall be repaired and refinished using original type finish.

2.11.1 Interior

Enclosures installed indoors shall meet the requirements of [NEMA 250](#) Type 12 or as shown.

2.11.2 Exterior

NOTE: For exterior applications where corrosive environments exist, Type 4X will be specified. Type 4X metallic enclosures should be used for security applications where physical hardening is required.

Enclosures installed outdoors shall meet the requirements of [NEMA 250](#) Type 4 unless otherwise specified or shown.

2.11.3 Corrosive Environment

NOTE: Show corrosive locations on the drawings.

Enclosures in a corrosive environment shall meet the requirements of NEMA 250, Type 4X.

2.11.4 Hazardous Environment

Enclosures in a hazardous environment shall be installed and shall meet the requirements as specified in paragraph ENVIRONMENTAL REQUIREMENTS.

2.12 TAMPER AND PHYSICAL PROTECTION PROVISIONS

NOTE: Tamper and physical protection provisions are only required for FO system applications involving security systems such as IDS, ESS or CCTV. This requirement should be deleted for all other applications. Generally, security screws are preferred over tack welding or brazing because the enclosure surface protection is not damaged.

Enclosures and fittings of every description having hinged doors or removable covers that contain the FO circuits, connections, splices, or power supplies, shall be provided with cover-operated, corrosion-resistant tamper switches, arranged to initiate an alarm signal when the door or cover is moved. Tamper switches shall be mechanically mounted to maximize the defeat time when enclosure covers are opened or removed. The enclosure and the tamper switch shall function together to not allow direct line of sight to any internal components and tampering with the switch or the circuits before the switch activates. Tamper switches shall be inaccessible until the switch is activated; have mounting hardware concealed so that the location of the switch cannot be observed from the exterior of the enclosure; be connected to circuits which are under electrical supervision at all times, irrespective of the protection mode in which the circuit is operating; shall be spring-loaded and held in the closed position by the door cover; and shall be wired so that they break the circuit when the door or cover is disturbed. Tamper switches located in enclosures which must be opened to make routine maintenance adjustments to the system and to service the power supplies shall be push/pull-set, automatic reset type.

2.12.1 Enclosure Covers

Covers of pull and junction boxes provided to facilitate installation of the system need not be provided with tamper switches if they contain no splices, connections or power supplies, but shall be protected by [security screws] [tack welding or brazing] to hold the covers in place. Zinc labels shall be affixed to such boxes indicating they contain no connections. These labels shall not indicate that the box is part of a security system. Any damage to the enclosure or its cover's surface protection shall be cleaned and repaired using the same type of surface protection as the original enclosure. Conduit enclosures constructed of fiberglass shall be secured with tamper proof security servers.

2.12.2 Conduit-Enclosure Connections

NOTE: Tamper and physical protection provisions are only required for FO system applications involving

security systems such as IDS, ESS, or CCTV. Delete this requirement for all other applications.

Conduit-enclosure connections shall be protected by tack welding or brazing the conduit to the enclosure. Tack welding or brazing shall be done in addition to standard conduit-enclosure connection methods as described in NFPA 70. Any damage to the enclosure or its cover's surface protection shall be cleaned and repaired using the same type of surface protection as the original enclosure. Conduit enclosures constructed of fiberglass shall be secured with tamper proof security screws.

2.12.3 Locks and Key-Lock-Operated Switches

NOTE: Either round key or conventional key type locks as defined in this specification are acceptable. Selection should be based on hardware availability at the time of design and the requirement for matching locks currently in use at the site. If the locks do not have to be matched to locks in use at the site, and the designer has no preference as to lock type, all brackets may be removed.

2.12.3.1 Locks

Locks required to be installed on system enclosures for maintenance purposes shall be UL listed, [round key type, with three dual, one mushroom, and three plain pin tumblers] [or] [conventional key type lock having a combination of five cylinder pin and five-point three position side bar]. Keys shall be stamped U.S. GOVT. DO NOT DUP. The locks shall be so arranged that the key can only be withdrawn when in the locked position.

All maintenance locks shall be keyed alike and only two keys shall be furnished for all of these locks.

2.12.3.2 Key-Lock-Operated Switches

Key-lock-operated switches required to be installed on system components shall be UL listed, [with three dual, one mushroom, and three plain pin tumblers,] [or] [conventional key type lock having a combination of five cylinder pin and five-point three position side bar]. Keys shall be stamped U.S. GOVT. DO NOT DUP. Key-lock-operated switches shall be two position, with the key removable in either position. All key-lock-operated switches shall be keyed differently and only two keys shall be furnished for each key-lock-operated switch.

2.13 SYSTEM REQUIREMENTS

2.13.1 Signal Transmission Format Code

NOTE: Different FO systems may use different modulation methods and codes. For example, the digital signal may turn the light source on or off, it may use frequency shift keying, or it may cause the intensity to shift between two preset levels. Likewise, the code can be the simple NRZ (non-return

to zero), or it can be the more complex and efficient RZ (return to zero) code, such as the Manchester code. The modulation method can be important to bandwidth limited systems since some methods required twice the bandwidth of other methods for transmitting the same data.

FO equipment shall use the same transmission code format from the beginning of a circuit to the end of that circuit. Different transmission code formats may be used for different circuits as required to interconnect supported equipment.

2.13.2 Flux Budget/Gain Margin

NOTE: The flux budget calculations for each FO link are used to determine if the gain margin designed into the link is large enough to allow for splicing of broken fibers and aging effects. The flux budget is the power difference between the transmitter output power and the receiver input power for a given bit error rate.

This power is usually measured in dBm (i.e. referenced to 1 milliwatt) and is an absolute measurement. LED transmitter output power is typically between -10 and -18 dBm. Positive Intrinsic Negative (PIN) receivers with pre-amplifiers have a power input typically between -24 and -37 dBm. Using the flux budget, the link designer can determine the total losses the system links can have and still work properly.

The flux budget is divided into components. The components are the real losses in the system and the gain margin. The real losses consist of all the system losses such as cable attenuation, coupling and splicing losses. The gain margin is a reserve for future losses, such as aging and future splices. System losses and the gain margin are usually measured in dB and are a relative measurement.

The receiver dynamic range is the range of input power that can be successfully detected by the receiver (also referred to as the maximum and minimum optical input power). The variables that can influence the flux budget include changing the transmitter power output, the receiver sensitivity, the imposed signal wavelength and system losses. Allow 3 dB for aging and 3 dB for each cable repair for a total margin of not less than 6 dB. Different wavelengths exhibit different cable attenuation; thus for links that use DWDM or DWDM, the flux budget should be determined using the cable attenuation and connector losses for the wavelength with greater loss (which is usually the shorter wavelength).

FO links shall have a minimum gain margin of 6 dB. The flux budget is the difference between the transmitter output power and the receiver input power required for signal discrimination when both are expressed in dBm. The flux budget shall be equal to the sum of losses (such as insertion losses, connector and splice losses, and transmission losses) plus the gain margin. When a repeater or other signal regenerating device is inserted to extend the length of an FO circuit, both the circuit between the transmitter and the repeater-receiver, and the circuit between the repeater-transmitter and the receiver are considered independent FO links for gain margin calculations.

2.13.3 Receiver Dynamic Range

The dynamic range of receivers shall be large enough to accommodate both the worst-case, minimum receiver flux density and the maximum possible, receiver flux density. The receiver dynamic range shall be at least 15 dB. Where required, optical attenuators shall be used to force the FO link power to fall within the receiver dynamic range.

2.14 OPTICAL FIBERS

NOTE: FO systems use one or two fibers for each full duplex FO link. In the two-fiber links data flows only in one direction in each fiber. DWM and CWM systems often use one fiber for each full duplex FO link in which differing wavelengths travel in opposite directions on one fiber. In some cases, such as sending sync and receiving video from long distances, bi-directional transmission on one fiber is desired. Shorter wavelengths generally have greater attenuation; loss budgets should be based on the wavelength with the greater attenuation.

2.14.1 General

Optical fibers shall be coated with a suitable material to preserve the intrinsic strength of the glass. The outside diameter of the glass-cladded fiber shall be nominally 125 microns, and shall be concentric with the fiber core. Optical fibers shall meet [TIA-455-46A](#), and [TIA-455-177-B](#).

2.14.2 50 Micron Multimode Fibers

Conductors shall be multimode, graded index, solid glass waveguides with a nominal core diameter of 50 microns. The fiber shall have transmission windows centered at 850 and 1300 nanometer wavelengths. The numerical aperture for each fiber shall be a minimum of 0.20. The attenuation at 850 nanometers shall be 3.5 dB/Km or less. The attenuation at 1300 nanometers shall be 1.5 dB/Km or less. The minimum bandwidth shall be 500 MHz-Km at both transmission windows. The fibers shall be certified to meet [EIA/TIA-455-30B](#) and [TIA-455-58-B](#).

2.14.3 62.5 Micron Multimode Fibers

Conductors shall be multimode, graded index, solid glass waveguides with a nominal core diameter of 62.5 microns. The fiber shall have transmission windows centered at 850 and 1300 nanometer wavelengths. The numerical

aperture for each fiber shall be a minimum of 0.275. The attenuation at 850 nanometers shall be 3.5 dB/Km or less. The attenuation at 1300 nanometers shall be 1.5 dB/Km or less. The minimum bandwidth shall be 160 MHz-Km at 850 nanometers and 500 MHz-Km at 1300 nanometers. FO cable shall be certified to meet EIA/TIA-455-30B and TIA-455-58-B.

2.14.4 8.3 Micron Single-Mode Fibers

NOTE: Single-mode FO DTS offer larger bandwidth, and lesser attenuation, usually at greater system cost than multimode FO DTS. Single-mode FO DTS will only be used when the designer determines that large bandwidth or low attenuation links warrant the single-mode FO DTS.

Conductors shall be single-mode, solid glass waveguides with a nominal core diameter of 8.3 microns. The fiber shall have a transmission windows centered at 1310 and 1550 nanometer wavelengths. The numerical aperture for each optical fiber shall be a minimum of 0.10. The attenuation for inside cable at 1310 and 1550 nanometers shall be 1.0 dB/Km or less. The attenuation for outside cable at 1310 and 1550 nanometers shall be 0.5 dB/Km or less. The fibers shall be certified to meet EIA/TIA-455-170.

2.15 CROSS-CONNECTS

2.15.1 Patch Panels

NOTE: Show cross-connect or interconnect configuration on the drawings.

Patch panels shall be a complete system of components by a single manufacturer, and shall provide termination, splice storage, routing, radius limiting, cable fastening, storage, and cross-connection. Patch panel connectors and couplers shall be the same type and configuration as used elsewhere in the system. Patch panels shall be [a 480 mm 19 inch rack mount type] [wall mounted] [as shown].

2.15.2 Patch Cords

Patch cords shall be cable assemblies consisting of factory connector-terminated flexible optical fiber cable with connectors of the same type as used elsewhere in the system. Optical fiber shall be the same type as used elsewhere in the system. Patch cords shall be complete assemblies from manufacturer's standard products.

2.16 CABLE CONSTRUCTION

NOTE: Either tight-buffer or loose-tube cable construction can be used. The loose tube construction is more appropriate where the cable is subject to thermal expansion. This would include outdoor aerial and long distance runs over 1 Km (0.62 mile). In multistory buildings or locations where the cable is installed vertically and will not

experience significant temperature variations, use
tight-buffer cables.

2.16.1 General

The cable shall contain a minimum of two fiber optic fibers for each link circuit. The number of fibers in each cable shall be [_____] [as shown]. Each fiber shall be protected by a protective tube. Cables shall have a jacketed strength member, and an exterior jacket. Cable and fiber protective covering shall be free from holes, splits, blisters, and other imperfections. All interior cables' insulation and jacketing material shall not contain any poly vinyl chloride (PVC) compounds. The covering shall be flame retardant, moisture resistant, non-nutrient to fungus, ultraviolet light resistant as specified and nontoxic. Mechanical stress present in cable shall not be transmitted to the optical fibers. Strength members shall be non-metallic and shall be an integral part of the cable construction. The combined strength of all the strength members shall be sufficient to support the stress of installation and to protect the cable in service. The exterior cables shall have a minimum storage temperature range of minus 40 to plus 75 degrees C minus 104 to plus 167 degrees F. Interior cables shall have a minimum storage temperature of minus 10 to plus 75 degrees C plus 14 to plus 167 degrees F. All optical fiber cables and all optical fiber raceways furnished shall meet the requirement of NFPA 70. Fire resistant characteristics of optical fiber cables and optical fiber raceways shall conform to Article 770, Sections 49, 50, and 51. A flooding compound shall be applied into the interior of the fiber tubes, into the interstitial spaces between the tubes, to the core covering, and between the core covering and jacket of all cable to be installed aerially, underground, and in locations susceptible to moisture. Flooded cables shall comply with TIA/EIA-455-81B and TIA-455-82B. Cables shall be from the same manufacturer, of the same cable type, of the same size, and of the same optical characteristics. Each fiber and protective coverings shall be continuous with no factory splices. Fiber optic cable assemblies, including jacketing and fibers, shall be certified by the manufacturer to have a minimum life of 30 years. Cables shall meet UL 1666. FO cable shall be certified to meet the following: TIA-455-13-A, TIA/EIA-455-25C, TIA/EIA-455-41A, TIA-455-47B, TIA-455-78-B, TIA/EIA-455-88, TIA-455-91, TIA-455-104-A, and TIA/EIA-455-171-A.

2.16.2 Exterior Cable

2.16.2.1 Aerial Cable

The optical fibers shall be surrounded by a tube buffer, shall be contained in a channel or otherwise loosely packaged to provide clearance between the fibers and inside of the container, and shall be extruded from a material having a coefficient of friction sufficiently low to allow the fiber free movement.

- a. The cable outer jacket shall be medium density polyethylene material containing at least 2.6 percent carbon black with only black pigment added for additional coloring.
- b. Tensile strength: Cables shall withstand an installation tensile load of not less than 2700 Newtons 608 pounds and not less than 600 Newtons 135 pounds continuous tensile load.
- c. Impact and Crush resistance: The cables shall withstand an impact

of 3 Newton-meters 1.7 lbs/in as a minimum, and shall have a crush resistance of 220 Newtons per square centimeter 317 psi as a minimum.

2.16.2.2 Duct Cable

The optical fibers shall be surrounded by a tube buffer, shall be contained in a channel or otherwise loosely packaged to provide clearance between the fibers and inside of the container, and shall be extruded from a material having a coefficient of friction sufficiently low to allow the fiber free movement.

a. The cable outer jacket shall be medium density polyethylene material with orange pigment added for ease of identification.

b. Tensile strength: Cables shall withstand an installation tensile load of not less than 2700 Newtons 608 pounds and not less than 600 Newtons 135 pounds continuous tensile load.

c. Impact and Crush resistance: The cables shall withstand an impact of 3 Newton-meters 1.7 lbs/in as a minimum, and shall have a crush resistance of 220 Newtons per square centimeter 317 psi as a minimum.

2.16.2.3 Direct Burial Cable

The optical fibers shall be surrounded by a tube buffer, shall be contained in a channel or otherwise loosely packaged to provide clearance between the fibers and inside of the container, and shall be extruded from a material having a coefficient of friction sufficiently low to allow the fiber free movement.

a. The cable outer jacket shall be medium density polyethylene material containing at least 2.6 percent carbon black with only black pigment added for additional coloring.

b. Tensile strength: Cables shall withstand an installation tensile load of not less than 2700 Newtons 608 pounds and not less than 600 Newtons 135 pounds continuous tensile load.

c. Impact and Crush resistance: The cables shall withstand an impact of 3 Newton-meters 1.7 lbs/in as a minimum, and shall have a crush resistance of 220 Newtons per square centimeter 317 psi as a minimum.

d. Direct burial cable shall be protected with plastic coated steel armor. The plastic coated steel armor shall be applied longitudinally directly over an inner jacket and have an overlap of 5 mm 0.20 inch minimum. Armoring materials shall provide corrosion protection from local environmental/soil conditions over the projected life of the cable.

2.16.3 Interior Cable

a. Loose buffer tube cable construction shall be such that the optical fibers shall be surrounded by a tube buffer, and shall be contained in a channel or otherwise loosely packaged to provide clearance between the fibers and the inside of the container to allow for thermal expansions without constraining the fiber. The protective container shall be extruded from a material having a coefficient of friction sufficiently low to allow the fiber free movement. The cable outer jacket shall be fluorocopolymer (FCP), which complies with NFPA 70 for

optical fiber nonconductive plenum (OFNP) applications. Manufacturers' recommended values for tensile strength, impact resistance, and crush resistance shall not be exceeded. Interior cables' insulation and jacketing material shall not contain any poly vinyl chloride (PVC) compounds.

b. Tight buffer tube cable construction shall be extrusion of plastic over each clad fiber, with an outer jacket of FCP, which complies with NFPA 70 for optical fiber nonconductive riser (OFNR) requirements for riser cables and vertical shaft installations. Optical fibers shall be covered in near contact with an extrusion tube and shall have an intermediate soft buffer to allow for the thermal expansions and minor pressures. Manufacturers' recommended values for tensile strength, impact resistance, and crush resistance shall not be exceeded. Interior cables' insulation and jacketing material shall not contain any poly vinyl chloride (PVC) compounds.

2.16.4 Pigtail Cables

Cable used for connections to equipment shall be flexible fiber pigtail cables having the same physical and operational characteristics as the parent cable. The cable jacket shall be FCP, which complies with NFPA 70 for OFNP applications. Maximum dB loss for pigtail cable shall be 3.5 dB/km at 850 nanometers, and 1.0 dB/km at 1300 nanometers, and [_____] dB/Km at 1550 nanometers.

2.17 FO CONNECTORS

NOTE: Available FO connector types include, but are not limited to, FC, SC, Duplex SE (568SC), ST, Duplex ST, LC, Duplex LC, ESCON, FDDI, and MT-RJ. Equipment manufacturers may offer both a manufacturer's standard termination connector type and also an optional termination connector type or types as available on a specific equipment component, whereas some equipment may only be available with one termination connector type (as an example, one manufacturer offers a choice of either ST, SC, or FC connectors on a specific FO transceiver).

For equipment additions to existing installation, the installed base of legacy systems may suggest use of a certain type of connector be continued and to be used for new equipment. Alternatively, use of hybrid adapters or hybrid cables, will allow the use of cables with different connector types on opposite cable ends to permit the cable connectors to be compatible with the equipment termination connectors. Connectors with a pull-proof feature are preferable, especially for patch cords.

Nominal and maximum connector pair losses vary by connector type, by manufacturer, and by cable type (e.g., multimode or single mode). Nominal connector pair loss of 0.3 dB, and maximum connector pair loss of 0.5 dB are common for older types of FO connectors. Small form factor types and newer

connector types may offer lesser nominal and lesser maximum loss value.

FO connectors shall be field installable, self-aligning and centering. FO connectors shall match the fiber core and cladding diameters. Provide FO cable connectors at field equipment [of the type to match the field equipment connectors] [of type [____]] [as shown]. Provide FO connectors at terminal head end equipment [of the type to match terminal head equipment connectors] [of type [____]] [as shown]. Connector insertion loss shall be nominally 0.3 dB and maximum loss shall be less than 0.7 dB.

2.18 MECHANICAL SPLICES

Mechanical splices shall be suitable for installation in the field. External power sources shall not be required to complete a mechanical splice. Mechanical splices shall be self-aligning for optimum signal coupling. Mechanical splices shall not be used for exterior applications where they may be buried underground or laced to aerial messenger cables. Mechanical splices may be used for interior locations and within enclosures. Splice closures shall protect the spliced fibers from moisture and shall prevent physical damage. The splice closure shall provide strain relief for the cable and the fibers at the splice points.

2.19 FUSION SPLICES

The fusion splicer shall be portable, fully automatic, and compact. It shall be suitable for fusion splicing all types of telecommunication grade optical fibers and individual fibers as well as cables containing multiple optical fibers. The fusion splicer shall be capable of operation under various environmental conditions (e.g., temperature, humidity, altitude, etc.) for all types of optical cable deployments. The fusion splicer shall be craft friendly and operation shall require only minimal training. Automatic splicing software shall be available to remove operator and environmental dependence from the splicing process. The controls of the fusion splicer shall be designed in accordance with ergonomic considerations. The automatic splicing process shall be started by pressing one button and can be interrupted at any time. Alternatively, semi-automatic (step-by-step) or manual splicing shall be available by menu selection. Communication with the fusion splicer shall be conducted through a language unspecific keyboard with universal symbols and the dialogue with the splicer shall be displayed on the device screen.

2.20 CONDUIT, FITTINGS AND ENCLOSURES

Conduit, fittings, and enclosures shall be as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM, and as shown.

2.21 FAN-OUT KITS

NOTE: Fan-out kits (also referred to as providing buffer tube fan-out kits, or furcating harnesses, or furcation kits, or installing furcating tubes) will be provided for terminating all loose-tube optical fibers (i.e., optical fibers with 250 micron outside diameter) and will additionally incorporate strain relief if the connectorization is not contained within a patch panel. Fan-out kits with furcating

tubes are typically not used for tight-buffered (e.g., 900 micron outside diameter) optical fibers which have the connectorization contained within a patch panel. Fan-out kits with strain relief furcating tubes are appropriate for field connectorization of tight-buffered optical fibers when the termination is not contained within a patch panel.

For all loose-tube optical fibers, furnish and install fan-out kits using furcating tubes for connectorization. Loose-tube optical fiber furcating tubes shall incorporate strain relief if the connectorization is not contained within a protective enclosure such as a patch panel. For tight-buffered optical fibers, furnish and install fan-out kits using furcating tubes and which incorporate strain relief, if the connectorization is not contained within a protective enclosure such as a patch panel. Furcating tubes required to incorporate strain relief shall provide increased pullout protection and shall be comprised of an inner tube, surrounded by a layer of nonconductive strength members, then surrounded by an enclosing outer jacket layer. [Fan-out kits shall be color coded to match the industry fiber color scheme.] Length of furcating tube shall be [610] [915] mm [24] [36] inches minimum when installation is complete. Fan-out kits shall be rated for the ambient conditions of the location in which installed as specified in paragraph Environmental Requirements. Provide terminations for each fiber, regardless whether fiber is active or spare.

PART 3 EXECUTION

3.1 INSTALLATION

System components and appurtenances shall be installed in accordance with the manufacturer's instructions and as shown. Interconnections, services, and adjustments required for a complete and operable data transmission system shall be provided.

3.1.1 Interior Work

NOTE: DTS cable should not be used for, or routed through, Sensitive Compartmented Information Facilities (SCIFs). The designer will not show any DTS cable routed through a SCIF. The designer should check DCID 1/21 for further direction.

Conduits, tubing and cable trays for interior FO cable shall be installed as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM and as shown.

Cable installation and applications shall meet the requirements of NFPA 70, Article 770, Sections 52 and 53. Cables not installed in conduits or wireways shall be properly supported, secured, and neat in appearance, and if installed in plenums or other spaces used for environmental air, shall comply with NFPA 70 requirements for this type of installation.

3.1.2 Exterior Work, Aerial

NOTE: Aerial cable should be installed on existing

poles where height, clearance, and structure loading allow addition of cables. Where this is not possible, requirements for new poles must be shown on drawings. Installations will comply with IEEE C2 for Grade B construction and NFPA 70. Designer must coordinate with facility personnel for ground clearance and establish clearances to be shown on the drawings.

The designer will verify local electrical installation requirements to determine if new grounding conductors and electrodes are required at each messenger cable ground connection and will select the first, or second, or both bracketed entries as determined to be necessary.

Common lashing machines provide 1 turn per 380 linear mm (1 turn per 15 linear inches) in a single pass, which is acceptable for locations where loading due to weather conditions is moderate. Other locations may require multiple passes with the lashing machine.

Percent values stated below for messenger rated breaking strength are based upon overload factors that apply to Grade B construction. If the aerial electrical distribution system construction is a lesser grade (e.g., Grade C, Grade N, or not graded) differing values will be provided by the designer in accordance with NESC and actual requirements.

Except as otherwise specified, poles and associated aerial hardware for an overhead FO cable system shall be installed as specified in Section 33 71 01 OVERHEAD TRANSMISSION AND DISTRIBUTION, as specified herein, and as shown.

a. A messenger system meeting the requirements of IEEE C2 to support aerial cables shall be furnished and installed. The messenger system shall include all messenger support and attachment hardware and appurtenances needed to install the messenger. Messenger tension due to combined ice and wind loading on the messenger with supported cables shall not exceed 60 percent of the messenger rated breaking strength. Messenger tension due to extreme wind loading on the messenger with supported cables shall not exceed 80 percent of the messenger rated breaking strength. Messenger support and attachment hardware shall have rated strength not less than the messenger rated breaking strength. All messenger support and attachment hardware and appurtenances shall be sized to exceed the rated breaking strength of the messenger cable. Messenger cables shall be galvanized zinc coated steel or aluminum clad steel.

b. The messenger cables shall be grounded at all corners, dead ends, at the entrance to each facility, and at intervals not exceeding 305 meters 1000 feet. [New grounding conductors and electrodes shall be provided at each ground connection.] [Where grounding connections are made in the vicinity of existing grounding conductors and electrodes, the grounding connection may be made by a bolted or welded connection to the existing grounding conductor.]

c. Aerial FO cables shall meet the horizontal, vertical and climbing space clearances prescribed in IEEE C2 and those of the installation.

d. Transitions from aerial cable to underground cable shall be as specified in paragraph CONNECTIONS BETWEEN AERIAL AND UNDERGROUND SYSTEMS in Section 33 71 01 OVERHEAD TRANSMISSION AND DISTRIBUTION and as shown.

e. Splices in aerial cable shall be within 1 meter 3 feet of a pole and placed inside a watertight enclosure. Drip loops shall be formed at the cable entrance to the enclosure. Lashing clamps shall be placed within 300 mm 12 inches of the enclosure.

f. Loops shall be formed in the aerial cables at points of connection and at poles to prevent damage from thermal stress and wind loading. The communications cable shall be protected from chafing and physical damage with the use of spiral cut tubing and PVC tape, or plastic sleeves. The ground clearance of installed cabling shall be as shown.

g. Cable shall be run vertically and when possible shall use gravity to assist in cable pulling. Cable shall be pulled from top of run to bottom of run. Cable shall be hand pull if possible. If machine assistance is required, tension shall be monitored using dynamometers or load-cell instruments and shall not exceed specified cable tension limits. After installation, the vertical tension on the cable shall be relieved at maximum intervals of 30 meters 100 feet using a split support grip.

h. Lashing wire shall be wound tightly around both the communication cable and the messenger cable by machine methods. The lashing wire shall have a minimum of 1 turn per 380 linear mm 1 turn per 15 linear inches and not less than the number of turns per unit length that is recommended by the cable manufacturer for the distance between cable support points and the combined ice and wind loading and extreme wind loading specified or normally encountered loading for the installed location. Lashing clamps shall be placed at all poles and splices.

i. Ground conductors shall be soft drawn copper, having a current capacity of at least 20 percent of that of the messenger to which it is connected. Ground conductors shall not be smaller than No. 6 AWG. The ground conductor shall be connected to a copper or copper clad steel ground rod not less than 19.1 mm 3/4 inch in diameter, and length shall be as needed to achieve the specified ground resistance. After installation is completed, the top of the ground rod shall be approximately 300 mm 1 foot) below finished grade. The ground conductor shall be protected by half-round wood, plastic, or fiber molding from the ground to a point at least 2.4 m 8 feet above the ground. Ground resistance shall be measured in normally dry conditions, not less than 48 hours after a rainfall, and the total ground resistance shall not exceed [25] [] ohms.

j. Design Parameters

NOTE: The designer will include the data listing the loading conditions, including radial thickness of ice, horizontal wind pressure, and temperature, for both combined ice and wind loading and extreme wind loading encountered at the project site.

The ice and wind loading conditions to be encountered at this installation are as follows:

aa. Combined ice and wind loading:

- (1) Radical thickness of ice [_____] mm in
- (2) Horizontal wind pressure [_____] Pa psf
- (3) Temperature [_____] degrees C degrees F
- (4) Constant to be added to the resultant [_____] N/m lb/ft

bb. Extreme wind loading:

- (1) Velocity pressure exposure coefficient, wire [_____]
- (2) Basic wind speed [_____] m/s mi/h
- (3) Temperature 15 degrees C 60 degrees F
- (4) Gust response factor, wire [1.0] [_____]
- (5) Importance factor [1.0] [_____]
- (6) Shape factor [1.0] [_____]

3.1.1.3 Exterior Work Underground

NOTE: For UMCS ESS or IDS projects, the designer will provide transition details in the drawings based on the details shown in UMCS/EMCS or IDS Typical Drawings and/or Standards installation Details.

Except as otherwise specified, conduits, ducts, and manholes for underground FO cable systems shall be installed as specified in Section 33 70 02.00 10 ELECTRICAL DISTRIBUTION SYSTEM, UNDERGROUND and as shown.

a. Minimum burial depth for cable shall be 760 mm 30 inches, but not less than the depth of the frost line. Burial depth specified shall take precedence over any requirements specified elsewhere.

b. Where direct burial cable will pass under sidewalks, roads, or other paved areas, the cable shall be placed in a 25 mm 1 inch zinc-coated rigid coated conduit or larger as required to limit conduit fill to 80 percent or less. Conduit may be installed by jacking or trenching, as approved.

c. Buried cables shall be placed below a plastic warning tape buried in the same trench or slot. The warning tape shall be 300 mm 12 inches above the cable. The warning tape shall be continuously imprinted with the words "WARNING - COMMUNICATIONS CABLE BELOW" at not more than 1.2 m 48 inch intervals. The warning tape shall be acid and alkali resistant polyethylene film, 76.2 mm 3 inches wide with a minimum thickness of 0.1 mm 0.004 inch. Warning tape shall have a minimum strength of 12066 kPa 1750 psi lengthwise and 10342 kPa 1500 psi crosswise.

d. Transitions from underground cable to aerial cable shall be as specified in paragraph CONNECTIONS BETWEEN AERIAL AND UNDERGROUND SYSTEMS in Section 33 71 01 OVERHEAD TRANSMISSION AND DISTRIBUTION and as shown.

e. For cables installed in ducts and conduit, a cable lubricant compatible with the cable sheathing material shall be used on all cables pulled. Pulling fixtures shall be attached to the cable strength members. If indirect attachments are used, the grip diameter and length shall be matched to the cable diameter and characteristics. If an indirect attachment is used on cables having only central strength members, the pulling forces shall be reduced to ensure that the fibers are not damaged from forces being transmitted to the strength member. During pulling the cable pull line tension shall be continuously monitored using dynamometers or load-cell instruments, and shall not exceed the maximum tension specified by the cable manufacturer. The mechanical stress placed upon the cable during installation shall be such that the cable is not twisted or stretched. A cable feeder guide shall be used between the cable reel and the face of the duct or conduit to protect the cable and guide it into the duct or conduit as it is unspooled from the reel. As the cable is unspooled from the reel, it shall be inspected for jacket defects or damage. The cable shall not be kinked or crushed and the minimum bend radius of the cable shall not be exceeded during installation. Cable shall be hand fed and guided through each manhole and additional lubricant shall be applied at all intermediate manholes. When practicable, the center pulling technique shall be used to lower pulling tension. That is, the cable shall be pulled from the center point of the cable run towards the end termination points. The method may require the cable to be pulled in successive pulls. If the cable is pulled out of a junction box or manhole the cable shall be protected from dirt and moisture by laying the cable on a ground covering.

3.1.4 Service Loops

Each fiber optic cable shall have service loops of not less than 3 meters 9.8 feet in length at each end. The service loops shall be housed in a service loop enclosure.

3.1.5 Metallic Sheath Grounding

NOTE: Direct burial cables with metallic sheath
will not be installed when transmission of
electromagnetic interference (EMI) or radio
frequency interference (RFI) through the metallic
sheath is a consideration.

Fiber optic cable with metallic sheath that enter buildings shall be grounded at a point as close as practical to the building point of entrance. Fiber optic cable with metallic sheath routed in the trench with a power cable shall have the metallic sheath grounded at the cable termination points.

3.1.6 Splices

NOTE: Maximum splice loss values per
ANSI/TIA/EIA-568B are 0.3 dB for fusion splices, and
0.3 dB for mechanical splices. These maximum loss
values are considered larger loss values than can be
provided by many manufacturers and installers. The
designer will specify lesser loss values when the

design and link loss budget require lesser values.

3.1.6.1 General

No splices will be permitted unless the length of cable being installed exceeds the maximum standard cable length available from a manufacturer or unless fiber optic pigtailed are used to connect transmitters, receivers, or other system components for terminations to the fiber. Splices shall be made using the method recommended by the cable manufacturer. Splices shall be housed in a splice enclosure and shall be encapsulated with an epoxy, ultraviolet light cured splice encapsulant or otherwise protected against infiltration of moisture or contaminants. FO splices shall be field tested at the time of splicing. Fusion splices shall have nominal splice loss of [0.15] [_____] dB for multimode and for single mode cable fusion splices and shall have maximum fusion splice loss not more than 0.3 dB loss.

3.1.6.2 Mechanical Splices

Mechanical splices shall have nominal splice loss of [0.15] [_____] for multimode fiber mechanical splices and [0.2] [_____] dB for single mode fiber mechanical splices and shall have maximum mechanical splice loss not more than [0.3] [_____] dB loss for multimode and for single mode fiber mechanical splices. There shall be no more than 1 splice per km 0.62 mile in any of the FO cables excluding terminations. Field splices shall be located in cable boxes. Sufficient cable shall be provided in each splicing location to properly rack and splice the cables, and to provide extra cable for additional splices. Cable ends shall be protected with end caps except during actual splicing. During the splicing operations, means shall be provided to protect the unspliced portions of the cable and its fibers from the intrusion of moisture and other foreign matter.

3.1.7 Connectors

NOTE: Maximum connector pair losses per ANSI/TIA/EIA-568B are provided in the first bracketed entry and are considered larger than connector pair losses that can be achieved by many manufacturers and installers. The designer will specify lesser loss values when the design and link loss budget requires lesser values. The designer will confirm with two manufacturers minimum, that the lesser connector pair loss value can be achieved for the connector type and fiber (i.e., multimode or single mode) type.

Prior to and during installation of connectors, appropriate cleaning should be performed to ensure that any contaminant particulates larger than 0.06 micron in size are removed. Connectors shall be as specified in paragraph FO CONNECTORS. Connectors or splices which leave residue on the connector ferrule or optical connector "lens", are not permitted. Fibers at each end of the cable shall have jumpers or pigtailed installed of not less than 1 meter 3 feet in length. Fibers at both ends of the cable shall have connectors installed on the jumpers. The mated connector pair loss shall not exceed [0.75] [_____] dB. The pull strength between the connector and the attached fiber shall not be less than 22.7 kg 50 pounds.

3.1.8 Identification and Labeling

Identification tags or labels shall be provided for each cable. Markers, tags and labels shall use indelible ink or etching which will not fade in sunlight, or in buried or underground applications. Markers, tags, and labels shall not become brittle or deteriorate for a period of 20 years due to moisture, sunlight, soil minerals, chemicals or other environmental elements. Label all termination blocks and panels with cable number or pair identifier for cables in accordance with TIA/EIA-606-A and as specified. The labeling format shall be identified and a complete record shall be provided to the Government with the final documentation. Each cable shall be identified with type of signal being carried and termination points.

3.1.9 Enclosure Sizing and Cable

Termination enclosures shall be sized to accommodate the FO equipment to be installed. Sizing shall include sufficient space for service loops to be provided and to accommodate a neat, workmanlike layout of equipment and the bend radii of fibers and cables terminated inside the enclosure.

3.1.10 Enclosure Penetrations

Enclosure penetrations shall be from the bottom and shall be sealed with rubber silicone sealant to preclude the entry of water. Conduits rising from underground shall be internally sealed.

3.2 TESTING

**NOTE: Insert the title of the appropriate system
specification (such as UMCS, IDS, ESS or CCTV).**

3.2.1 General

The Contractor shall provide personnel, equipment, instrumentation, and supplies necessary to perform testing.

3.2.2 Contractor's Field Test

The Contractor shall verify the complete operation of the data transmission system in conjunction with field testing associated with systems supported by the fiber optic data transmission system as specified in Section [_____] prior to formal acceptance testing. Field tests shall include a flux density test. These tests shall be performed on each link and repeated from the opposite end of each link.

3.2.2.1 Optical Time Domain Reflectometer Tests

Optical time domain reflectometer tests shall be performed using the FO test procedures of TIA-455-78-B. An optical time domain reflectometer test shall be performed on all fibers of the FO cable on the reel prior to installation. The optical time domain reflectometer shall be calibrated to show anomalies of 0.2 dB as a minimum. Photographs of the traces shall be furnished to the Government. An optical time domain reflectometer test shall be performed on all fibers of the FO cable after it is installed. The optical time domain reflectometer shall be calibrated to show anomalies of 0.2 dB as a minimum. If the optical time domain reflectometer test

results show anomalies greater than 1 dB, the FO cable segment is unacceptable to the Government. The unsatisfactory segments of cable shall be replaced with a new segment of cable. The new segment of cable shall then be tested to demonstrate acceptability. Photographs of the traces shall be furnished to the Government for each link.

3.2.2.2 Power Attenuation Test

Power attenuation test shall be performed at each light wavelength of the transmitter to be used on the circuit being tested. The flux shall be measured at the FO receiver end and shall be compared to the flux injected at the transmitter end. There shall be a jumper added at each end of the circuit under test so that end connector loss shall be validated. Rotational optimization of the connectors will not be permitted. If the circuit loss exceeds the calculated circuit loss by more than 2 dB, the circuit is unsatisfactory and shall be examined to determine the problem. The Government shall be notified of the problem and what procedures the Contractor proposes to eliminate the problem. The Contractor shall prepare and submit a report documenting the results of the test.

3.2.2.3 Gain Margin Test

The Contractor shall test and verify that each circuit has a gain margin which exceeds the circuit loss by at least the minimum gain margin specified in paragraph FLUX BUDGET/GAIN MARGIN.

3.2.2.4 Analog Video Signal Test

Analog video circuits shall be tested using a signal conforming to CEA 170. The monitor or automated test set shall be stable, and shall be as described in CEA 170. If the result is unsatisfactory, the circuit shall be examined to determine the problem. The Government shall be notified of the problem and of the procedures the Contractor proposes to eliminate the problem. The Contractor shall prepare and submit a report documenting the results of the test.

3.2.2.5 Digital Video Signal Test

Digital video circuits shall be tested using a signal conforming to CEA 170. The monitor or automated test set shall be stable, and shall be as described in CEA 170. If the result is unsatisfactory, the circuit shall be examined to determine the problem. The Government shall be notified of the problem and of the procedures the Contractor proposes to eliminate the problem. The Contractor shall prepare and submit a report documenting the results of the test.

3.2.2.6 Performance Verification Test and Endurance Test

**NOTE: This requirement pertains only to UMCS, IDS,
ESS and CCTV projects.**

The FO data transmission system shall be tested as a part of the completed [UMCS] [IDS] [ESS] [CCTV] [_____] during the Performance Verification Test and Endurance Test as specified in Section [_____].

3.3 TRAINING

3.3.1 General

The Contractor shall conduct a training course for designated personnel in the maintenance of the FO system. The training shall be oriented to the specific system being installed under this specification. The Contractor shall furnish training materials and supplies.

3.3.2 System Maintenance Course

The system maintenance course shall be taught at the project site after completion of the endurance test for a period of 1 training day. A maximum of five personnel designated by the Government will attend the course. A training day shall be 8 hours of classroom or lab instruction, including two 15 minute breaks and excluding lunchtime during the daytime shift in effect at the facility. Training shall include:

- a. Physical layout of the system and each piece of hardware.
- b. Troubleshooting and diagnostics procedures.
- c. Repair instructions.
- d. Preventative maintenance procedures and schedules.
- e. Calibration procedures. Upon completion of this course, the students shall be fully proficient in the maintenance of the system.

-- End of Section --