

## SECTION 27 13 01

### COMMUNICATION CABLES AND RELATED EQUIPMENT

#### PART 1 - GENERAL

##### 1.01 SECTION INCLUDES

- A. Single mode and multimode fiber optic cables.
- B. Telephone cables.
- C. Emergency trip and fire telephone cables.
- D. DeviceNet cables.
- E. Category 6 cables.
- F. Video Coaxial Cables.
- G. Radio Coaxial Cables.
- H. Radiating Coaxial Cables.
- I. Related equipment including connectors, outlets, jumpers, patch cords, pigtails, interconnect panels, fiber and copper patch panels, splice cases, innerducts, terminal blocks and cable test equipment.

##### 1.02 RELATED SECTIONS

- A. Section 01 33 00 Submittal Procedures
- B. Section 01 33 23 Shop Drawings, Product Data and Samples.
- C. Section 01 43 00 Quality Assurance
- D. Section 01 45 00 Quality Control
- E. Section 01 78 44 Spare Parts and Maintenance Materials
- F. Section 20 50 13 Raceways for Facility Services.
- G. Section 20 70 13 Common Materials and Methods for Electronic Services
- H. Section 20 70 19 Indoor Cabinets, Racks, Frames and Enclosures.
- I. Section 20 70 23 Electronic Circuits, Wires and Cables.
- J. Section 20 70 26 Common Materials and Methods for Electrical Services
- K. Section 20 80 00 Systems Integration Testing
- L. Section 20 72 25 Factory and Field Testing.
- M. Section 26 05 24 Low Voltage Wires and Cables

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- N. Section 26 05 26 Grounding and Bonding.
- O. Section 27 21 00 Unified Optical Network.
- P. Section 28 41 29 Closed Circuit Television System.
- Q. Section 33 83 03 Radio Network / Antenna System.
- R. Section 33 83 06 Radio Network / Bidirectional Radio Amplifier System.

### 1.03 MEASUREMENT AND PAYMENT

- A. The work specified in this Section will be paid for under the applicable Bid Items based on the locations where work is performed, as identified in the Form – Description of Bid Items, in accordance with Contract Specifications Section 01 20 00, Price and Payment Procedures.

### 1.04 REFERENCES

- A. American National Standards Institute (ANSI):
  - 1. ANSI J-STD-607-A Commercial Building Grounding and Bonding Requirements for Telecommunications, 2002.
- B. ASTM International (ASTM):
  - 1. ASTM E662 Test Method for Specific Optical Density of Smoke Generated by Solid Materials
- C. California Code of Regulations (CCR):
  - 1. CCR Title 24, Part 3, California Electrical Code
- D. Electronics Industries Association (EIA):
  - 1. EIA 359-A Standard Colors for Color Identification and Coding
  - 2. EIA TIA-455-A Standard Test Procedure for Fiber Optic Fibers, Cables, Transducers, Sensors, Connecting and Terminating Devices, and Other Fiber Optic Components
  - 3. EIA TIA-455-3 FOTP-3 Procedure to Measure Temperature Cycling Effects on Optical Fibers, Optical Cable, and Other Passive Fiber Optic Components
  - 4. EIA TIA-455-8 Measurement of Splice or Connector Loss and Reflectance using an OTDR
  - 5. EIA TIA-455-13 FOTP-13 Visual and Mechanical Inspection of Fibers, Cables, Connectors and/or Other Fiber Optic Devices
  - 6. EIA TIA-455-25 FOTP-25 Repeated Impact Testing of Fiber Optic Cables and Cable Assemblies

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7. EIA TIA-455-30 FOTP-30 Frequency Domain Measurement of Multimode Optical Fiber Information Transmission Capacity
  8. EIA TIA-455-34 Interconnection Device Insertion Loss Test
  9. EIA TIA-455-41 FOTP-41 Compressive Loading Resistance of Fiber Optic Cables
  10. EIA TIA-455-47 FOTP-47 Output Far Field Radiation Pattern Measurement
  11. EIA TIA-455-51 FOTP-51 Pulse Distortion Measurement of Multimode Glass Optical Fiber Information Transmission Capacity
  12. EIA TIA-455-59 FOTP-59 Measurement of Fiber Point Defects Using an OTDR
  13. EIA TIA-455-61 FOTP-61 Measurement of Fiber or Cable Attenuation Using an OTDR
  14. EIA TIA-455-88 FOTP-88 Fiber Optic Cable Bend Test
  15. EIA TIA- 455-91 FOTP-91 Fiber Optic Cable Twist-Bend Test
  16. EIA TIA-455-104 FOTP-104 Fiber Optic Cable Cyclic Flexing Test
  17. EIA TIA-455-171 FOTP-171 Attenuation by Substitution Measurement - for Short-Length Multimode Graded-Index and Single-Mode Optical Fiber Cable Assemblies
  18. EIA TIA-472 A Generic Specification for Fiber Optic Cable
  19. EIA 492 A Detail Specification for 62.5- $\mu$ m Core Diameter/125- $\mu$ m Cladding Diameter Class 1a Multimode, Graded Index Optical Waveguide Fibers.
  20. EIA/TIA-568-C.0 Generic Telecommunication Cabling For Customer Premises.
  21. EIA/TIA-568-C.1 Commercial Building Telecommunications Cabling Standards, Part 1: General Requirements
  22. EIA/TIA-568-C.2 Balanced Twisted Pair Telecommunications Cabling and Components Standard.
  23. EIA/TIA-568-C.3 Optical Fiber Cabling Components Standard
  24. EIA TIA-598-A Optical Fiber Cable Color Coding
  25. EIA TIA-606 Administration Standards for the Telecommunications Infrastructure of Commercial Buildings
- E. Insulated Cable Engineers Association, Inc. (ICEA):
1. ICEA S-84-608 Telecommunications Cable Filled, Polyolefin Insulated, Copper Conductor Technical Requirements.

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- F. Institute of Electrical and Electronics Engineers (IEEE):
1. IEEE 383 Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations
- G. National Electrical Manufacturers Association (NEMA):
1. NEMA WC7 Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
- H. National Fire Protection Association (NFPA):
1. NFPA 258 Standard Research Test Method for Determining Smoke Generation of Solid Materials
- I. Rural Electrification Administration (REA):
1. REA PE-39 Filled Telephone Cables
- J. Underwriters Laboratories Inc. (UL):
1. UL 1581 Electrical Wires, Cables, and Flexible Cords
  2. UL 1666 Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts

### 1.05 ABBREVIATIONS

AWG	American Wire Gauge
CD	Chromatic Dispersion
DC	Direct Current
DS	Digital Signal
ETS	Emergency Trip System
FRPE	Flame-retardant Polyethylene
GRP	Glass Reinforced Plastic
IP	Internet Protocol
IPP	IP Precedence
LAN	Local Area Network
LC	Lucent Connector
LSZH	Low Smoke, Zero Halogen

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MM	Multimode
NMS	Network Management System
OADM	Optical Add-Drop Multiplexer
OCC	Operations Control Center
OFNP	Optical Fiber Non-Conductive Plenum
ONS	Optical Network System
OPL	Optical Power Loss
ORL	Optical Return Loss
OSA	Optical Spectrum Analyzer
OTDR	Optical Time Domain Reflectometer
OTN	Optical Transport Network
PMD	Polarization Mode Dispersion
PTC	Project Test Center
QoS	Quality of Service
SC	Subscriber Connector
SCADA	Supervisory Control and Data Acquisition
SDH	Synchronous Digital Hierarchy
SFP	Small Form-Factor Pluggable
SM	Single mode
TCH	Train Control House
TCR	Train Control Room
TDM	Time Division Multiplexing
ToS	Type of Service
UAN	Unified Administration Network
UON	Unified Optical Network
UPC	Ultra Physical Contact

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UTP	Unshielded Twisted Pair
UV	Ultraviolet
VLAN	Virtual Local Area Network
VSS	Video Surveillance System
WDM	Wave Division Multiplexing
XFP	Small Form-Factor Pluggable (10 Gigabit)

### 1.06 SUBMITTALS

- A. General: Refer to Contract Specifications Section 01 33 00 - Submittal Procedures, and Section 01 33 23 - Shop Drawings, Product Data, and Samples, for submittal requirements and procedures.
- B. Submittal Requirements: Before installation of wires and cables, submit complete product data sheets for each type and size of wire and cable required for the project. Provide optical loss calculations for each span of the fiber optic network and indicate total anticipated optical loss in dB between OADM nodes.
- C. Factory and Field Test Plans and Reports: Submit factory and field test plans and reports in accordance with Contract Specifications Section 20 72 25 - Factory and Field Testing and Contract Specifications Section 20 80 00 - Systems Integration Testing. Completed field test reports for all fiber and copper cables shall be submitted to the District for approval.

### 1.07 QUALITY ASSURANCE AND QUALITY CONTROL

- A. Refer to Contract Specifications Section 01 43 00 – Quality Assurance, and Contract Specifications Section 01 45 00 - Quality Control, for hardware quality assurance requirements and IEEE STD 730 for software quality assurance requirements.
- B. Products shall be manufactured by firms regularly engaged in manufacturing products described in this Section.
- C. Field testing shall be performed by persons having five or more years of relevant testing experience.

### 1.08 DELIVERY, STORAGE, AND HANDLING

- A. Provide markings on wire and cable in accordance with applicable NEMA and California Electrical Code requirements. Each item shall be labeled with UL listing approval.
- B. Ship each unit securely wrapped, packaged, and labeled for safe handling in shipment and to avoid damage.
- C. Store wire and cable in a secure and dry storage facility.
- D. If fiber optic cable is packaged for shipment, the reels shall be non-returnable wooden reels with a maximum reel diameter of 78". The top and bottom ends of the cable shall be available for

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testing. Both ends of each cable shall be sealed to prevent the ingress of moisture.

### **PART 2 - PRODUCTS**

#### **2.01 SINGLE MODE FIBER OPTIC CABLE**

##### **A. General**

1. Outside plant inter-facility cables shall be gel-free, single mode.
2. Single mode cable shall meet the requirements of the National Electrical Code<sup>®</sup> (NEC)<sup>®</sup> Section 770 and the Low Smoke Zero Halogen – Applicable Flame-Smoke Test: UL 1685. Cables shall be manufactured in accordance with EIA TIA-455-13, EIA TIA-455-25, EIA TIA-455-41, EIA TIA-455-47, EIA TIA-455-59, EIA TIA-455-61, EIA 455-88, EIA 455-91, EIA 455-104, and EIA 455-171.
3. Finished cables shall conform to the applicable performance requirements of the Insulated Cable Engineers Association, Inc. (ICEA) Standard for Indoor-Outdoor Optical Fiber Cable (ICEA S-104-696).
4. Fiber optic cable assemblies, including jacketing and fibers shall be certified by the manufacturer to have a minimum life of 25 years.
5. Jacket printing: Each shipping length of cable shall be permanently identified by printing on the outer surface of the jacket, at intervals of five feet or less. Information shall include count of fibers, fiber type and size, cumulative footage markers, manufacturer's designation, plant name (if applicable), and manufacturer's name.
6. Single mode fiber optic cables shall be Corning SMF-28 or equal.
7. Count of optical fibers in each cable run, including fibers reserved for future use and for spares, shall be as indicated.

##### **B. Fiber Specifications**

1. Type: Single-mode, loose tube.
2. Operating wavelength: 1310/1550 nm
3. Attenuation at 1310 nm: 0.35 dB/km, maximum
4. Attenuation at 1383 nm: 0.35 dB/km, maximum
5. Attenuation at 1550 nm: 0.22 dB/km, maximum
6. Polarization Mode Dispersion Link Value: 0.1 maximum.

##### **C. Cable Construction**

1. Optical fibers shall be placed inside a loose buffer tube. The nominal outer diameter of the buffer tube shall be 3.0 mm.

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2. Each buffer tube shall contain up to 12 fibers. The fibers shall not adhere to the inside of the buffer tube. Buffer tubes shall be resistant to kinking.
3. Each fiber shall be distinguishable by means of color coding in accordance with TIA/EIA-598, "Optical Fiber Cable Color Coding." The fibers shall be colored with ultraviolet (UV) curable inks. Buffer tube colored stripes shall be inlaid in the tube by means of co-extrusion when required. The nominal stripe width shall be 1 mm.
4. In buffer tubes containing multiple fibers, the colors shall be stable across the specified storage and operating temperature range and not subject to fading or smearing onto each other. Colors shall not cause fibers to stick together.
5. Fillers may be included in the cable core to lend symmetry to the cable cross-section where needed. Fillers shall be placed so that they do not interrupt the consecutive positioning of the buffer tubes.
6. The central member shall consist of a dielectric, glass reinforced plastic (GRP) rod. The purpose of the central member is to prevent buckling of the cable. The GRP rod shall be over coated with a thermoplastic, when required, to achieve dimensional sizing to accommodate buffer tubes/fillers.
7. Buffer tubes shall be stranded around the dielectric central member using the reverse oscillation, or "S-Z," stranding process. Water blocking yarn(s) shall be applied longitudinally along the central member during stranding.
8. Two polyester yarn binders shall be applied contra helically and with sufficient tension to secure each buffer tube layer to the dielectric central member without crushing the buffer tubes. The binders shall be non-hygroscopic, non-wicking and dielectric with low shrinkage.
9. Flame-retardant tape may be applied to provide resistance to flame propagation. A water blocking tape shall be applied longitudinally around the outside of the flame retardant tape.
10. The tensile strength shall be provided by the central member, and additional dielectric yarns as required. The dielectric yarns shall be helically stranded evenly around the cable core.
11. The jacket material shall be a flame-retardant, low-smoke, zero-halogen (LSZH) insulating compound that is ultraviolet (UV) resistant. Cables shall contain at least one ripcord under the sheath for easy sheath removal
12. The jacket shall be continuous, free from pinholes, splits, blisters, or other imperfections. The jacket shall have a consistent, uniform thickness; jackets extruded under high pressure are not acceptable. The jacket shall be smooth, as is consistent with the best commercial practice. The jacket shall provide the cable with a tough, flexible, protective coating, able to withstand the stresses expected in normal installation and service.

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### 2.02 MULTIMODE FIBER OPTIC CABLE

#### A. General

1. Inside plant, intra-facility cables shall be multimode.
2. Cables shall be manufactured in accordance with EIA TIA-455-13, EIA TIA-455-25, EIA TIA-455-41, EIA TIA-455-47, EIA TIA-455-59, EIA TIA-455-61, EIA 455-88, EIA 455-91, EIA 455-104, and EIA 455-171.
3. Finished cables shall conform to the applicable performance requirements of the Insulated Cable Engineers Association, Inc. (ICEA) Standard for Indoor-Outdoor Optical Fiber Cable (ICEA S-104-696).
4. Fiber optic cable assemblies, including jacketing and fibers shall be certified by the manufacturer to have a minimum life of 25 years.
5. Jacket printing: Each shipping length of cable shall be permanently identified by printing on the outer surface of the jacket, at intervals of five feet or less. Information shall include count of fibers, fiber type and size, cumulative footage markers, manufacturer's designation, plant name (if applicable), and manufacturer's name or UL file number.
6. Individual fibers shall be color coded for identification in accordance with EIA TIA-598-A.
7. Count of optical fibers in each cable run, including fibers reserved for future use and for spares, shall be as indicated.

#### B. Fiber Specifications

1. Type: Tight buffered, graded index multimode cables without armor and with an outer jacket rated for plenum or non-plenum duty as applicable.
2. Operating Wavelength and Bandwidth: 160 MHz·km at 850 nm and 500 MHz·km at 1300 nm.
3. Attenuation at 850 nm: 3.75 dB/km, maximum.
4. Attenuation at 1300 nm: 1.00 dB/km, maximum.
5. Core diameter: 50  $\mu\text{m}$  plus or minus 3.0  $\mu\text{m}$  optimized for 550 meters.
6. Cladding diameter: 125.0  $\mu\text{m}$  plus or minus 2.0  $\mu\text{m}$ .
7. Each tube and buffered fiber shall be color-coded to provide unique and permanently visible identification, in accordance with EIA 359-A.
8. Optical Performance: The attenuation shall be measured in accordance with EIA TIA-455-61. The bandwidth shall be measured in accordance with EIA TIA-455-30 or EIA TIA-455-.

#### C. Cable Construction

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1. Fibers shall be tight buffered to 900 µm diameter, using a tough elastomeric buffer material.
2. Buffered fibers to be stranded together with dielectric strength members.
3. Inner cable jacket to be pressure-extruded onto cabled fibers and strength members in the core assembly. This jacket material shall be of zero-halogen flame-retardant composition.
4. The jacket material shall be a flame-retardant, LSZH insulating compound that is UV resistant. The outer jacket shall be extruded over the shield in a tight-fitting assembly.
5. A 0.006-inch thick (minimum) corrugated electrolytic chrome coated steel tape, plastic coated on both sides, shall be tightly wrapped, around the inner jacket.
6. A ripcord (or two ripcords) of compatible material shall be built into the cable assembly, to facilitate removal of the wrap and jackets during installation.

### **2.03 TELEPHONE CABLES**

- A. Refer to Section 20 70 23 for Non-IP telephone requirements.
- B. Provide Category 6 telephone cables with a minimum of four pairs for inside plant line circuits. Inter-cabinet tie cables shall be UTP, 25, 50 or 100 pair cables as required to meet the active pair count as shown on the Contract Drawings including 50% spare pairs. Plenum cable shall be used where required by code(s). Use blue-jacketed cable for data and data/voice cables and green-jacketed cable for voice-only cables.
- C. Telephone cables shall be certified by the manufacturer to have a minimum life of 40 years.
- D. A plan for the usage of Category 5E telephone cables must be submitted for District approval.

### **2.04 FIRE TELEPHONE AND EMERGENCY TRIP SYSTEM CABLES**

- A. Fire telephone and emergency trip system cables shall be six pair, 19 AWG solid, soft-annealed, insulated copper conductors with an overall shield. Cables shall meet the requirements of REA Specification PE-39 – Filled Telephone Cables. Fire telephone and emergency trip system cables shall be certified by the manufacturer to have a minimum life of 40 years.

### **2.05 SCADA DEVICENET CABLE**

- A. SCADA DeviceNet cable shall be Belden 3082A or equal.

### **2.06 CATEGORY 6 CABLE**

- A. Category 6 cable and patch cables shall meet with the TIA/EIA 568C standard and conform to the following requirements:
  1. Unshielded cables shall only be utilized in non-wayside facilities such as the Lake Merritt, maintenance facilities, administrative offices, etc. Unshielded cables shall be plenum rated with four balanced, unshielded twisted pairs (UTP). Conductors shall be #24 AWG solid copper. Cable insulation jackets shall be color coded for the service type: blue for data, white for voice, and green for video applications.

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2. Shielded cables shall be used in all wayside facilities. Shielded cables shall be plenum rated with an overall foil tape shield and four balanced, unshielded twisted pairs (F/UTP). Conductors shall be #24 AWG solid copper. The shield shall be an aluminum foil tape enclosing a 24 AWG tinned copper drain wire. Cable insulation jackets shall be color coded for the service type: blue for data, white for voice, and green for video applications.
3. Cable jackets shall be legibly marked with the following information:
  - a. Manufacturer's Name
  - b. Copper conductor gauge
  - c. Pair count
  - d. UL or CSA listing
  - e. Manufacturer's Trademark
  - f. Category rating, including UTP, F/UTP or ScTP (screened twisted pair)
  - g. Sequential foot markings, in one or two foot increments
4. Unshielded Category 6 patch cables shall be rated for 250 MHz or better and shall be composed of four, 24 AWG stranded copper conductors with 50-micron, gold plated RJ-45 male to male connectors and a plenum jacket.
5. Shielded Category 6 patch cables shall be rated for 250 MHz or better and shall be composed of four, 24 AWG stranded copper conductors with shielded 50-micron, gold plated RJ-45 male to male connectors, an overall shield with aluminum foil tape enclosing a 24 AWG tinned copper drain wire, and a plenum jacket.

### **2.07 VIDEO COAXIAL CABLE**

- A. Provide coaxial cables for analog video signal transmission:
  1. 75  $\Omega$  characteristic impedance.
  2. Double braided copper shield.
  3. AWG No. 20 solid copper center conductor.

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### 2.08 RADIO COAXIAL CABLE

- A. Provide coaxial cables for radio signal transmission. Coaxial cables shall be size ¼" minimum, jacketed, corrugated, low density foam-filled for trunked radio applications. The minimum design requirements and general characteristics are as follows:
1. 50  $\Omega$  characteristic impedance.
  2. VSWR shall be 1.2: maximum at center frequency.
  3. Minimum bending radius shall be 10 inches.
  4. Attenuation shall not exceed 1.8dB, referenced to MHz.
  5. Outer conductor shall be solid copper.
  6. Inner conductor shall be copper.
  7. The cable shall be permanently identified.
  8. Connectors shall be EIA type N jack (female) on both ends.
  9. Grounding kits shall be provided to ground all coaxial cables to the tower top, tower bottom, and at the building entrance.
  10. Snap-in hanger kits shall be provided to mount coax cable directly into holes in the tower support members.

### 2.09 SLOTTED RADIO COAXIAL CABLE

- A. The minimal design requirements and general characteristics of the slotted coaxial cables are as follows:
1. The slotted coaxial cables shall pass the UL 854 and 1581 flame tests (similar to IEEE 383, NES 711/713, and IEC 332-3), UL listed under Article 820 of the National Electrical Code, and all code requirements must be approved by the fire inspector.
  2. The slotted coaxial cables shall be jacketed, corrugated foam-filled cables suitable for mounting to a metallic (galvanized steel) messenger wire or hangers.
  3. Cable jacket shall offer fire-retardant, hydro-carbon protection, halogen-free performance, low-level smoke and toxic fume emissions. The jacket shall be vertical tested and approved by Underwriters Laboratories.
  4. Coupling loss measured at 20 feet shall not exceed the following:
    - a. Coupling Loss (dB) @ Frequency Band (MHz).
      - i. 82 @ 800
      - ii. 82 @ 900

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- iii. 73 @ 1800
  - iv. 72 @ 1900
  - v. 71 @ 2200
5. Characteristics impedance shall be 50 ohms.
  6. Typical VSWR shall be less than 1.3:1, referenced to 30, 150, 450 and 900MHz.
  7. Minimum bending radius shall be 10 x diameter.
  8. Attenuation measured at free space shall be less than 1.0 dB per 100 feet, referenced to 900 MHz.
  9. Inner and outer conductors shall be copper
  10. The cable shall be permanently identified.
  11. Slotted coaxial cables shall be factory assembled, tested and furnished in continuous reel lengths of 2300 feet maximum with factory installed EIA type N female connectors on both ends.
  12. The outer conductor shall be two layers of mica insulated barrier tape wrapped around the conductor to prevent dielectric material from leaking through the slots under fire conditions.
  13. The cable shall have a flooding compound between the jacket and outer conductor barrier tape to prevent entry of water.

### 2.10 OPTICAL CONNECTORS

- A. Patch Panel Connectors: LC ultra physical contact (UPC) connector with 126um (single mode) or aqua 127um (multimode) ceramic zirconia alignment ferrules shall be used for fiber patch panels. Connector insertion loss shall be nominally 0.3 db and less than 0.5 db. LC connectors shall be field installable. Dust caps shall be provided for all sleeves.
- B. Equipment Connectors
  1. Fiber optic connectors shall match and be compatible with equipment terminations. Connector insertion loss shall be nominally 0.3 db and less than 0.5 db. Connectors shall be field installable. Dust caps shall be provided for all sleeves.
    - a. Equipment connector preference order:
      - i. LC (Lucent Connector) UPC
      - ii. SC (Subscriber Connector)
      - iii. BART-approved

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2. Multimode connectors shall be an aqua multimode LC connector pair with a duplex clip, a 127 um ceramic zirconia ferrule, supplied with a white 900 um for buffered fiber and a 1.6 mm boot with white and yellow shrink sleeves for patch cables.
3. Singlemode connectors shall be a single mode LC connector pair with a duplex clip, a 126 um ceramic zirconia ferrule, supplied with a white 900 um for buffered fiber and a 1.6 mm boot with white and yellow shrink sleeves for patch cables.

### 2.11 FIBER PATCH PANELS

- A. Fiber patch panels shall be a complete system of components furnished by a single manufacturer, and shall provide termination, splice storage, routing, radius limiting, cable fastening, storage, and cross-connection. Fiber patch panels shall be ADC TFP series with specified accessories or approved equal. Patch panels shall employ wall-mountable connector housings equipped as follows:
  1. Sized to accommodate 48 fibers.
  2. Three multi-mode connector panels accommodating 12 fibers with LC connectors.
  3. One single-mode connector panel accommodating six fibers with LC connectors.
  4. Four splice trays with splice protectors.
  5. One splice tray holder.

### 2.12 CATEGORY 6 PATCH PANELS

- A. Category 6 Patch Panel Design Requirements
  1. Unshielded category 6 patch panels shall employ a modular design that utilizes jacks installed into each panel position.
  2. Unshielded category 6 jacks supplied with the panel shall meet the TIA/EIA-568-C.2: "Balanced Twisted – Pair Telecommunications Cabling and Component Standard". Unshielded category 6 jacks shall also be available separately with detailed installation instructions.
  3. Panel ports shall have a rectangular, industry standard keystone opening (.760" x .580") with a permanent port identifier number under each opening.
  4. Panels shall have integral cable management features in front for patch cords and features in the rear for horizontal cable management.
  5. Panels with installed jacks shall be backward compatible with existing category 3, 5, 5E, and category 6 cabling systems for fit, form, and function.
  6. Shielded patch panels shall have provisions for connection of grounding jumpers from each installed shielded jack.

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### B. Category 6 Patch Panel Performance Requirements

1. All transmission parameters shall be verified by a UL or ETL testing organization. Transmission testing shall be to 250 MHz.
2. Unshielded category 6 panels with unshielded jacks installed shall exceed transmission requirements specified in ANSI/TIA/EIA-568-C (specification limit is 250 MHz).
3. The Manufacturer shall provide compliance certificates from a third party testing organization upon request.
4. Panels shall be UL listed 1863 and CSA certified.
5. Panels shall exceed IEEE 802.3 DTE power specification to four times the rated current limits with no degradation of performance or materials.
6. Panels shall be third party verified to Gigabit Ethernet performance according to IEEE 802.3Z (current draft).
7. Panels shall meet or exceed the four-connector channel performance requirements of ANSI/TIA/EIA-568-C.2 standard.
8. Unshielded Patch Panels: The four-connector channel test configuration shall utilize unshielded Category 6 jacks, patch panels and patch cords, from the same manufacturer, with qualified unshielded twisted pair (UTP) Category 6 cable.
9. Shielded Patch Panels: The four-connector channel test configuration shall utilize shielded Category 6 jacks, patch panels and patch cords, from the same manufacturer, with qualified screened (ScTP OR F/UTP), or shielded (STP) Category 6 cable.

### 2.13 OUTLETS, HARDWARE, AND CONNECTIONS

- A. Work Area Outlets (WAOs): WAOs shall be Category 6 keystone jacks with universal wiring (TIA568A/B) mounted in single or dual port faceplates as required when within TIA568C.1 length specifications. Category 6 WAOs exceeding TIA568C.1 length specifications can use fiber cable terminated to District approved flush-mounted wall boxes or fiber style keystone jacks with 2 or 3 duplex port face plates as required.
- B. Category 6 Keystone Jack color:
  1. Wayside Facilities
    - a. Red - Analog Telephone
    - b. Yellow - Digital Telephone
    - c. Purple - IP Telephone (voice only)
    - d. Green - Async, T1 Connection
    - e. White - Administrative network
    - f. Orange - Network Management Systems (NMS) network
    - g. Black - Security network
    - h. Blue - BARTnet network
    - i. Grey - Unassigned
    - j. Beige - Unassigned

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2. Central Facilities
  - a. Shall be coordinated with the District.
- C. Fiber Keystone Jack Color:
  1. Shall be coordinated with the District.
- D. Destination Sign Units (DSUs): Connector modules for DSU outlets shall be Designated Matching Product, Seimon SMC-SA-02-C. Sign hangers shall be constructed of ASTM A500 Grade B structural steel tubing.
- E. Automatic Fare Collection (AFC) Equipment: Telecommunication outlets for AFC equipment fiber cable connection shall be Designated Matching Product Seimon Model SM6-BL-02. Three dual ST to ST connector sleeve insert modules, Designated Matching Products, Seimon Part No. SMC-SA-02-C, shall be furnished for each AFC equipment outlet.

### 2.14 FIBER OPTIC PATCH CORDS

- A. Patch cords shall be cable assemblies consisting of flexible optical fiber cable equipped with compatible connectors. Patch cords shall be complete assemblies from manufacturer's standard product lines. Length shall be as required. Patch cords shall meet the following requirements:
  1. Fiber optic patch cords shall be two-fiber zip cord type with a 1.6 mm OD or approved equal.
  2. Cable construction shall allow a small bend radius for installation in space constrained areas. The cable shall contain a dielectric strength member and a protective outer jacket. The cable jacket color shall be orange. The fiber core size shall be identified on the outer jacket
  3. Fibers shall be terminated at each end with connectors as specified herein.

### 2.15 RADIO COAXIAL PATCH CORDS

- A. Jumper Cables shall be size ¼" minimum, jacketed, corrugated, super flexible foam-filled for patch applications. The cables shall be suitable for connecting coaxial foam cable to antenna and trunk radio combiners and/or multicouplers. The minimum design requirements and general characteristics are as follows:
  1. VSWR shall be less than 1.2:1.
  2. Connectors shall be type N plug (male) on both ends.
  3. Attenuation measured at 100 feet shall not exceed 5 dB referenced to 1800 MHz.
  4. Characteristics impedance shall be 50 ohms.
  5. Length shall be approximately 6 feet.

## COMMUNICATION CABLES AND RELATED EQUIPMENT

6. Cables shall be factory assembled and tested.

### 2.16 SLOTTED RADIO COAXIAL PATCH CORDS

- A. Patch Cables shall be size ¼" minimum, jacketed, corrugated, super flexible foam-filled for patch applications. The cables shall be suitable for connecting coaxial foam cable to antennas and bidirectional heterodyne repeater amplifiers. The minimum design requirements and general characteristics are as follows:
  1. VSWR shall be less than 1.5:1.
  2. Connectors shall be type N plug (male) on both ends.
  3. Characteristics impedance shall be 50 ohms.
  4. Length shall be approximately 6 feet.
  5. Cables shall be factory assembled and tested.
  6. Patch cables shall be designed to meet the minimum requirement of 2.11.A, 1 and 2,

### 2.17 PIGTAIL CABLES

- A. Cables 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 flame retardant PVC or FCP, which complies with NFPA 70 for OFNP applications. Maximum db loss for pigtail cables shall be 3.5 db/km at 850 nm, and 1.0 db/km at 1300 nm.

### 2.18 INNERDUCTS

- A. Innerducts shall be corrugated semi-ridged construction, LSZT material, and shall have an inner diameter of no less than 1.25 inches and no more than 2.0 inches. Couplers, if used, shall not reduce the inside diameter of the innerduct.

### 2.19 COPPER CABLE SPLICE CASES

- A. Cases for splicing copper cables shall be of the type capable of being re-opened without disturbing splices, and of being reclosed. Cases shall have devices for centering cable so as to allow filling compound to cover conductors. Hardware shall be of stainless steel. Cases shall be braced to prevent cracking.
  1. Filling Compound: Compound for filling splice cases shall be a polyurethane telephone material that is transparent after curing. The compound shall adhere to conductors and splices, but shall be capable of being easily pulled away in a mass from conductors and splices. Compound shall be non-corrosive to conductors and splicing devices and shall not be toxic.
  2. Splice Connectors: Connectors shall be sized for the specific conductors to be spliced or tapped. The connector material shall be compatible with the conductor. The tools used for application shall have a positive action that will prevent over- or under-crimping.

## COMMUNICATION CABLES AND RELATED EQUIPMENT

### 2.20 TERMINAL BLOCKS

- A. Terminal blocks shall be DIN-rail mounted, single or two level as required by the application, and meet the following requirements:
  - 1. Wire gauge range: 28 – 12 AWG.
  - 2. Current rating: 25 amps.
  - 3. Voltage rating: 600 V
  - 4. Terminal width: 5 or 6 mm.
  - 5. DIN rail: 35 mm.
- B. Terminal blocks shall be as manufactured by ASI. Inc., series ASI1492 or equal.

### 2.21 TEST EQUIPMENT

- A. A test report including data sheets shall be generated by tester and submitted to the District for approval.
- B. Multifunction loss testers shall perform the following instrument functions:
  - 1. Loss meter.
  - 2. Power meter.
  - 3. Optical return loss (ORL) meter.
  - 4. Visual fault locator.
  - 5. Multimode and single mode light sources.
  - 6. Digital talk set.
  - 7. Fiber length tester.
  - 8. Video fiber inspection probe.
- C. The multifunction loss tester shall be an EXFO FOT-930 MaxTester or equal. The Contractor may use the testers for ORL and optical power loss testing.
- D. The optical spectrum analyzer (OSA) shall be optimized for 100 GHz spacing and DWDM network testing. The OSA shall be EXFO model FTB-5230 or equal.
- E. The copper and fiber cable analyzer shall provide certification testing meeting EIA/TIA standards. The Cable Analyzer (copper and fiber) shall be model FLUKE DTX-1800-MSO or equal.
- F. Surface Inspection interferometer testing for field fiber connector termination. The surface

## COMMUNICATION CABLES AND RELATED EQUIPMENT

Inspection interferometer shall be model DAISI Digital Automated Interferometer or equal.

### PART 3 - EXECUTION

#### 3.01 INSTALLATION

- A. Coordinate installation of wires and cables with the requirements of Section 20 70 26 - Common Materials and Methods for Electrical Systems, and Section 20 50 13 - Raceways for Facility Services.
- B. Provide wiring complete as indicated. Provide ample slack for field terminated wires and preformed cables with connections, including wires for motor loops, service connections, and extensions. In outlet or junction boxes provided for installation of equipment by others, tape ends of wires and install blank covers.
- C. Do not bend cables during installation, either permanently or temporarily, to radii less than 12 times the outer diameters, except where conditions make the specified radius impractical and shorter radii are permitted by the California Electrical Code and NEMA WC70, Appendix N.
- D. Bundle cable and conductors neatly and securely with nylon straps located in branch circuit panel boards, equipment cabinets and control panels. Use nylon bundling straps; bundle power cables separately from control cables.
- E. For wire pulling, comply with the following requirements:
  - 1. Do not pull wires into conduit until conduits and outlets have been thoroughly cleaned and swabbed. Do not use a block and tackle or other mechanical means for pulling conductors smaller than 2 AWG in raceways.
  - 2. Use lubricant and installation procedure as recommended by the cable manufacturer.
  - 3. Pulling tension shall not exceed manufacturer's recommendations. For conduit runs with three bends, provide the Engineer with cable pulling calculations prior to making the pull.
  - 4. Provide masking or other means to prevent obliteration of cable identifications when solid color coating or colored tracers are used.
  - 5. Multiple cables to be installed in a single conduit shall be pulled together.
- F. Power and Control Cable Installation in Manholes and Pull boxes: Route cables along the manhole or handhole walls providing the longest possible slack. Form cables closely parallel to the walls so that they do not interfere with duct entrances, supported on brackets and cable insulators spaced at a maximum of four feet. In existing manholes and handholes where new ducts are to be terminated or where new cables are to be installed, modify the existing locations of cables, cable supports, and grounding as required providing a properly arranged and supported installation.
- G. Wayside Copper Cable: Wayside copper cable shall be homerun from the device such as the telephone in a BLS to the protector blocks in the associated wayside facility. Wayside copper cable splicing is not allowed.

## COMMUNICATION CABLES AND RELATED EQUIPMENT

- H. Install fiber optic cables as follows:
1. Install all horizontal and interfacility fiber optic cables in innerducts. Provide all unused innerducts with lubricated pull tape or line.
  2. Install each communication cable, including traction power cables, between wayside facilities in an innerduct in the communications section of the system-wide raceway.
  3. Install each train control cable between TCRs or TCHs in an innerduct in the train control section of the system-wide raceway.
  4. Install all lateral cables between the system-wide raceway and wayside facilities in separate innerducts.
  5. Spare fibers shall be secured and supported neatly with Velcro.
  6. Terminate all backbone and horizontal fiber optic cable to maintain manufacturer-recommended bending radii, pulling tension, and cable support requirements. All cables and equipment shall be securely and neatly installed. Inside routing shall be installed parallel and perpendicular to existing structural lines and members. Plastic or metal cable ties shall not be used; only Velcro or Millipede ties are permitted.
- I. Fiber optic cable pulling shall comply with the following:
1. Pull on the cable strength members only. Do not pull on the jacket unless it is specifically approved by the cable manufacturer and an approved cable grip is used.
  2. Do not exceed the maximum pulling load rating. On long runs, use proper lubricants and make sure they are compatible with the cable jacket. If possible, use an automated puller with tension control or at least a breakaway pulling eye.
  3. Do not exceed the cable bend radius.
  4. Do not twist the cable. Roll the cable off the spool instead of spinning it off the spool end. When laying cable out for a long pull, use a "Figure 8" on the ground or use a swivel pulling eye to prevent twisting forces on the cable.
  5. Verify that the cable is long enough for the run.

### 3.02 CABLE IDENTIFICATION

- A. Provide nonmetallic fiberboard or plastic identification tags or pressure sensitive labels designed for fastening to cables, feeders, and power circuits in vaults, pull boxes, manholes, and switchboard rooms, and at all terminations of cable or wire.
- B. Stamp or print tags or labels to correspond with markings on the Contract Drawings, or mark so that feeder or cable may be readily identified.
- C. If suspended type identification tags are provided, attach the tags to slip-free plastic cable lacing units or to nylon bundling straps.

## COMMUNICATION CABLES AND RELATED EQUIPMENT

### 3.03 CABLE LABELING

- A. Provide identification tags or labels for each cable. Markers, tags and labels shall use indelible ink or etching which will not fade in sunlight or in duct applications. Markers, tags, and labels shall not become brittle or deteriorate for 30 years. Label all termination panels with cable number or pair identifier for cables in accordance with EIA TIA-606 and as specified. Identify the labeling format and provide a complete record to the District with the final documentation. Identify each cable with type of signal being carried and termination points.
- B. Affix identification and warning signs and tags to fiber distribution panels, terminal equipment, patch cords and fiber optic cables.
- C. Provide weatherproof warning tags to flag the presence of optical cables. Install such tags on or near optical cables, using distinctive tags to identify the cables, in the following locations:
  - 1. Every 100 feet in underground track ways.
  - 2. Every 10 feet in communications equipment areas.
  - 3. At each location where optical cables enter or exit raceways of any sort.
  - 4. On exposed conduit runs under station platforms or in plenums, at intervals of 50 feet.
  - 5. At each manhole location along the communications wayside conduit bank runs.

### 3.04 SPLICING AND TERMINATION OF FIBER OPTIC CABLES

- A. Make splices in fiber optic cable fibers only inside TCRs and TCHs, protected equipment rooms, or in accessible wayside splice enclosures. Submit a description of each type and location of splice that will be used, naming the materials, devices, tools, instruments, and other details.
  - 1. All splices, including splices of pigtails to incoming fibers, shall be the fusion type. Apply protective covering and coating, made of compatible material, to all completed and tested splices.
  - 2. Contain splices within re-enterable splice modules that are designed specifically to accommodate fiber splices and the prescribed extra lengths of fiber.
  - 3. If splices are not made immediately after cable installation, seal the free ends of such cables as recommended by the manufacturer to prevent entrance of moisture and contaminants.
  - 4. Do not splice optical cables along the wayside unless all other options have been explored and found to be technically impractical. Splices along the wayside shall be subject to the approval of the District Representative. Where allowed, make splices in outdoor weatherproof splice enclosures, complete with entry raceways, foundations, mounting hardware, secured access door, and exterior fittings.
  - 5. Equip the interior of wayside splice enclosures with modules and fittings designed to organize the cables, splices, and prescribed extra length of fibers. Make provisions to add a renewable desiccant compound to protect against condensation or migration of water.

## COMMUNICATION CABLES AND RELATED EQUIPMENT

6. Optical Cable Terminations at TCRs/TCHs, Vent Structures and Portal Communication Cases (PCCs): Terminate all fibers at the fiber distribution panel within each TCR/TCH, vent structure and PCC as follows:
  - a. Terminate incoming optical fibers using matching single-mode optical fiber pigtail assemblies. Splice such optical fibers to the pigtail assemblies within a splice tray or trays.
  - b. Assign and terminate incoming and outgoing optical fibers; spares that are designed to pass through the local site shall be spliced together within a splice tray or trays where designated splices are configured.
  - c. Configure terminations so as to use the least number of splices feasible.

### **3.05 CATEGORY 6 CABLE AND PATCH CORD INSTALLATION**

- A. All backbone and horizontal Category 6 cable shall be terminated to Keystone style jacks. Maintain Manufacturer- recommended bending radius, pulling tension, and cable support requirements. All cables, wires, and equipment shall be securely and neatly installed. Inside routing shall be installed parallel and perpendicular to existing structural lines and members. Plastic or metal cable ties may not be used; only Velcro or Millipede ties may be used.
- B. Category 6 data cabling shall be terminated in accordance with the TIA/EIA 568B sequence specification.
- C. Category 6 patch cords shall be terminated in accordance with the TIA/EIA 568A or TIA/EIA 568B sequence specification.

### **3.06 CATEGORY 6 PATCH PANEL INSTALLATION**

- A. Mount patch panels into the designated rack, cabinet, or bracket locations. Surface mount or DIN rail patch panels may be used when the use of rack mount patch panels is not feasible.
- B. Keystone jacks are required for Category 6 cable termination. Terminate the shielded or unshielded jacks as applicable and install into the patch panel according to manufacturer's instructions.
- C. Cable terminations shall have no tensile or bending strain on the installed shielded jacks.
- D. Consolidation point equipment, where applicable, shall be fully installed and terminated prior to testing.
- E. Panels shall be labeled on front and back with the cable number and port connections for each port.
- F. Shielded Patch Panels: The panel grounding strap shall be installed to connect the cable shield and drain wire to the building signal ground in accordance with ANSI-J-STD-607-A.

### **3.07 FACTORY TESTS**

- A. Refer to Contract Specifications Section 20 72 25 - Factory and Field Testing.

## COMMUNICATION CABLES AND RELATED EQUIPMENT

- B. Cable Tests: Test single mode and multimode fiber optic cables in accordance with EIA RS-455.

### 3.08 FIELD TESTS

- A. The requirements for test planning, scheduling, performance, recording of data, and reporting of test results shall be as specified in Contract Specifications Section 20 72 25 - Factory and Field Testing.

- B. Fiber Optic Cable Reel Tests.

1. Fiber Optic Reel tests: Perform the following tests on fiber optic cable at the job site before it is removed from the cable reel. For cables with factory installed pulling eyes, these tests shall be performed at the factory and certified test results shall accompany the media. Perform optical time domain reflectometer (OTDR) tests with media on the reels and compare factory and field test data.
2. Reel Test Results: Provide results of reel tests to the District at least 10 working days before installation is to commence. Results shall indicate reel number of the media, manufacturer, type and number of fiber tested, and recorded readings. When reel tests indicate that the media does not comply with factory reel test results, remove the media from the job site and replace with compliant media.

- C. Fiber Optic Cable Installation Tests:

1. Test all single mode and multimode fiber strands end-to-end for bi-directional attenuation, 850 nm/1300 nm for multimode and 1310 nm/1550 nm for single mode fibers. Conduct tests in compliance with EIA/TIA-526-14 or OFSTP 14, Method B, according to the manufacturer's instructions for the test set being utilized.
2. Tests must ensure that the measured link loss for each strand does not exceed the "worst case" allowable loss defined as the sum of the connector loss (based on the number of mated connector pairs at the EIA/TIA-568 B maximum allowable loss of 0.75 dB per mated pair) and the optical loss (based on the previously-specified performance standards).
3. After the cable is terminated, perform the following tests:
  - a. After termination, test each fiber with an OTDR for length, transmission anomalies, and end-to-end attenuation. Perform the test in accordance with ANSI/TIA/EIA-455-8-2000, Measurement of Splice or Connector Loss and Reflectance Using an OTDR.
  - b. Insertion Loss: An OTDR shall be used to measure splice losses and identify events such as bad or dirty connectors, fiber bends, bad splices, and mismatched core sizes. Conduct the test in accordance with ANSI/TIA/EIA-455-34-A-2002, Interconnection Device Insertion Loss Test. Detected problems on a given link shall be corrected and then retested before proceeding with subsequent tests.
  - c. Optical Power Loss (OPL) and Optical Return Loss (ORL): The specified multifunction loss tester shall be used to measure OPL and ORL on each link. The ORL shall be 20 dB minimum for multimode fiber and 26 dB minimum for single mode fiber.

## COMMUNICATION CABLES AND RELATED EQUIPMENT

- d. The maximum allowable attenuation for any splice or termination is 0.3 dB.
  4. Review all end faces of field terminated connectors with a fiber inspection scope following the final polish. Connector end faces with hackles, scratches, cracks, chips, or surface pitting shall be rejected and repolished or replaced if repolishing will not remove the end face surface defects. The recommended minimum viewing magnifications for connector ends are 100X for multimode fiber and 200X for single mode fiber.
  5. Conduct surface inspection testing of each fiber connector using the DAISI interferometer. The return loss performance of UPC fiber optic connectors shall be 50 dB or higher. Surface inspection testing for manufactured connector pigtails provided with factory certification documentation is not required.
- D. Fiber Optic Network End-to-End Testing.
1. General: End-to-end testing shall be performed for all links that comprise two or more link segments that are connected via splices or patch cords. In each of the following tests, inspect and clean the fiber connectors before hooking them up to the test equipment. Test patchcords and patch panels shall also be cleaned. All tests shall be performed in both directions for each end-to-end fiber link.
  2. Repeat the OTDR, OPL and ORL tests specified in Section 3.08C.
  3. Spectral Domain Measurements for UON cables: Use the specified optical spectrum analyzer to measure the following parameters in an end-to-end test of all 24 WSX UON fibers from S20 to cabinet 204 located in the computer room at LMA designated for DWDM. This test shall be coordinated with and supervised by BART.
    - a. Chromatic dispersion (CD)
    - b. Polarization mode dispersion (PMD)
    - c. Spectral attenuation (multi-lambda)
- E. Shielded Category 6 Patch Panel Testing
1. Shielded category 6 patch panels shall be tested as part of the installed horizontal or backbone cabling system. Jacks and faceplates shall be assembled complete and properly mounted. Panels shall be terminated and fully dressed with proper cable management.
  2. Each link or channel in the cabling system shall be identified and tested individually, using at minimum an industry standard level IIIIE tester, capable of testing to TIA/EIA-568-C.2 field test requirements.
  3. Each panel port in the cable channel or link shall be tested for the shielded category 6 parameters listed below.

## COMMUNICATION CABLES AND RELATED EQUIPMENT

WIRE MAP / CONTINUITY	LENGTH	INSERTION LOSS
NEXT	PSNEXT	ELFEXT
PSELFEXT	Delay and delay skew	Return loss

**LEGEND:**

ELFEXT - Equal Level Far-End Crosstalk

NEXT - Near End Cross Talk

PSELFEXT – Power Sum Equal Level Far-End Crosstalk

PSNEXT - Power Sum Near End Cross Talk

4. In addition to the above test parameters, the continuity of the cable shield and drain wire shall also be verified.
5. A “pass” indication shall be obtained for each channel or link, using at minimum a level IIIE tester that complies with TIA/EIA-568-C.2 field testing requirements.

**F. Category 6 Cable Testing.**

1. **General:** Test pairs of all installed F/UTP wiring for full compliance with Category 6 specifications regardless of intended use. Provide documentation of test results for all conductor pairs of each cable. Perform testing using the specified Category 6 cable tester. Test results shall be approved by the District prior to cable activation for voice, video, or data applications.
2. **Testing Parameters:** All four pairs shall meet or exceed the following measured specifications. Inspect any cable not meeting or exceeding the following for anomalies, and re-terminate or replace if necessary to ensure compliance.
  - a. Line map cables to verify pin-to-pin continuity, lack of opens, shorts, and/or polarity reversals.
  - b. The characteristic cable impedance shall be 100 ohms plus or minus 15 percent at 1 MHz to 100 MHz.
  - c. Mutual capacitance of any pair at 1 kHz shall not exceed 17 nF per 1000 feet.
  - d. Ambient noise shall be less than or equal to 40 dB.
  - e. Signal to noise ratio shall be greater than or equal to 7 dB.
  - f. Cable length shall be less than or equal to 90 meters.

**END OF SECTION 27 13 01**