# Section 271323
# Communications Optical Fiber Splicing and Termination
## Part 1 - Part 1 - General
### 1.1 - Work Included

A. Provide all labor, materials, tools and equipment required for the complete installation of work called for in the Construction Document.

### 1.2 - Scope of Work

A. This document describes the products and execution requirements relating to furnishing and installing Telecommunications Cabling. Optical fiber backbone cabling (optical fiber splicing and terminations) is covered under this document.
B. This section includes minimum requirements for the following:
   1. Optical Fiber Backbone Cabling System
C. Product specifications, general design considerations, and installation guidelines are provided in this document. Quantities of telecommunications outlets, typical installation details, cable routing and outlet types will be provided as an attachment to this document. If the bid documents are in conflict, this specification shall take precedence. The successful vendor shall meet or exceed all requirements for the cable system described in this document.

### 1.3 - Regulatory References

A. All products, services, materials and documentation provided by the Installer shall meet the requirements of the following where applicable:
   1. National Electrical Manufacturer's Association (NEMA)
   2. American National Standards Institute (ANSI)
   3. National Fire Prevention Act (NFPA)
      a. National Electric Code 2020 (NEC)
   4. Relevant State Electric and Fire Codes
   5. Institute of Electrical and Electronic Engineers (IEEE)
   6. Underwriters Laboratories, Inc. (UL)
   7. Telecommunications Industry Association / Electronic Industries Alliance (TIA/EIA)
      a. TIA-526-7A Fiber-Optical Power Loss Measurements SM
      b. TIA-526-14C Fiber Optical Power Loss Measurements MM
      c. TIA-568_0-D Generic Telco Cabling Customer Premises
      d. TIA-568_0-D1 Generic Telecom Cabling for Customer Premise Addendum
      e. TIA-568_1-D Commercial Building Telcom Infrastructure Std
      f. TIA-568_1-D1 Commercial Building Infrastructure Standard Addendum
      g. TIA-568_2D Balanced Twisted Pair Cabling and Components
      h. TIA-568_3-D Optical Fiber Cabling Components Standards
      i. TIA-569-E Telecom Pathways and Spaces
      j. TIA-598-D Optical Fiber

k. TIA-598-D Optical Fiber Addendum
l. TIA-598-D1 Optical Fiber Color Coding Addendum
m. TIA-606-C Admin for Telecom Infrastructure
n. TIA-607-D Grounding and Bonding
o. TIA-758-B Customer Owned OSP
p. TIA-942-B Data-Centers

8. Building Industry Consulting Service International (BICSI) publications:
   a. Telecommunications Distribution Methods Manual (TDMM), 14th ed.
   b. Outside Plant Design Reference Manual (OSPDRM), 6th ed.
   c. Information Technology Systems Installation Methods Manual (ITSIMM), 7th ed.
   d. Telecommunications Project Management Manual (TPMM), 1st edition
   e. ANSI/BICSI 006, Distributed Antenna System (DAS) Design and Implementation Best Practices
   f. ANSI/BICSI 008, Wireless Local Area Network (WLAN) Systems Design and Implementation Best Practices
   g. ANSI/BICSI 005, Electronic Safety and Security (ESS) System Design and Implementation Best Practices
   h. ANSI/BICSI 007, Information Communication Technology Design and Implementation Practices for Intelligent Buildings and Premises
   i. ANSI/BICSI 001, Information and Communication Technology Systems Design and Implementation Best Practices for Educational Institutions and Facilities
9. Manufacturer's recommendations and installation guidelines
10. All cabling shall comply with all appropriate requirements of NEC Articles 770 and 800 and shall comply with the State Fire Codes as interpreted by the State Fire Marshall's Dept.

B. All publications referred to in this document shall be the latest edition thereof together with any amendments and/or addenda.

## 1.4 - Quality Assurance

A. Corning Solution
   1. Corning Optical Fiber Extended Warranty Program shall provide a complete system warranty to guarantee end-to-end high performance cabling systems that meet application requirements. The guarantee shall include cable and connectivity components and have one point of contact for all cabling system issues. The system shall be warranted for a period of at least 25 years.
   2. A factory registered Network Preferred Installer (NPI) shall complete the installation.
   3. Contractor shall have completed standards-based product and installation training.
   4. A copy of the NPI Contractor Registration shall be submitted in the proposal.

B. Panduit Solution
   1. Panduit Certification Plus System Warranty shall provide a complete system warranty to guarantee end-to-end high performance cabling systems that meet application requirements. The guarantee shall include cable and connectivity components and

have one point of contact for all cabling system issues. The system shall be warranted for a period of at least 25 years against defect.

2. The warranty covers each product component of the Panduit cabling system including optical fiber cables, interconnection and splice hardware, mechanical splicing products, and field-installable connectors.
3. A factory registered Panduit PCI contractor shall complete network installation.
4. Contractor shall have completed standards-based product and installation training.
5. A copy of the PCI Contractor Registration shall be submitted in the proposal.
6. Corning Cable Systems will repair or replace defective products.

C. Corning LANScape Solution

D. Corning Optical Fiber extended warranty program shall provide a complete system warranty to guarantee end-to-end high performance cabling systems that meet application requirements. The guarantee shall include cable and connectivity components and have one point of contact for all cabling system issues. The system shall be warranted for a period of at least 25 years against defect.

E. The warranty covers each product component of the Corning Cable Systems cabling system including optical fiber cables, interconnection and splice hardware, mechanical splicing products, and field-installable connectors.

F. A factory registered Network Preferred Installer (NPI) shall complete the installation.

G. Contractor shall have completed standards-based product and installation training.

H. A copy of the NPI Contractor Registration shall be submitted in the proposal.

I. Panduit will repair or replace defective products.

J. In order to qualify for the guarantee, the structured cabling system must be installed per the following:

1. Meet all TIA/EIA commercial building wiring standards.
2. Manufacturer categorized products must be used in conjunction with an equivalent or higher Category UL or ETL verified cable.
3. Manufacturer's products must be installed per Manufacturer's instruction sheets.

K. If any Manufacturer's product fails to perform as stated above, Manufacturer will provide new components at no charge.

L. This guarantee is made in lieu of and excludes all other warranties, expressed or implied. The implied warranties of merchantability and fitness for a particular use are specifically excluded. Neither seller nor manufacturer shall be liable for any other injury, loss or damage, whether direct or consequential arising out of the use of, or the inability to use, the product. Before using, user shall determine the suitability of the product for its intended use, and user assumes all risk and liability whatsoever in connection therewith. The foregoing may not be altered except by an agreement signed by officers of seller and manufacturer.

## Part 2 - Products

### 2.1 - Approved Products

A. Approved backbone fiber optic cable manufacturer: Panduit or Corning
B. Approved duplex jack module and plug manufacturer: Panduit
C. Approved fiber optic patch cord manufacturer: Panduit or Corning
D. Approved fiber optic pigtail manufacturer: Panduit or Corning
E. Approved fiber optic connector manufacturer: Panduit or Corning
F. Approved fiber optic tray manufacturer: Panduit or Corning
G. Approved fiber optic drawer manufacturer: Panduit or Corning
H. Approved fiber optic enclosure manufacturer: Panduit or Corning

### 2.2 - Equivalent Products

A. Corning shall manufacture all products, including but not limited to optical fiber backbone cabling (optical fiber splicing and terminations) to provide a Corning certified end to end solution.
B. Panduit shall manufacture all products, including but not limited to optical fiber backbone cabling (optical fiber splicing and terminations) to provide a Panduit certified end to end solution.
C. Refer to section 270000 Part 6 for additional information regarding substitution of materials.

### 2.3 - Backbone Cabling System

A. The Backbone Cable Subsystem in a building is the part of the premises distribution system that provides connection between equipment rooms, telecommunication rooms, and telecommunications service entrance facilities. A backbone subsystem provides either intra-building connections between floors in multi-story buildings or inter-building connections in campus-like environments.
B. All cables shall be run using a star topology (home run) from the Main Cross-Connect (MC) to each Horizontal Cross-Connect (HC) within the telecommunications room. One additional Intermediate Cross-Connect (IC) may be implemented between the MC and HC if so required. The length of each individual run of backbone fiber cable shall not exceed 150 meters for multimode OM4 and 1000 meters for singlemode and the length of each UTP cable run for voice applications is not to exceed 800 meters (85 meters for data) as specified under TIA/EIA-568.
C. The length of the media between the IC and HC shall not exceed 300 meters.
D. The type of backbone fiber cable shall be 50/125 µm multimode fiber cable or 8.3/125 µm singlemode fiber cable. The bending radius and maximum pulling tension of the cable shall be adhered to during handling and installation.

## 2.4 - Data Cable

A. All backbone fiber optic cable shall be 50/125 µm tight buffered or 8.3/125 µm jacketed fiber optic cable.
B. Fiber cable shall be plenum (OFNP), or plenum (OFNP) armored.
C. Fiber cabling system shall utilize faceplates, couplers and modules compatible with Industry Standard LC connectors.

## 2.5 - Optical Fiber Cables

A. Multimode Cable Elements
   1. Multimode cable to be 50-micron core.
   2. Fiber shall have a maximum Attenuation of 3.0 dB/km @ 850nm and 1.0 dB/km @ 1300nm.
   3. Fiber shall have a minimum LED Bandwidth 3500 MHz•km @ 850nm and 500 MHz•km @ 1300nm
   4. Fiber shall have a minimum Effective Modal Bandwidth 4700 (MHz•km) @ 850nm
   5. Fiber shall have a serial Gigabit Ethernet Distance Guarantee 1100m @ 850nm and 600m @ 1300nm
   6. Fiber shall have a serial 10 Gigabit Ethernet Distance 550m @ 850nm.
   7. Fiber shall have a serial 40 Gigabit Ethernet Distance of 150m @ 850nm.
   8. Fiber shall have a minimum tensile load strength of 2700 Newtons.
   9. Fiber shall conform to RUS 7 CFR 1755.900 and ANSO/ICEA S-87-640
   10. Fiber shall have 3.0mm buffer tube size.
   11. Fiber shall have SZ-stranded, loose tube design to isolate fibers from installation and environmental elements.
   12. Fiber shall have a jacket made of medium density polyethylene.
   13. Fiber cable construction shall be of all-dielectric construction.
   14. Fiber shall be plenum rated.

B. Singlemode Cable Elements:
   1. Singlemode cable to be 8.3-micron core.
   2. Fiber shall be G.652.D and G.657.A1 compliant.
   3. Fiber shall have a maximum Attenuation of 0.4 dB/km @ 1310 nm and 0.3 dB/km @ 1550 nm
   4. Fiber shall have a serial Gigabit Ethernet Distance Guarantee of 5000 m @ 1310 nm.
   5. Fiber shall have a serial 10 Gigabit Ethernet Distance of 10000 m @ 1310 nm and 40000 m @ 1510 nm.
   6. Fiber shall have a serial 1000 Gigabit Ethernet Distance of 10000 m @ 1310 nm and 40000 m @ 1510 nm.
   7. Fiber shall have a minimum tensile load strength of 2700 Newtons.
   8. Fiber shall conform to RUS 7 CFR 1755.900 and ANSO/ICEA S-87-640
   9. Fiber shall have 3.0mm buffer tube size.
   10. Fiber shall have SZ-stranded, loose tube design to isolate fibers from installation and environmental elements.
   11. Fiber shall have a jacket made of medium density polyethylene.

12. Fiber cable construction shall be of all-dielectric construction.
13. Fiber shall be plenum rated.
14. Cable shall be capable of supporting 1470, 1490, 1510, 1530, 1550, 1570, 1590 and 1610 nm wavelengths.

C. Link Cable (the following fiber counts are subject to job specific needs):
1. Not used for this project.

D. Backbone Cable (the following fiber counts are subject to job specific needs):
1. Provide Corning Altos All-Dielectric internal use riser rated optical fiber cable with 48 elements of single modem optical fiber cable and 48 elements of multimode optical fiber cable in a single riser rated jacket.
2. The cable shall be riser rated (CMR) for use as an internal cable in a plenum environment.
3. Provide printed length markings on the cable jacket every two feet.

E. External Cable (the following fiber counts are subject to job specific needs):
1. Provide Corning Altos All-Dielectric external optical fiber cable with 48 elements of singlemode optical fiber and 48 elements of multimode optical fiber cable.
2. The cable shall be recommended by the manufacturer for use as an external cable suitable for installation in an underground duct or direct buried.
3. Provide printed length markings on the cable jacket every two feet.
4. Optical fibers will be contained within loose buffer tubes utilizing water blocking tapes or compounds surrounding these tubes. The cable will be an all-dielectric construction, with a central strength member.
5. Optical cable to be armored and plenum rated.

## 2.6 - Rack and Mounted Optical Fiber Patch Panel

A. Provide Corning (CCH-04U), conforming to the following specification
B. Each panel shall be suitable for installation in EIA 19" mounting frame.
C. Enclosure is compatible with splice cassette modules.
D. Patch panels shall be capable of holding 12 couplers (bulkhead) adapters (24 strands per bulkhead).
E. Each panel shall provide either compression glands or internal clips and entrapment of yarn-based impact resistance to provide strain relief.
F. Each panel shall provide fiber handling for fiber elements, including 24" fiber reserve (service loop) and 36” of buffer tube inside the patch panel with no bends sharper than 2" bend radius.
G. Each patch panel shall be fitted with bulkhead duplex adapters (with ceramic alignment sleeves for 24 LC connectors). Provide sufficient quantity of adapters to support all terminated fibers. Bulkhead adapters to be sourced from the same manufacturer as the connectors provided as a part of this project, or they are to be recommended by the manufacturer for use with the connector.
H. Provide adapter plates to house bulkhead adapters and provide blanking adapter plates to cover all unused spaces as necessary.

I. Each patch panel shall allow any individual element to be terminated or otherwise handled without disturbing or damaging other elements.

## 2.7 - Optical Fiber Connectors

A. Multimode Optical Fiber Connectors
   1. Corning compatible optical fiber connectors of LC type.
   2. Optical fiber connectors must be part of cable manufacturer's approved extended warranted end to end cabling solution.
   3. Maximum insertion loss, of mated pair, less than 0.2 dB at acceptance.
   4. Optimally keyed, allowing reproducible mating conditions each time a connection is made between connector and coupler.
   5. Fitted with color coded strain relief boots to ensure durable and robust connections.
   6. Durability better than 500 mattings, with a maximum increase in insertion loss of not more than 0.2 dB.
   7. Fitted with a tight polymer cap, until the connector is fitted to a bulkhead adapter, over the connector to prevent ingress of dirt and dust, until the connector is fitted to a coupler.
   8. Having 24 LC connectors per mounting panel (bulkhead adapter).

B. Singlemode Optical Fiber Connectors.
   1. Corning compatible optical fiber connectors of LC type.
   2. Optical fiber connectors must be part of cable manufacturer's approved extended warranted end to end cabling solution.
   3. Insertion loss of mated pair at 1310 nm to be less than 0.2 dB at acceptance for every duplex connector.
   4. Minimum return loss of 36dB at 1310 nm.
   5. Optimally keyed, allowing reproducible mating conditions each time a connection is made between connector and coupler.
   6. Fitted with strain relief boots to ensure durable and robust connections
   7. Durability better than 500 mattings, with a maximum increase in insertion loss of not more than 0.2 dB.
   8. Fitted with a tight polymer cap over the connector to prevent ingress of dirt and dust, until the connector is fitted to a coupler.
   9. Having 24 LC connectors per mounting panel (bulkhead adapter).

## 2.8 - Fiber Optic Equipment Trays, Drawers and Enclosures

A. Rack Mount Fiber Trays - No movable or adjustable parts
   1. Not used at Caltech.

B. Rack Mount Drawers - Metal shell with non-removable drawer
   1. Not used at Caltech.

C. Rack Mounted Enclosures
   1. Shall fit in a standard 19" rack.
   2. Shall be 4 RackUnits (7.0" / 17.8cm) in height.
   3. Shall accept 12 insert modules.

4. Shall accept a minimum of 288 strands of fiber.
5. Shall provide protection and strain relief for fiber optic cable.
6. Shall protect fiber strands of fiber from pinch, crimp or other damage.
7. Shall accept installable splice enclosures (cassettes).

D. Wall Mounted
1. Used only under special circumstances, not a normal construction item.

E. Fusion Splice Enclosures
1. Used only under special circumstances, not a normal construction item.

F. Weather Rated
1. Used only under special circumstances, not a normal construction item.
2. To be used at all locations on campus, including but not limited to:
3. In buildings at locations subject to moisture and dust.
4. In steam tunnels.
5. Aerial installations.
6. Below grade pull boxes, manholes and vaults.

G. Contact Caltech Voice and Data for examples of current installations on campus.

H. Panel Inserts
1. Single Mode – Standard
   a. Shall be compatible with existing fiber optic enclosures.
   b. Shall support 24 terminated strands of fiber.
   c. Adapter housing type shall be LC duplex.
   d. Adapter housing color shall be blue.
   e. Adapter inserts shall be solid ceramic (as opposed to split ceramic).
2. Multimode – Standard
   a. Shall be compatible with existing fiber optic enclosures.
   b. Shall support 24 terminated strands of fiber.
   c. Adapter housing type shall be LC duplex.
   d. Adapter housing color shall be aqua.
   e. Adapter insert shall be solid ceramic (as opposed to split ceramic).
3. Single Mode – Fusion Splice Cassette
   a. Shall be compatible with existing fiber optic enclosures.
   b. Shall support 24 terminated strands of fiber.
   c. Adapter housing type shall be LC duplex.
   d. Adapter housing color shall be blue.
   e. Adapter inserts shall be solid ceramic (as opposed to split ceramic).
   f. Cassettes shall provide fusion splice cassettes compatible with Corning CCH-04U housings.
   g. Cassettes shall provide routing for factory polished pigtails.
   h. Cassettes shall provide routing for house cable terminations.
   i. Cassettes shall provide storage for completed fusion splices.
4. Multimode – Fusion Splice Cassette
   a. Shall be compatible with existing fiber optic enclosures.
   b. Shall support 24 terminated strands of fiber.

c. Adapter housing type shall be LC duplex.
d. Adapter housing color shall be blue.
e. Adapter inserts shall be solid ceramic (as opposed to split ceramic).
f. Cassettes shall provide fusion splice cassettes compatible with Corning CCH-04U housings.
g. Cassettes shall provide routing for factory polished pigtails.
h. Cassettes shall provide routing for house cable terminations.
i. Cassettes shall provide storage for completed fusion splices.

## Part 3 - Execution

### 3.1 - Optical Fiber Termination Hardware

A. Fiber slack shall be neatly coiled within the fiber splice tray or enclosure.
B. No slack loops shall be allowed external to the fiber panel outside the service loop.
C. Each cable shall be individually attached to the respective fiber enclosure by mechanical means. The cables strength member shall be securely attached the cable strain relief bracket in the enclosure.
D. Each fiber bundle shall be stripped upon entering the splice tray and the individual fibers routed in the splice tray.
E. Each cable shall be clearly labeled at the entrance to the splice enclosure. Cables labeled within the bundle shall not be acceptable.
F. A maximum of 24 strands of fiber shall be spliced in each tray.
G. All spare strands shall be installed into spare splice trays.
H. All strands in the splice tray or enclosure are secured from damage caused by opening and closing and/or removal and insertion of all parts contained in the splice tray or enclosure.

### 3.2 - Testing and Acceptance

A. General
B. All cables and termination hardware shall be 100% tested for defects in installation and to verify cabling system performance under installed conditions according to the requirements of:
   1. TIA 526-7 Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant
   2. TIA-526-14 Optical Power Loss Measurement of Installed Multimode Fiber Cable Plant
   3. TIA-568_3-D Optical Fiber Cabling Components Standards
   4. TIA-569-E Telecom Pathways and Spaces
   5. TIA-598-D Optical Fiber
   6. TIA-598-D Optical Fiber Addendum
   7. TIA-598-D1 Optical Fiber Color Coding Addendum
   8. TIA-606-C Admin for Telecom Infrastructure
   9. TIA-607-D Grounding and Bonding
   10. TIA-758-B Customer Owned OSP

C. All pairs of each installed cable shall be verified prior to system acceptance. Any defect in the cabling system installation including but not limited to cable, connectors, feed through couplers, patch panels, and connector blocks shall be repaired or replaced in order to ensure 100% useable conductors in all cables installed.

D. All cables shall be tested in accordance with this document, the ANSI/TIA/EIA standards, the Panduit Certification Plus System Warranty guidelines (when Panduit components are used), Corning LANscape Solutions Extended Warranty guidelines (when Corning components are used) and best industry practice. If any of these are in conflict, the Contractor shall bring any discrepancies to the attention of the project team for clarification and resolution.

E. Optical Fiber Cable & Connectors

1. Test each optical fiber cable element and its associated connectors. Carry out the following test on every element of every optical fiber cable:
2. Visually check optical connectors using microscope (minimal magnification x200) to ensure that no physical damage has occurred during the installation process. There are to be no scratches on the core of the fiber or pits on the core or cladding. If any defect cannot be rectified with polishing, the connector is to be replaced.
3. Carry out OTDR tests on all elements at 1300nm wavelength for multimode cable runs and at 1310 nm for singlemode. These tests shall be carried out from both ends (bi-directional testing) using a near end launch lead and a far end drop lead.
4. The number of samples (averages) for each OTDR test shall be such that the noise amplitude is significantly less than the smallest loss of any component under test. This may vary for different cable runs, for shorter runs and fusion splices etc.; it may be necessary to run multiple samples.
5. Record the length and loss of each mated connector pair on the test results schedule for all elements.
6. Verify the labeling of the cable and connectors is correct.
7. If an element has an excessive attenuation coefficient, a sudden step in attenuation coefficient (greater than 0.2 dB) or back scatter, losses due to micro bending or macro bending or has any other fault then the fault on that element shall be rectified.
8. The following table lists the pass/fail criteria for all connectors and fusion splices under test. Any component that does not pass these figures shall be re-worked or replaced.

| Single Mode | dB |
|---|---|
| Maximum attenuation across mated connector pair – outward test | 0.2 |
| Maximum attenuation across mated connector pair – return test | 0.2 |
| Maximum Attenuation across fusion splice – averaged over both directions | 0.1 |
| Minimum Return Loss (dB) – outward test | 36 |
| Minimum Return Loss (dB) – return test | 36 |

| Multimode | dB |
|---|---|
| Maximum attenuation across mated connector pair – outward test | 0.5 |
| Maximum Attenuation across fusion splice – averaged over both directions | 0.1 |

9. The attenuation of each multimode connector shall be measured in one direction (outward). The attenuation of each singlemode connector shall be measured in both directions.
10. Each fusion splice shall be tested in both directions for both multimode and singlemode elements. The measurements for each direction shall be averaged for the final attenuation figure for each fusion splice.
11. The return loss must be measured in both directions for singlemode connectors. The return loss shall be greater or equal to the value shown in the table above.
12. Any failures shall be recorded (including value of excessively lossy terminations) and the results obtained after rectification of the fault shall be recorded.
13. Graphical printouts shall be taken of OTDR tests for each element. These printouts shall be digitally recorded. They shall be printed at an appropriate scale, such as 0.5 dB per division for the attenuation axis. Provide electronic copies of the OTDR traces in source format to the Owner on completion of the testing. Provide a copy of the emulation software and the appropriate license to the client.
14. All fiber testing shall be performed on all fibers in the completed end-to-end system. There shall be no splices unless clearly defined in an RFP. The system loss measurements shall be provided at 850 and/or 1300 nanometers for multimode fibers and 1310 and 1550 nanometers for single mode fibers. These tests also include continuity checking of each fiber.
15. Horizontal multimode optical fiber cabling attenuation shall be measured in one direction at either 850 nanometer (nm) or 1300 nm using an LED light source and power meter.
16. Backbone multimode fiber cabling shall be tested at both 850 nm and 1300 nm (or 1310 and 1550 nm for singlemode) in one direction.
17. Test set-up and performance shall be conducted in accordance with TIA-526.14 Standard, Method B.
18. Where links are combined to complete a circuit between devices, the Contractor shall test each link from end to end to ensure the performance of the system. ONLY BASIC LINK TEST IS REQUIRED. The contractor can optionally install patch cords to complete the circuit and then test the entire channel. The test method shall be the same used for the test described above. The values for calculating loss shall be those defined in the ANSI/TIA/EIA Standard.
19. Attenuation testing shall be performed with a stable launch condition using two-meter (or longer) jumpers to attach the test equipment to the cable plant. The light source shall be left in place after calibration and the power meter moved to the far end to take measurements.

## 3.3 - 3.3 System Documentation

A. Documentation shall be submitted within ten (10) working days of the completion of each testing phase. This is inclusive of all test results and draft as-built drawings. Draft drawings may include annotations done by hand. Machine generated (final) copies of all drawings shall be submitted within 30 working days of the completion of each testing phase. At the request of the Engineer, the telecommunications contractor shall provide copies of the original test results.

B. The Engineer may request that a 10% random field re-test be conducted on the cable system, at no additional cost, to verify documented findings. Tests shall be a repeat of those defined above. If findings contradict the documentation submitted by the telecommunications contractor, additional testing can be requested to the extent determined necessary by the Engineer, including a 100% re-test. This re-test shall be at no additional cost to the Owner.

C. Test results documentation shall be provided in digital form within three weeks after the completion of the project. The files shall be clearly marked with the words "Project Test Documentation", the project name, and the date of completion (month and year). The results shall include a record of test frequencies, cable type, conductor pair and cable (or outlet) I.D., measurement direction, reference setup, and crew member name(s). The test equipment name, manufacturer, model number, serial number, software version and last calibration date will also be provided at the end of the document. Unless the manufacturer specifies a more frequent calibration cycle, an annual calibration cycle is anticipated on all test equipment used for this installation. The test document shall detail the test method used and the specific settings of the equipment during the test as well as the software version being used in the field test equipment.

D. Printouts generated for each cable by the wire (or fiber) test instrument shall be submitted as part of the documentation package. Alternately, the telecommunications contractor may furnish this information in electronic form using a file format agreed to by the Owner.

E. When repairs and re-tests are performed, the problem found and corrective action taken shall be noted, and both the failed and passed test data shall be documented.

F. The As-Built drawings are to include cable routes and outlet locations. Their sequential number as defined elsewhere in this document shall identify outlet locations. Numbering, icons, and drawing conventions used shall be consistent throughout all documentation provided. The Owner will provide floor plans in paper and electronic (DWG, AutoCAD) formats on which as-built construction information can be added. These documents will be modified accordingly by the telecommunications contractor to denote as-built information as defined above and returned to the Owner. Numbering, icons, pathways and other drawing conventions are to be assigned their own individual AutoCAD layer.

G. The Contractor shall annotate the base drawings and return a hard copy (same plot size as originals) and electronic (AutoCAD or as agreed to by Caltech) form.

End Section