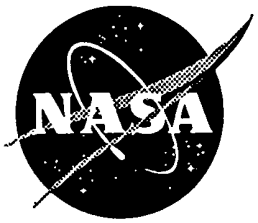


National Aeronautics and
Space Administration

HYBRID

NASA-STD-8739.5
February 1998

INITIAL RELEASE

FIBER OPTIC TERMINATIONS, CABLE ASSEMBLIES, AND INSTALLATION

NASA TECHNICAL STANDARD

FOREWORD

Effective Date: February 9, 1998

This Standard provides a baseline for NASA project offices to use when preparing or evaluating process procedures for the manufacture of space flight hardware or mission critical ground support equipment.

This Standard:

a. Prescribes NASA's process and end-item requirements for reliable fiber optic terminations, cables, assemblies, and the installation thereof.

b. Establishes responsibilities for training personnel.

c. Establishes responsibilities for documenting process procedures including supplier innovations, special processes, and changes in technology.

d. For the purpose of this Standard, the term supplier is defined as in-house NASA, NASA contractors, and subtier contractors.

NASA Installations shall:

a. Review and invoke the provisions of this Standard for procurements involving fabrication or installation of fiber optic terminations, cables, or assemblies for space flight hardware and mission critical ground support equipment.

b. Review and invoke the provisions of this Standard for in-house operations involving fabrication or installation of fiber optic terminations, cables, or assemblies for space flight hardware and mission critical ground support equipment.

c. Tailor specific provisions of this Standard to address program or unique contractual or mission requirements.

d. Assure that NASA suppliers invoke this Standard on subcontractors, purchase orders, and on subtier suppliers where applicable.

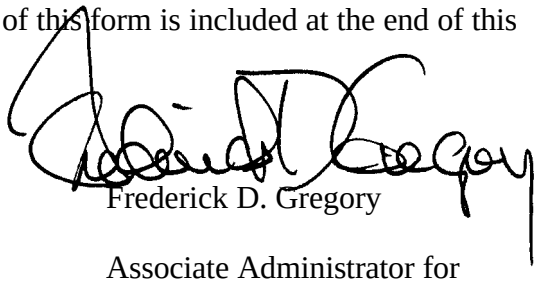
e. Furnish copies of this Standard in the quantities required to NASA suppliers and subtier suppliers.

Questions concerning the application of this Standard to specific procurements shall be referred to the procuring NASA installation, or its designated representative.

This Standard shall not be rewritten or reissued in any other form not approved by NASA.

Other processes not covered by this Standard may be required. The design, materials, and processes shall be defined in engineering documentation.

Comments and suggestions for improving this Standard may be submitted using the form "NASA Technical Standard Improvement Proposal." A copy of this form is included at the end of this standard.



Frederick D. Gregory

Associate Administrator for
Safety and Mission Assurance

DISTRIBUTION:

SDL1 (SIQ)

NASA TECHNICAL STANDARDS FOR SPACE FLIGHT AND MISSION CRITICAL GROUND SUPPORT HARDWARE

NASA Technical Standards can be found on the World Wide Web at URL address http://www/hq.nasa.gov/office/codeq/qdoc.pdf.

Title	Number
Soldered Electrical Connections	NASA-STD-8739.3
Crimping, Interconnecting Cables, Harnesses, and Wiring	NASA-STD-8739.4
Fiber Optic Terminations, Cable Assemblies, and Installation	NASA-STD-8739.5
Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies	NAS 5300.4(3J-1)
Workmanship Standard for Surface Mount Technology	NAS 5300.4(3M)
Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices)	NASA-STD-8739.7

CONTENTS

CONTENTS - CONT.

CONTENTS - CONT.

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1 - SCOPE

1.1 Purpose

1. This Standard sets forth fiber optic termination and cabling requirements for reliable fiber optic installations, both single- and multi-mode fiber.

2. Special requirements may exist which are not covered by or are not in conformance with the requirements of this Standard. Engineering documentation shall contain the detail for such requirements, including modifications to existing hardware, and shall take precedence over appropriate portions of this Standard when approved in writing by the procuring NASA Center prior to use.

3. Processing of fiber optic cable assemblies will vary with the specific end item. However, the requirements established in this Standard shall be used for the development of these project-related processes.

1.2 Applicability

This Standard is applicable to NASA programs involving fiber optic splices, fiber optic cable assemblies, and fiber optic assemblies for flight hardware, mission critical ground support equipment, and elements thereof, and wherever invoked contractually.

CHAPTER 2 - APPLICABLE DOCUMENTS

2.1 Applicable Specifications

Copies of the following specifications, when required in connection with a specific procurement, can be obtained from the procuring NASA Center or as directed by the contracting officer. Unless otherwise specified, the issue and/or revision in effect on the date of invitation for bids or requests for proposal shall apply. The following related documents form a part of this publication to the extent specified herein.

NASA SPECIFICATIONS:

NHB 1700.1(V1)	NASA Safety Policy and Requirements Document
NASA-STD-8739.7	NASA Technical Standard: Electrostatic Discharge Control (Excluding Electronically Initiated Explosive Devices)
NHB 8060.1C	Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion.

INDUSTRY STANDARDS:

American National Standards Institute (ANSI):

ANSI Z136.1	Safe Use of Lasers
ANSI Z136.2	Safe Use of Optical Communication Systems Utilizing Laser Diode and LED Sources
ANSI/NCSL Z540-1-1994	General Requirements for Calibration Laboratories and Measuring and Test Equipment

American Society for Testing and Materials (ASTM):

ASTM/D1007	Standard Specification for Secondary Butyl Alcohol

OTHER DOCUMENTS:

EIA/TIA 440	Fiber Optic Terminology
EIA/TIA 455 Series	Standard Test Procedures for Fiber Optic Fibers, Cables, Transducers, Connecting, and Terminating Devices

2.2 Other Documents:

Industrial Ventilation: A Manual of Recommended Practice.

Published by the American Conference of Governmental Industrial Hygienists;

1330 Kemper Meadow Drive; Cincinnati, OH 45240.

URL http://www.acgih.org

Occupational Safety and Health Administration, 29 CFR 1910.

NOTE: ***SOME USEFUL REFERENCE SPECIFICATIONS ARE LISTED IN APPENDIX B***

CHAPTER 3 - DEFINITIONS AND ACRONYMS

3.1 Definitions

Unique definitions and acronyms for this Standard are as follows. Related terms and definitions can be found in EIA/TIA-440, Fiber Optic Terminology.

Adhesive. A polymeric compound, usually an epoxy, used to secure the optical fiber in a splice assembly or connector.

Back-lit. A method of illuminating the fiber endface by launching incoherent light into the optical fiber core through the opposite end of the fiber.

Backreflection (Backscattering). The return of a portion of scattered light to the input end of a fiber; the scattering of light in the direction opposite to its original propagation.

Buffer. A material applied over the coating that may be used to protect an optical fiber from physical damage, providing mechanical isolation or protection, or both.

Bend Radius

- Long Term - The minimum radius to which a cable, without tensile load, can be bent for its lifetime without causing broken fibers, a localized weakening of the fibers, or a permanent increase in attenuation.
- Short Term - The minimum radius to which a cable can be bent while under the maximum installation load without causing broken fibers, a localized weakening of the fibers, or a permanent increase in cable attenuation.

Cladding. The dielectric material surrounding the core of an optical fiber.

Cleave. The process of separating an optical fiber by a controlled fracture of the glass for the purpose of obtaining a fiber end that is flat, smooth, and perpendicular to the fiber axis.

Coating. A material put on a fiber during the drawing process to protect it from the environment.

Coupling Loss. The optical power loss suffered when light is coupled from one optical device to another.

Degas. The removal of entrapped bubbles from a viscous fluid by placing that fluid in a centrifuge or vacuum.

Direct-lit. A method of illuminating the fiber endface by projecting a light source onto the fiber.

Ferrule. A mechanical fixture, generally a rigid tube, used to confine the stripped end of a fiber bundle or an optical fiber.

Fiber (Optical). A filament shaped optical waveguide made of dielectric material.

Fiber Optic Cable. A fiber, multiple fiber or fiber bundle in a cable structure fabricated to meet optical mechanical and environmental specifications.

Fiber Optic Connector. A fiber optic component normally assembled onto a cable and attached to a piece of apparatus for the purpose of providing interconnecting/disconnecting of fiber optic cables.

Glass Transition Temperature (T_g). The temperature above which an amorphous polymer displays viscous behavior caused by chain slip.

Hackle. A surface irregularity characterized by a rippled or stepped break in the fiber, usually due to improper cleaving.

Insertion Loss. The optical attenuation caused by the insertion of an extra optical component into an optical system.

Installation Load, maximum. The maximum load which can be applied along the axis of a cable during installation without breaking fibers or causing a permanent increase in the cable attenuation.

Interferometer. An instrument that employs the interference of light waves for purposes of measurement.

Laser. A device that produces coherent optical radiation by stimulated emission and amplification.

Mode. In general, an electromagnetic field distribution that depends on wavelength of light and material properties of the traveling medium. In guided wave propagation, such as through a waveguide or optical fiber, a distribution of electromagnetic energy that satisfies Maxwell's equations and boundary conditions. In terms of ray optics, a possible path followed by light rays dependent on index of refraction, wavelength of light and waveguide dimensions.

Multi-mode Fiber. An optical fiber that will allow two or more bound modes to propagate in the core at the wavelengths of interest.

Optical Time Domain Reflectometry (OTDR) Backscattering Technique. A method for characterizing an optical fiber whereby an optical pulse is transmitted through the fiber and the optical power of the resulting light scattered and reflected back to the input is measured as a function of time.

Peer Verification. For the purposes of this Standard, a peer verification is an in-process examination that must be documented. The person performing the peer verification must be trained and certified in accordance with the requirements of this Standard.

Pistoning. The axial movement of an optical fiber within a connector or connector ferrule.

Pot Life. The length of time that a catalyzed resin system takes to double its original viscosity.

Radiant Power; Optical Power; Optical Flux; Radiant Flux. The time rate of radiant flux.

Reflection. The change in direction of an incident wave at an interface between two dissimilar media so that the wave returns partially or totally into the medium from which it originated.

Refraction. The bending of a beam of light in transmission through an interface between two dissimilar media or in a medium whose refractive index is a continuous function of position, for example graded index medium.

Single-Mode Fiber. An optical fiber in which only the lowest order bound mode can propagate at the wavelength of interest.

Soxhlet Extraction. A process similar to distillation used to separate materials. Uses relative to this standard include removing oils, resins, or other contaminants from cotton swabs or wipes.

Splice. An interconnection method for joining the ends of two optical fibers in a permanent or semipermanent fashion.

- Chemical Splice - A permanent joint made with an adhesive such as UV-cured polymer or epoxy.
- Fusion Splice - A splice accomplished by the application of localized heat sufficient to fuse or melt the ends of two lengths of optical fiber, forming a continuous single optical fiber.
- Mechanical Splice - A fiber splice accomplished by fixtures or materials, rather than by thermal fusion.

Splice Enclosure. A device surrounding the spliced area of an optical fiber used to protect the splice from physical damage.

Splice Tray. A container used to organize and protect spliced fibers.

Strength Member. That part of a fiber optic cable composed of kevlar aramid yarn, steel strands, or fiberglass filaments included to increase the tensile strength of the cable, and in some applications, to support the weight of the cable.

Ultraviolet (UV). Optical radiation for which the wavelengths are shorter than those for visible radiation that is approximately between 1nm and 400nm.

3.2 Acronyms

The following acronyms apply to terms used in this Standard.

ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
CFR	Code of Federal Regulations
CVCM	Collectable Volatile Condensable Material
EEE	Electrical, Electronic, and Electromechanical
EIA	Electronic Industries Association

ESD	Electrostatic Discharge
FOTP	Fiber Optic Test Procedure
GSFC	Goddard Space Flight Center
JPL	Jet Propulsion Laboratory
LED	Light Emitting Diode
lm/m^2	Lumens per square meter
MIL-STD	Military Standard
MSDS	Material Safety Data Sheet
NAS	NASA Assurance Standard
NASA	National Aeronautics and Space Administration
NASA-STD	NASA Standard
NHB	NASA Handbook
NSPL	NASA Standard Parts List
NIST	National Institute of Standards and Technology
OSHA	Occupational Safety and Health Administration
OTDR	Optical Time Domain Reflectometry
RH	Relative Humidity
TIA	Telecommunications Industry Association
TML	Total Mass Loss
UV	Ultraviolet

CHAPTER 4 - GENERAL

4.1 GENERAL

1. **Implementation.** NASA quality assurance personnel will advise and assist contractors, suppliers, NASA personnel, and delegated agencies in the proper and effective implementation of the provisions of this Standard. Effective implementation includes establishing a system which will identify inspection points and provide records.

2. **Changes in Requirements.** When related requirements or changes in the requirements are specified, NASA quality assurance personnel will ensure that the Government agency delegated to inspect at the supplier's site of fabrication has received full instructions so that the work will be inspected to the actual contract requirements.

3. **Nonstandard Processes or Materials.** When the supplier intends to use processes or materials not covered by this Standard, the supplier shall document the details of fabrication and inspection, including acceptance and rejection criteria, and provide appropriate test data. Such documentation shall be approved by the procuring NASA Center prior to use.

4.2 Documentation

1. The supplier shall document the methods and procedures proposed to incorporate the requirements of this Standard into the design, fabrication, and inspection of fiber optic terminations or cables involved in the contract or purchase order.

2. Documents required herein, except as specified, shall be submitted to the procuring NASA Center or its designated representative as required by the contract or purchase order. Applicable supplier fiber optic termination and cable program documents, or portions thereof, accepted on other NASA contracts shall be included to avoid duplication of effort.

4.3 Approval of Departures from this Standard

1. Departures from this Standard require written approval from the cognizant NASA contracting officer. The supplier is responsible for assuring that any departures from this Standard are evaluated by, coordinated with, and submitted to the procuring NASA Center for approval prior to use or implementation.

2. For in-house NASA projects, this Standard requires written approval by the in-house NASA project management to deviate from the provisions herein.

4.4 Rework and Repair

1. **Rework.** Rework is permissible unless excluded by other provisions of the contract. All rework shall meet the requirements of this Standard and design documentation.

2. **Repair is not rework.** Repairs shall be made only in compliance with applicable contractual requirements and after authorization for each incident by the procuring NASA Center. Repairs shall be accomplished using documented methods previously approved in writing by the procuring NASA Center. For in-house NASA projects, repairs shall be authorized for each incident by the Project Office and Quality Management, as appropriate.

CHAPTER 5 - TRAINING AND CERTIFICATION PROGRAM

5.1 General

1. The supplier is responsible for maintaining a documented training program that meets the requirements of this Standard.

2. The supplier shall assure that personnel are familiar with the requirements of this Standard, fiber optic termination and cabling techniques, and other pertinent requirements of the contract. The supplier shall implement a training program that provides the necessary training of fiber optic termination, cabling, and inspection personnel in termination requirements, splicing techniques, and use of equipment and procedures pertinent to their responsibilities in performance of the contract requirements. The supplier is responsible for certifying and maintaining the certification of each individual who performs, inspects or instructs others in making fiber optic terminations or cables. Operators, inspectors, or instructors shall be qualified to fulfill all requirements of this Standard that relate to their assigned tasks.

3. Demonstration of proficiency and understanding of the requirements is a requisite for certification and recertification. Evidence of certification status shall be maintained in the work area.

5.2 Vision Requirements

1. The supplier is responsible for ensuring that all personnel who fabricate or inspect fiber optic terminations and cables meet the following vision test requirements as a prerequisite to training, certification, and recertification. The vision requirements may be met with corrected vision (personal eyeglasses). The vision tests shall be administered every 2 years by a qualified eye examiner accepted by the procuring supplier and using standard instruments and techniques. Results of the visual examinations shall be maintained and available for review.

2. The following are minimum vision requirements:

a. **Far Vision.** Snellen Chart 20/50.

b. **Near Vision.** Jaeger 1 at 355.0 mm (14 inches), reduced Snellen 20/20, or equivalent.

c. **Color Vision.** Ability to distinguish red, green, blue, and yellow colors as prescribed in Dvorine Charts, Ishihara Plates, or AO-HRR Tests.

<u>NOTE</u>: A PRACTICAL TEST USING COLOR CODED WIRES OR ELECTRICAL PARTS IS ACCEPTABLE FOR COLOR VISION TESTING.

5.3 Certification Levels

1. Level A NASA instructors are certified by the NASA Training and Certification Board. Level A NASA instructors have the authority to train Level B supplier instructors,

operators, and inspectors. Upon successful course completion, a certificate shall be issued by the NASA Training and Certification Board.

2. Certification of Level B supplier instructors shall be provided by the supplier based on successful completion of training by a Level A NASA instructor. Level B instructors are authorized to train operators and inspectors employed at their organization and subtier contractors.

3. Certification of inspectors shall be provided by the supplier based on successful completion of training by a Level A NASA instructor or a Level B supplier instructor. An inspector is trained and certified to inspect for conformance with the requirements of this Standard.

4. Certification of operators shall be provided by the supplier based on successful completion of training by a Level A NASA instructor or a Level B supplier instructor. An operator is trained and certified to fabricate fiber optic terminations and cables in conformance with the requirements of this Standard. When operators are certified to perform limited operations or processes, it shall be stated on the certification card.

5.4 Training Program Requirements

1. The supplier is responsible for training and certification of operators and inspectors in the processes and equipment used in the termination of optical fibers, fabrication of fiber optic cables, and general installation requirements.

2. The supplier training program documentation shall be submitted to the procuring activity as directed by contract. A NASA Generic Fiber Optic Termination and Cabling Training Plan from the NASA Training Centers is available for use as a guideline.

3. The training program shall:

a. Identify the criteria for qualification and certification of Level B instructors, inspectors, and operators.

b. Document the methods and procedures proposed to fulfill the requirements of this Standard.

c. Use visual standards consisting of satisfactory work samples or visual aids that clearly illustrate the quality characteristics of fiber optic terminations and cables applicable to the contract.

d. Use applicable illustrations in this Standard, supplemented as necessary, for visual standards. Standards of unacceptable conditions may also be used for clarification or comparison.

e. Make applicable standards readily available.

5.5 Documentation

1. The supplier training program documentation shall describe the training and certification program proposed to satisfy the requirements herein for the types of fiber optic terminations, cables to be made, and general installation requirements. This documentation shall include the following, as applicable:

a. Qualifications of instructors.

b. Procedures for training, including who will be trained and for what purpose, (e.g., operator, inspector).

c. Lesson plan(s)/student workbook.

d. Hours of instruction.

e. Procedures for certification and recertification.

f. Procedures for recording training, recertification, and method of identifying/recalling trained personnel.

g. Certification criteria.

2. Records of training and certification shall become part of the supplier's quality data and shall be retained for a minimum of 5 years.

3. Evidence of certification status, including limitations, shall be available in the work area.

5.6 Maintenance of Certification Status

1. Maintenance of certification for instructors, operators, and inspectors requires continuous proficiency.

2. Recertification of Level A NASA instructors shall include periodic evaluation of training courses by the NASA Training and Certification Board.

3. Recertification of Level B instructors shall include the successful completion of retraining by a Level A NASA instructor. Recertification of operators and inspectors shall include successful completion of retraining by a Level A NASA instructor or a Level B supplier instructor.

4. Recertification shall be required when:

a. Proficiency requirements herein are not met.

(1). Instructors - proficiency unacceptable.

(2). Operators - unsatisfactory quality of articles fabricated.

(3). Inspectors - unsatisfactory quality of inspection.

(4). Quality/quantitative data demonstrates need for recertification.

b. New fabrication or inspection techniques have been approved that require different skills.

c. Work period interruption of greater than 6 months occurs.

d. Two years have elapsed since last certification.

5. Certification shall be revoked when:

a. Certificate holder fails recertification or retraining.

b. Certificate holder fails to meet visual acuity requirements of paragraph 5.2.

c. Employment is terminated.

d. Supplier training program fails to meet requirements set forth herein or set forth otherwise in the contract.

5.7 Training Resources

1. Training of Level B supplier instructors is available at either the Goddard Space Flight Center (GSFC) or Jet Propulsion Laboratory (JPL). The NASA Generic Fiber Optic Termination and Cabling Training Plan will be supplied to Level B supplier instructors at the time of course completion.

a. GSFC
Training Center
Code 300.1
Greenbelt, MD 20771
(301)731-8632
FAX (301)731-8628

b. JPL
Training Center
MS83-204
4800 Oak Grove Drive
Pasadena, CA 91109
(818)354-6730
FAX (818)393-0090

2. Suppliers may train operator or inspector personnel in-house for certification or recertification using certified instructors and approved training programs, or arrange for this training at one of the NASA-conducted schools.

3. A fee is required. Contact either training center for information.

CHAPTER 6 - FACILITIES, EQUIPMENT AND MATERIALS

6.1 Facility Cleanliness

The work area shall be maintained in a clean and orderly condition. Smoking, eating, and drinking at individual work stations shall not be permitted. Nonessential tools and materials are not permitted at the workstation. Personnel access to the work area shall be limited to direct performance, monitoring, and support personnel. As a minimum, facilities used for connector or cable assembly, splicing, inspection, storage, and tests specified herein shall be established and maintained in accordance with engineering documentation and this chapter.

6.2 Environmental Conditions

1. **Controlled Environment**. The fiber optic work area shall have a controlled environment which limits the entry of contamination. Procedures shall require environmental parameters be recorded and documented. Dust, dirt, fiber fragments, or strength member pieces shall be cleared on a regularly established schedule sufficient to preclude contamination of the hardware. The temperature and humidity of this area shall be monitored, documented, and maintained within the limits defined as the comfort zone in Figure 6-1.

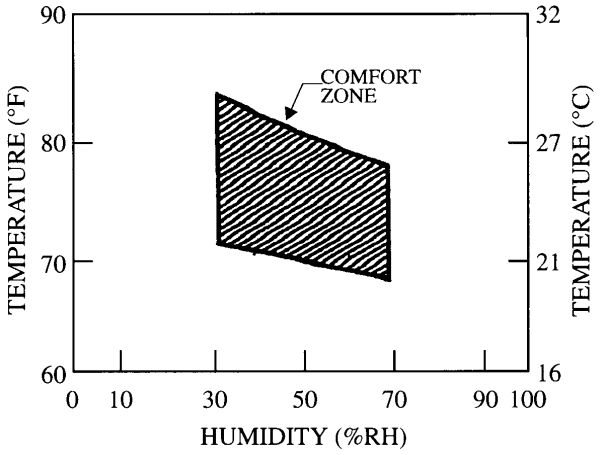


Figure 6-1. Comfort Zone--Temperature Versus Humidity Requirements

2. **Special Environmental Requirements**. Parts or equipment being processed that require more stringent control of environmental conditions than those stated above shall have those special requirements and controls identified and specified in the engineering documentation.

3. **Ventilation System**. Areas used for cleaning parts, and areas where toxic or volatile vapors are generated, shall have a ventilation system for removing air contaminants. The ventilation system shall comply with the recommendations and guidelines of the Occupational Safety and Health Administration (OSHA) requirements, CFR29 1910.94.

4. **Field Operations Requirements**. In field operations where the required controlled conditions cannot be effectively achieved, special precautions shall be taken to minimize the

effects of the uncontrolled environment on the operation being performed on the hardware. These precautions shall be identified in the appropriate documentation.

5. **Lighting.** Light intensity shall be a minimum of 1077 lumens per square meter (lm/m^2) (100 foot-candles) on the surface where fiber optic fabrication operations are being performed, inspected, or tested. Supplemental lighting may be used to achieve the required lighting levels.

6.3 Tools and Equipment

1. **General.** Tooling and equipment used in the termination of fiber optics shall not impart damage to the optical fiber, or to any part of the termination.

a. Equipment shall be appropriately stored and adequately protected when not in use. It shall be verified or recalibrated at established intervals to assure compliance and precision.

b. A program shall be established to assure continuing process capability. Special controls shall be developed for equipment characteristics that control key product requirements.

2. **Cable Preparation Tools.** Tools used in the cable preparation process shall be capable of cutting, slicing, or stripping a portion of the cable without causing damage to adjacent portions of the cable.

3. **Stripping.** Chemical and mechanical stripping methods and materials shall be of a design that will not impart damage to the optical fiber or termination elements.

a. Fixed fiber diameter tools shall be capable of removing the coating from one specific fiber diameter (e.g., 125 microns).

b. Variable fiber diameter tools shall be capable of removing the coating from a range of fiber diameters. This shall be accomplished by using interchangeable die to accommodate the different fiber diameters.

CAUTION: STRIPPING CAN CAUSE NICKS, SCRATCHES, OR CHIPS THAT ARE NOT EASILY DETECTABLE. THEREFORE, EXTREME CARE SHALL BE TAKEN DURING TOOL EVALUATION AND SELECTION.

c. Refer to Material Safety Data Sheets (MSDS) for proper handling of chemical stripping materials.

4. **Fiber Cleaving Tools.** Fiber cleaving tools should be of a design that will allow a clean, fragment-free, crack-free cleave which minimizes chips or other defects as shown in Appendix A on the cleaved fiber end.

a. The cleaving tool shall be capable of allowing the operator to control the strip length of the fiber in order to meet engineering documentation requirements.

b. The tool design shall be such that the cleaved fiber end is retained, thus preventing possible injury to personnel.

c. The cleaving tool shall be capable of producing a cleaved fiber with an endface angle as required by engineering documentation.

5. **Fiber Polishing Tools.** Tools used for polishing the connector shall not damage the connector and shall be capable of producing the end item requirements.

6. **Fusion Splicing Tools and Equipment.** Tools and equipment used in the fusing of two optical fibers shall be of a type that will allow repeatable termination of the fibers. The equipment must be capable of producing a finished termination that meets the design criteria.

7. **Mechanical Splicing Tools and Equipment.** Tools and equipment used to perform a mechanical splice of two optical fibers shall be consistent with the design requirements of the splicing assembly. The equipment must be capable of producing a finished termination that meets the design criteria.

8. **Supplementary Equipment.** Supplementary equipment may be used as required for auxiliary illumination, positioning, handling, accelerating cure times, examination of the prepared end, etc., provided it meets the requirements in this Standard.

6.4 Tool and Equipment Control

The supplier shall:

1. Select tools and equipment used in fiber optic termination and cabling operations appropriate to their intended function.

2. Clean and properly maintain equipment and tooling.

3. Document or reference in the supplier's fiber optic program the detailed operating procedures and maintenance schedules for tools and equipment requiring calibration, functional testing, or setup. The supplier's process documentation for tool and equipment control is subject to review and approval by the procuring NASA Center. Suppliers may elect to use tools not mentioned in this Standard provided the process documentation is reviewed and approved by the procuring NASA Center prior to use.

4. Maintain records of tool and equipment calibration and verification. Calibration shall be in accordance with ANSI/NCSL Z540-1-1994 and traceable to the National Institute of Standards and Technology (NIST). Calibration intervals shall be based on the type of tool and records of the tool's calibration. Intervals may be lengthened or shall be shortened on the basis of stability demonstrated over previous calibration periods.

5. Tools requiring calibration shall be labeled to indicate, as a minimum:

a. Date of calibration.

b. Calibration due date.

c. Any limitation of use. If not practical to place the label directly on the tool, then the label shall be affixed to the tool container.

d. The identification of the organization performing the calibration.

e. Tool identification.

f. Traceability on the tool to the container if the container contains the calibration label.

6. Prohibit unauthorized, defective, or uncalibrated tools in the work area.

6.5 Inspection Aids

Inspections shall be performed using aids conforming to the following:

1. Magnification aids shall be capable of viewing both the bare optical fiber or the termination without imparting damage.

2. Magnification aids shall be capable of rendering true colors, proportional dimensions, and adequate resolution at the magnification chosen to perform the specified inspection. Magnification aids shall be between 50X and 200X.

3. The use of an interferometer to measure the physical profile of the fiber endface is acceptable. For critical endface measurements, an interferometer shall be required.

4. The use of other nondestructive inspection methods (e.g., laser or automated inspection systems) is permitted. The method chosen shall be fully documented and shall not damage parts.

6.6 Storage and Handling

1. The supplier is responsible for the development and implementation of requirements and procedures necessary to prevent damage and to control conditions that could degrade the reliability of parts and deliverable items. Containers shall be compatible with the stored materials.

2. Personnel shall ensure that hands and tools are clean prior to processing optical parts.

3. Stripped fibers or connector interfaces shall not be handled with bare hands due to risk of contamination to fiber interface.

6.7 Electrostatic Discharge Requirements

If the fiber optics are connected to electrostatic discharge sensitive (ESDS) parts or assemblies, the supplier shall implement an electrostatic discharge (ESD) Control Program. ESD requirements shall be in accordance with NASA-STD-8739.7 or other approved ESD control procedures. This

program shall define the ESD control requirements for any activity that tests, inspects, services, manufacturers, installs, packages, labels, or otherwise processes ESD sensitive parts or assemblies. All personnel who handle static-sensitive parts and assemblies shall have been trained in the proper procedures and in the use of appropriate protective equipment to prevent ESD damage.

6.8 Materials Selection

1. All material shall be selected to conform to the project contamination control requirements plan and be compatible with both the termination process and the environment in which the finished product will be used.

2. All materials except metals used in habitable areas of spacecraft, stowed equipment, and experiments shall be evaluated for flammability, odor, and offgassing characteristics in accordance with NHB 8060.1C.

3. All materials used in vacuum or low-pressure compartments shall not release greater than 1.0 percent total mass loss (TML) or 0.1 percent collectable volatile condensable material (CVCM) when tested in accordance with ASTM-E-595.

4. Exterior parts shall be corrosion resistant. The use of cadmium plating is prohibited.

5. Materials shall have no adverse effects on the health of personnel during handling and when used for the intended purpose.

6. Fire-rated fiber optic cables are available for use for specific applications when required.

7. Vinyl dust caps shall not be used for flight applications.

6.9 Solvents

1. The solvents used for the removal of grease, oil, dirt, or other debris shall be selected for their ability to remove both ionic and nonionic contamination. The solvents used shall not degrade the materials or parts being cleaned. Solvent containers shall be properly labeled. Solvents shall be identified in the supplier's engineering documentation. MSDS for solvents shall be available for personnel review and posted where solvents are being used.

2. When any type of water is used, care shall be exercised to ensure that proper drying is accomplished immediately after its use. Exposure of bare fiber to water shall be minimized.

3. Solvents have the potential of removing marking information from parts. Appropriate marking permanency testing shall be performed as part of the evaluation procedure for any solvent.

6.10 Adhesives

1. Adhesives shall be readily dispensable. Dispensing equipment shall not contaminate the adhesive material (e.g., silicone lubricated syringes).

2. Adhesives shall be compatible with the part and process and shall not interfere with the termination performance.

3. Adhesives shall be noncorrosive.

4. Some adhesives can become brittle when in contact with solvents. Prior to use, the appropriate engineering activity shall verify compatibility between adhesives and solvents used for cleaning the assembly.

5. The adhesive material shall meet program and contractual requirements per paragraph 6.8.

6. Adhesives shall not be used in the optical path of the termination.

7. Adhesives shall provide good wetting action that develops strong bonding between the fiber and the internal fiber channel of the connector or mechanical splice.

8. For flight hardware applications, adhesives shall be selected such that the glass transition temperature (T_g) is compatible with processing, testing, and mission environments.

9. Mixed adhesives shall be degassed (e.g., centrifuge or vacuum) before they are applied to optical fibers and connectors.

CAUTION: ***CARE SHOULD BE TAKEN NOT TO INTRODUCE BUBBLES OR VOIDS INTO ADHESIVE DURING MIXING OPERATIONS. BUBBLES AND VOIDS IN THE ADHESIVE SURROUNDING OPTICAL FIBERS IN CONNECTORS HAVE BEEN CORRELATED TO FIBER BREAKAGE.***

10. The adhesive cure schedule shall be compatible with the thermal limitations of the hardware and the processing, testing, and mission environments.

11. The adhesive cure schedule shall ensure greater than 98 percent cure per manufacturer's guidelines.

12. Adhesive lot numbers shall be documented and traceable to the hardware.

13. Detailed instructions on adhesive system weighing, mixing, and proper curing shall be included in engineering documentation as applicable. Uncontrolled heat sources (e.g., heat guns or hotplates) to cure adhesives shall not be used.

6.11 Material Shelf Life Requirements

Materials with a limited shelf life shall be subject to the following requirements:

1. **Shelf Life Labels**. Material storage shall be controlled by shelf life labels attached to each material container.

2. **Purchase Date Recording**. Records for manufacturing date, lot number, and receiving date of each material shipment shall be maintained.

3. **Expired Shelf Life**. Material shall not be used if the shelf life has expired. Shelf life extension may be granted on an individual basis when tested in accordance with the material specification or approved test procedure and found to be in acceptable condition. The expiration date may be extended one time provided the extension is less than one-half the original shelf life. This test shall be documented and shall be approved by the procuring NASA Center prior to use.

4. **Pot Life or Working Life.** The pot life or working life of an adhesive shall be determined as a function of temperature. Engineering documentation shall include requirements for the adhesive's shortest pot life or working life for the temperature range specified during adhesive application.

6.12 Personnel Protection

All necessary safety precautions shall be taken to protect personnel from injury while fabricating, inspecting, or testing fiber optic cable assemblies. Protective equipment shall comply with the requirements of Occupational Safety and Health Administration (OSHA), 29 CFR Part 1910.

1. Protection from bare fibers.

   a. As a minimum, personnel who may come in contact with bare fibers shall wear wrap-around safety goggles for eye protection.

   b. Slivers of bare fiber shall be wrapped in a heavy tape (e.g., duct tape) and placed in a specially marked container for later disposal.

   c. Fiber waste is a personnel safety concern and shall be handled as such during disposal. Incineration is the recommended method of safe disposal.

2. Protection from eye exposure to light sources shall be in accordance with ANSI Z136.1, American National Standard for the Safe Use of Lasers; and ANSI Z136.2, American National Standard for the Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources.

<u>WARNING</u>: SOME LIGHT SOURCES USED IN TESTING AND OPERATING FIBER OPTIC CABLE ASSEMBLIES MAY CAUSE PERMANENT EYE DAMAGE.

CHAPTER 7 - OPTICAL FIBER END PREPARATION

7.1 General

The supplier engineering documentation shall define the parts, tooling, equipment, and procedures used in preparing the fiber optic cable for termination. All parts, materials, and tooling and equipment shall be verified for compliance to the engineering documentation prior to the start of fabrication activities.

7.2 Safety Requirements

All necessary precautions shall be taken to protect personnel from injury while fabricating, inspecting, or testing fiber optic cable assemblies.

1. Protection from bare fibers.

a. As a minimum, personnel who may come in contact with bare fibers shall wear wrap-around safety goggles for eye protection.

b. Slivers of bare fiber shall be wrapped in a heavy tape (e.g., duct tape) and placed in a specially marked container for later disposal.

c. Fiber waste is a personnel safety concern and shall be handled as such during disposal. Incineration is the recommended method of safe disposal.

2. Protection from eye exposure to light sources shall be in accordance with ANSI Z136.1, American National Standard for the Safe Use of Lasers; and ANSI Z136.2, American National Standard for the Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources.

WARNING: SOME LIGHT SOURCES USED IN TESTING AND OPERATING FIBER OPTIC CABLE ASSEMBLIES MAY CAUSE PERMANENT EYE DAMAGE.

7.3 Procedures

1. Fiber optic cables shall be thermally preconditioned prior to preparation for termination. Engineering documentation shall define parameters for preconditioning.

2. Cables (see Figure 7-1 for a typical fiber optic cable) shall be prepared for termination in a fashion that will allow for the fiber to be exposed without sustaining damage or contamination.

3. All outer protective materials shall be removed, in the proper dimensions, in accordance with the supplier's engineering documentation.

4. The use of chemical strippers (e.g., acetone) for removal of certain buffer materials is acceptable. Chemically stripped fiber ends shall be thoroughly cleaned to remove any residual

chemical stripping compounds and buffer materials immediately after stripping. This process shall be documented by the supplier. All necessary safety precautions shall be observed.

5. All parts that come in contact with the adhesives, including all dispenser parts and mixing pans, as well as the fiber and connector to be bonded, must be thoroughly cleaned with appropriate solvents before bonding.

6. The optical fiber shall be further prepared if warranted by the specific application, fiber construction, or process requirement. The supplier's engineering documentation shall document any additional requirements.

7. Procedures for collecting, controlling, and disposing of fiber optic waste shall be documented (see also paragraph 7.2 Safety Requirements).

8. The optical fiber shall be back-lit using an incoherent, low intensity light source from the opposite end of the cable, without touching the fiber, when inspecting for cracks on or through the fiber endface. When the opposite end of the cable is not accessible, inspection techniques which produce core illumination shall be used.

9. The connector endface may be finished either by polishing or cleaving provided that the process is compatible with the finished product quality requirements established by the supplier's engineering documentation.

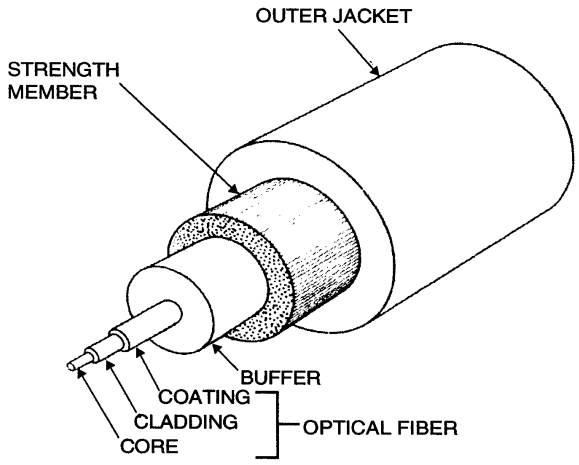


Figure 7-1. Parts of a Typical-Optic Cable

CHAPTER 8 - CLEANING

8.1 General

1. Specific procedures shall be developed, documented, and maintained for cleaning, drying parts, and examination.

2. Cleaning solvents shall be of the type specified in the engineering documentation.

3. Fiber optic terminations to be cleaned shall be handled in a manner that will not degrade or damage the termination.

4. Terminations shall be cleaned within a time frame that permits removal of all contaminants.

5. Manual cleaning of fiber optic terminations shall be performed using a solvent and a wipe or swab. The wipe or swab shall be non-abrasive, lint free, and either soxhlet extracted, or equivalent, or low non-volatile residue.

6. Cleaning processes shall not degrade the optical characteristics of the termination.

7. Prior to use, the appropriate engineering activity shall verify compatibility between solvents used for cleaning the assembly and all materials, including epoxies.

8. Cleaning shall ensure removal of dirt, oil, grease, and particulate matter.

9. If not terminated immediately, prepared cable components shall be protected from contamination.

CHAPTER 9 - FIBER OPTIC SPLICING

9.1 General

Materials shall be in accordance with 6.8.

9.2 Splice Assembly

Fiber optic cables shall be prepared for splicing in accordance with the procedures established in Chapter 7 of this Standard.

1. Prior to splicing, the fiber shall be examined to ensure there is no contamination, blockage of the internal fiber channel, unacceptable conditions as shown in Appendix A, as applicable, or other nonconformances with specific requirements of the engineering documentation.

2. Splices shall be performed using the appropriate method shown below, or as specified in the engineering documentation.

a. **Fusion Splicing**. Fusion splicing of fiber optics shall be performed in accordance with engineering documentation using equipment that meets the criteria established in Chapter 6 of this Standard. Completed fusion splices shall be able to withstand a minimum 4.45 newton (1 pound) pull test, or as specified in the engineering documentation.

b. **Mechanical Splicing**. Mechanical splicing shall not be used for spaceflight operations. Mechanical splicing of fiber optics shall be performed in accordance with engineering documentation using equipment and material established in Chapter 6 of this Standard.

c. **Chemical Splicing** . Chemical splicing shall only be used for temporary joining of fiber optics (i.e., testing).

3. Completed splices shall meet the following minimum requirements:

a. **Location.** Splices shall not be located in flexure areas of the cable except when a splice is recoated and rejacketed in accordance with the manufacturer's original specifications.

b. **Protection.** Splices shall be protected. If a splice enclosure cannot be used for a specific application, engineering documentation shall provide for other means of protection.

c. **Strength Member.** Strength members shall be secured to splice enclosures, or other means of protection, to prevent mechanical stress on the optical fiber.

4. Splices shall be verified. Optical Time Domain Reflectometry (OTDR), as well as other appropriate test procedures from Appendix B, should be used after the completion of the splicing operation to ensure that loss characteristics are consistent with the loss allowances established by design and operation engineering documentation. Records of testing shall be maintained with the assembly/subassembly documentation. Appendix B provides a list of available test and verification documents.

9.3 Design Considerations

1. The splices should be of the construction, weight, and physical dimensions specified by engineering documentation.

2. Design should provide tensile strength continuity between spliced cables without application of the cable tensile load to the splice junction.

3. Design should provide cable stress relief and environmental sealing between the cables and splice to prevent the entry of external contaminants. The stress relief should provide protection from both cable tensile forces and cable axial compressive forces.

4. Design should meet the requirements for optical, mechanical, and environmental performance as specified by engineering requirements. For further information, refer to the documents listed in paragraph 2.1 and Appendix B.

5. All splice parts of the same type should be physically and functionally interchangeable without the need for modification of such items or of the splicing equipment.

6. When dissimilar metals are used in contact with each other, protection against electrolysis and corrosion should be provided. Metal spraying or metal plating of dissimilar base metals to provide similar or suitable abutting surfaces is permitted.

7. Seals should provide isolation from humidity and/or contamination for splice interior parts.

8. Staking should be defined in engineering documentation.

9. The use of splice trays is recommended for multiple splices.

10. Minimum fiber bend radii should be defined in engineering documentation. Reference Chapter 12.

CHAPTER 10 - FIBER OPTIC CABLE ASSEMBLIES

10.1 General

A fiber optic cable assembly consists of a prepared fiber optic cable, connector, and associated hardware. Materials used in this assembly shall be in accordance with 6.8.

10.2 Cable Assembly

1. Fiber optic cables shall be prepared for connector assembly in accordance with the procedures established in Chapter 7 of this Standard.

2. Fiber optic cables shall be identified in such a way to distinguish these cables from wire or coaxial cables.

3. Cable connectors shall be permanently marked with mating connector designation within 15cm (6 in) of connector body, or as stated in the engineering documentation.

4. As a minimum, prior to assembly, prepared fiber optic cables shall be subject to documented in-process peer verification for the following:

   a. Correct cable stripping dimensions.

   b. Strength member damage.

   c. Cracks, nicks, cuts, or other damage in the termination area to all cable components, including the optical fiber.

   d. Chemical strip wicking or damage.

   e. Cleanliness as per Chapter 8.

5. Prior to assembly, prepared fiber optic connector parts shall be examined for the following:

   a. Blockage in the internal fiber channel. The prepared fiber shall not be used to check for blockage.

   b. Cleanliness as per Chapter 8.

   c. Cracks or deformities on the connector ferrule.

6. Prior to assembly, verification of other requirements (e.g., heat shrinkable sleeving dimensions or crimp sleeve requirements) shall be in accordance with engineering documentation.

7. Completed cable assemblies shall be inspected for the following:

a. Strength member, when visible, is uniformly distributed and securely attached to the connector.

b. Heat shrinkable sleeving and/or crimp sleeve positioned properly.

c. Connector endface geometry compliant with engineering documentation.

d. Connector ferrule length compliant with engineering documentation.

e. Connector endface requirements in accordance with Appendix A or the engineering documentation.

f. Proper positioning and attachment of the strain relief device per the engineering documentation.

g. Cleanliness as per Chapter 8.

h. Cable axial alignment with the connector within 5cm (2 inches) of the termination or per the engineering documentation.

i. Freedom from nicks exposing underlying elements.

j. Freedom from kinks or twists.

k. Cable designation marking.

8. If cracks in a flight fiber optic cable endface are found, the cable shall be reterminated or scrapped. Re-polishing to fix cracks in flight hardware is prohibited.

10.3 Post Assembly Testing

1. All completed flight cable assemblies shall be tested to ensure that measured optical performance (e.g., insertion loss or return loss) meets or exceeds the performance requirements in the engineering documentation. Records of testing shall be maintained with the assembly or subassembly documentation. Appendix B provides a list of available test and verification documents.

2. Upon completion of the test(s) required in paragraph 10.3.1, the flight cable assemblies shall be subjected to workmanship temperature cycling or preconditioning as identified in the engineering documentation.

3. Retest the cable assembly per paragraph 10.3.1 and, in addition, examine for the following:

a. Cracks in fiber endface using normal and back lighting. The fiber optic cable assembly shall be back-lit using a non-coherent, low intensity light source from the opposite end of the cable, without touching the fiber as part of the examination.

b. Pistoning of the fiber in connector.

c. Cracks in epoxy bond line at the endface.

d. Shrinkage of the outer jacket. Other cable components shall also be evaluated for shrinkage. An unacceptable amount of shrinkage after temperature cycling shall be defined by an excessive optical loss value as specified in the engineering documentation.

10.4 Design Considerations

1. The connector should be of the construction, weight, and physical dimensions specified by engineering requirements.

2. Design should provide cable stress relief and environmental sealing between the cables and connector to prevent the entry of external contaminants. The stress relief and connector/cable attachment method should provide protection from both cable tensile forces, and cable axial compressive forces.

3. Design should meet the requirements for optical, mechanical, and environmental performance as specified by engineering requirements.

4. All connector parts of the same type should be physically and functionally interchangeable without the need for modification of such items or of the termination equipment. A complete mated connector design should be comprised only of parts from the same manufacturer to prevent connector intermateability problems.

5. When dissimilar metals are used in contact with each other, protection against electrolysis and corrosion should be provided. Metal spraying or metal plating of dissimilar base metals to provide similar or suitable abutting surfaces is permitted.

6. Seals should provide isolation from humidity and/or contamination for connector interior parts.

7. The maximum allowable connector coupling loss should be specified in the engineering documentation.

8. The connector mate durability should be addressed in the engineering documentation.

9. Staking and torque values should be defined in the engineering documentation.

10. Minimum cable bend radii should be defined in the engineering documentation. Reference Chapter 12.

11. For inspection purposes, clear heat shrinkable sleeving is recommended.

CHAPTER 11 - FIBER OPTIC ASSEMBLIES

11.1 General

Fiber optic assemblies include such devices as electro-optical components, star couplers, and splice enclosures. The optical fibers found in these devices consist of the fiber (core and cladding) and the coating surrounding the fiber. Optical fibers differ from fiber optic cables which may have a buffer, loose tube, strength members, and outer jacket as additional protective sheathing.

11.2 Fiber Optic Connector Termination

1. The optical fiber shall be prepared in accordance with Chapter 7, as applicable.

2. As a minimum, prior to assembly, prepared optical fibers shall be subject to documented in-process peer verification for the following:

a. Correct stripping dimensions.

b. Cracks, nicks, cuts, or other damage to the coating and fiber.

c. Chemical strip wicking or damage.

d. Cleanliness as per Chapter 8.

3. Prior to assembly, fiber optic connector parts shall be examined for the following:

a. Blockage in the internal fiber channel. The prepared fiber shall not be used to check for blockage.

b. Cleanliness as per Chapter 8.

c. Cracks or deformities on the connector ferrule.

4. Prior to assembly, verification of other requirements (e.g. heat shrinkable sleeving dimensions or crimp sleeve requirements) shall be in accordance with engineering documentation.

11.3 Post Fiber Optic Connector Termination

1. Terminated fiber optics shall be inspected for the following:

a. Heat shrinkable sleeving and/or crimp sleeve positioned properly.

b. Connector endface geometry compliant with engineering documentation.

c. Connector endface requirements in accordance with Appendix A or engineering documentation. The optical fiber shall be backlit using an incoherent, low intensity light source from the opposite end of the fiber, without touching the fiber, as part of the examination, when

appropriate. When the opposite end of the fiber is not accessible, inspection techniques which produce core illumination shall be used.

d. Proper positioning of the strain relief per the engineering documentation.

2. If cracks in a flight fiber optic assembly endface are found, the assembly shall be reterminated or scrapped. Re-polishing to fix cracks in flight hardware is prohibited.

11.4 Fiber Optic Routing

1. The optical fiber shall not be routed over sharp edges or corners unless appropriate protection is provided.

2. The minimum bend radius of the routed optical fiber shall be in accordance with the engineering documentation.

3. The optical fiber shall be tied down (e.g., lacing cord) per the engineering documentation to prevent subsequent damage due to processing, handling and operational environments. The ties shall not pinch, deform or otherwise stress the optical fiber. The ties shall be loose enough to allow the fibers to move slightly due to thermal expansion and contraction. Overly tight ties can cause microbending of the fiber and affect performance or reliability.

4. Conduits should be used to route optical fibers through areas where access is limited or restricted.

5. Staking or conformal coating shall not be applied to optical fiber unless specifically required in the engineering documentation.

11.5 Fiber Optic Assembly Testing

1. All finished flight fiber optic assemblies shall be tested to ensure that measured optical performance meets the performance requirements in the engineering documentation. Records of testing shall be maintained with the assembly or subassembly documentation. Appendix B provides a list of available test and verification documents.

2. Upon completion of the test(s) required in paragraph 11.5.1 the flight fiber optic assemblies shall be subjected to workmanship temperature cycling or preconditioning as identified in the engineering documentation.

3. Retest the flight fiber optic assembly per paragraph 11.5.1 and, in addition, examine for the following:

a. Cracks in fiber endface using direct and back lighting. The optical fiber shall be back-lit using an incoherent, low intensity light source from the opposite end of the fiber, without touching the fiber as part of the examination. When the opposite end of the fiber is not accessible, inspection techniques which produce core illumination shall be used.

b. Pistoning of the fiber in connector or termination.

c. Cracks in epoxy bond line at the endface.

d. Shrinkage of buffer or outer jacket.

CHAPTER 12 - FIBER OPTIC CABLE ASSEMBLY INSTALLATION

12.1 General

Fiber optic cable assemblies should not be combined in the same wiring bundle as wire or coaxial cable assemblies. Care must be taken to prevent damage to fiber optic cable assemblies during the installation process. Fiber optic cables shall only be installed by trained and certified fiber optic personnel.

12.2 Installation Requirements For Flight Applications

1. Fiber optic cable assemblies shall not be subjected to axial loads exceeding the manufacturer's specification.

2. The minimum bend radius shall not be less than 10 times the cable diameter unless specified on the engineering documentation.

3. For installation, fiber optic cable assemblies shall be tied at least once every 20cm (8 in), or per the engineering documentation. The minimum bend radius shall not be violated at connector backshells. Tie downs shall be tight enough to capture the fiber optic cable but shall not deform the cable outer jacket. The ties shall not pinch, deform, kink, or otherwise stress the cable assembly.

4. Conduits should be used to route optical fibers where access is limited or restricted.

5. Dust caps shall be installed on all connectors when not in use. Vinyl dust caps shall not be used.

6. Fiber optic cable connector or termination endfaces shall be examined before each mate and cleaned if necessary in accordance with Chapter 8.

7. Fiber optic connectors shall be torqued or staked per engineering documentation.

8. Fiber optic cable assemblies shall not be routed over sharp edges or corners unless appropriate protection is provided.

12.3 Installation Requirements for Mission Critical Ground Support Applications

1. The maximum installation tensile load, the maximum use tensile load, and the maximum vertical rise for cable assemblies installed in raceways, trays, ducts or conduits and multifiber cables shall be specified on the engineering documentation.

2. The minimum installation (short term) bend radius shall not be less than 10 times the cable diameter unless specified on the engineering documentation.

3. The minimum long term bend radius shall not be less than 15 times the cable diameter unless specified on the engineering documentation.

4. For installation, fiber optic cable assemblies shall be tied per the engineering documentation. The minimum long term bend radius shall not be violated at connector backshells. Tie downs shall be tight enough to capture the fiber optic cable but shall not deform the cable outer jacket. The ties shall not pinch, deform, kink, or otherwise stress the cable assembly.

5. Dust caps shall be installed on all connectors when not in use.

6. Fiber optic cable connector or termination endfaces shall be examined before each mate and cleaned if necessary in accordance with Chapter 8.

7. Fiber optic connectors shall be torqued per engineering documentation.

8. Fiber optic cable assemblies shall not be routed over sharp edges or corners unless appropriate protection is provided.

CHAPTER 13 - QUALITY ASSURANCE PROVISIONS

13.1 General

In addition to requirements previously stated:

1. **Workmanship**. Workmanship shall be of sufficient quality to assure that the products meet the performance requirements of the engineering documentation and criteria delineated herein.

2. **Inspection.** Inspection for acceptability shall be performed on all fiber optic terminations and cable assemblies to the requirements specified in this Standard. If any elements of the fiber optic components must be moved to aid inspection, they shall not be disturbed in a fashion that will cause damage.

3. **Method of Inspection.** X-ray or other means of automated inspection are permissible provided that it has been determined that the x-ray emission level is not detrimental to the product being inspected.

4. **Quality Assurance.** The following functions shall be performed:

a. **Product Verification.** Witness or verify that all tests, examinations, peer verifications, inspections, and measurements specified by this Standard and the specific engineering documentation have been performed.

b. **Personnel Certification.** Verify that all personnel who assemble, inspect, or install hardware in accordance with this Standard have been trained and certified as specified in Chapter 5.

c. **Processes and Procedures.** Verify, through in-process surveillance of all assembly operations, that all processes and procedures implementing the requirements of this Standard are current, approved, adequate, and are being accurately used.

d. **Part Cleanliness.** Verify that all parts were cleaned and undamaged prior to being assembled.

e. **Facility Control.** Verify that the facility cleanliness, environmental conditions, and lighting requirements of Chapter 6 are met.

13.2 Magnification Requirements

1. Magnification requirements shall be specified in the engineering documentation.

2. Magnification for inspection of cleanliness, chemical strip wicking, cracks, nicks, and cuts in the glass fiber and coating shall be between 50X and 80X.

3. Magnification for inspection of connector endfaces and cleaved bare fibers shall be between 100X and 200X.

4. Magnification aids shall be sufficient to view the item under inspection. Higher magnification may be used to resolve suspected anomalies.

13.3 Documentation Verification

Quality Assurance personnel shall verify that all required documentation is current and approved. The documentation shall include:

1. Records:

   a. Visual examination as per paragraph 5.2.

   b. Operator and inspector certification as per paragraph 5.3.

   c. Environmental monitoring as per paragraph 6.2.

   d. Production and inspection tool calibration as per paragraph 6.3.

   e. Post assembly testing as per paragraphs 9.2.4, 10.3, and 11.5.

2. Procedures:

   a. Optical fiber termination and cabling program as per paragraph 4.2.

   b. Training and certification program as per paragraph 5.4.3

   c. Work area maintenance program as per paragraphs 6.1 and 6.2.

   d. Tooling and equipment operating procedures as per paragraph 6.4.3.

   e. Equipment preventative maintenance program as per paragraph 6.4.3.

   f. Calibration system as per paragraph 6.4.4.

   g. Automated inspection procedures as per paragraph 6.5.4

   h. Storage and handling procedures as per paragraph 6.6.

   i. ESD control program as per paragraph 6.7.

   j. Controlling and disposing of waste as per paragraph 7.3.7.

   k. Cleaning procedures as per Chapter 8.

13.4 Documentation Authorization

Quality Assurance personnel shall verify that the following documentation has been approved by the procuring NASA Center prior to implementation:

1. Special engineering requirements as per paragraph 1.1.2.

2. Nonstandard Processes, Materials as per paragraph 4.1.3.

3. Departures from this Standard as per paragraph 4.3.1.

4. Repair as per paragraph 4.4.

5. Special equipment and equipment procedures as per paragraph 6.4.3.

6. Verification Test Plan as per Chapter 14.

13.5 Verification Of Tools And Equipment, Material, And Facilities

1. **Tools and Equipment**. Tools and equipment shall be verified for conformance to the applicable requirements found in paragraphs 6.3 and 6.4.

2. **Material**. Verify that all materials comply with engineering documentation and contract requirements. All materials shall conform to the requirements of paragraphs 6.8 through 6.11. Material controls shall be implemented to ensure that only conforming materials are used. Materials not conforming or not required for the operation involved shall be removed from the work area or tagged as unusable.

3. **Facilities**. Work area cleanliness as per paragraph 6.1.

13.6 Verifications

1. Optical fiber preparation in accordance with paragraphs 7.3 as appropriate, 9.2, and 11.2.

2. Fiber optic cable preparation in accordance with 7.3 as appropriate, and 10.2.

3. Other fiber optic requirements in accordance with engineering documentation in accordance with paragraphs 7.3, 9.2, 10.2, and 11.2.

4. Compatibility of solvents with all materials, including epoxies, in accordance with Chapter 8.

5. Fiber optic connector parts in accordance with paragraphs 10. 2 and 11.2.

13.7 Inspections

1. Splices in accordance with paragraph 9.2.

2. Fiber optic cable assemblies in accordance with paragraph 10.2.

3. Fiber optic assemblies in accordance with paragraph 11.3.

4. Other specific requirements as defined on engineering documentation.

13.8 Tests

1. Splices in accordance with paragraph 9.2.

2. Fiber optic cable assemblies in accordance with paragraph 10.3.

3. Fiber optic assemblies in accordance with paragraph 11.5.

CHAPTER 14 - GENERAL REQUIREMENTS FOR VERIFICATION

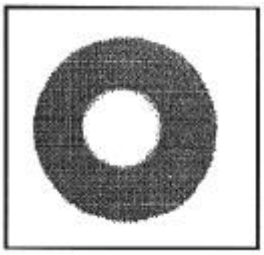
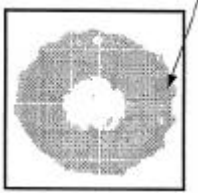
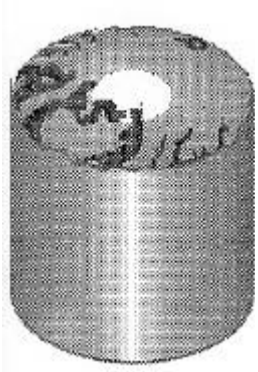
14.1 General

When prescribed by the procuring NASA Center, verification tests shall be conducted to establish confidence in the reliability of the fiber optic termination. Prior to use, a test plan shall be submitted to the procuring NASA Center or its designated representative for approval. The test plan shall detail the test environment, test duration, test termination design, and failure criteria based on the life and mission requirements.

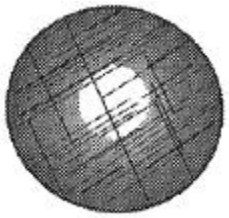
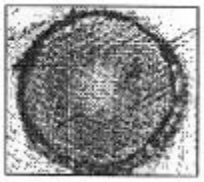
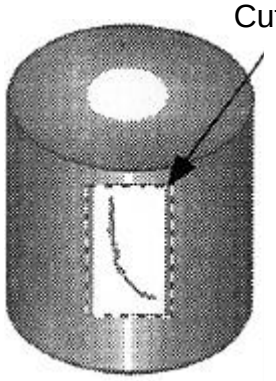
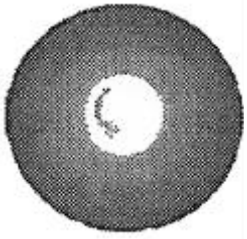
APPENDIX A

FIBER ENDFACE INSPECTION CRITERIA AFTER POLISHING

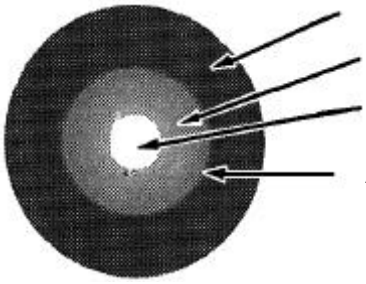
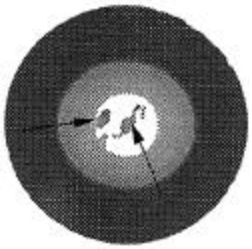
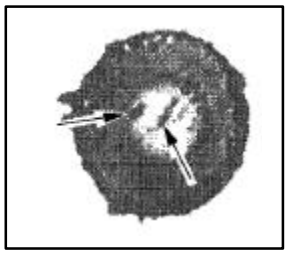
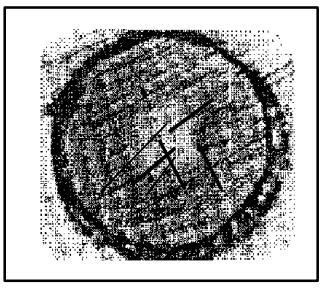
BARE FIBER - BACK-LIT

PERFECT FIBER Oblique View  Top View  Photo Image 		ACCEPTABLE Accept. Free from cracks, scratches, edge chips, hackles, pits and other anomalies and core is clearly discerned.
EDGE CHIPS Oblique View Cladding Core  Top View  Photo Image Chip 		ACCEPTABLE Acceptable if chip maximum dimension ≤ 3% of fiber diameter and number of chips ≤ 3.
HACKLE Oblique View  Top View  Photo Image 		REJECT Surface irregularity due to improper cleaving. Reject/re-cleave. Reject for splice connection. May be fixable by polishing if used in connector.

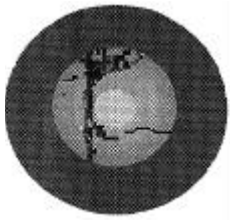
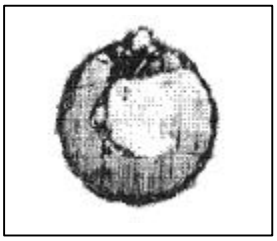
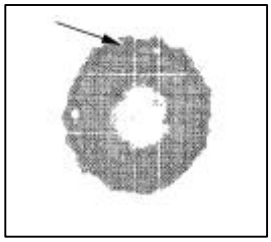
BARE FIBER - BACK-LIT - continued

SCRATCHES Oblique View  Top View  Photo Image 		REJECT Reject/Repolish. Reject if performance is affected.
CRACK Oblique View  Top View  Photo Image 		REJECT Any cracks are rejectable.
CRACK (Below Surface) Oblique View Cut Away View  Top View 		REJECT Any cracks are rejectable. Most often only detected by back-lit operation.

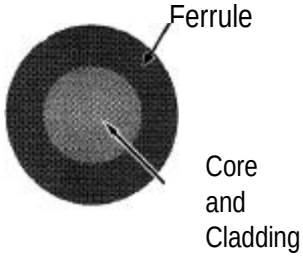
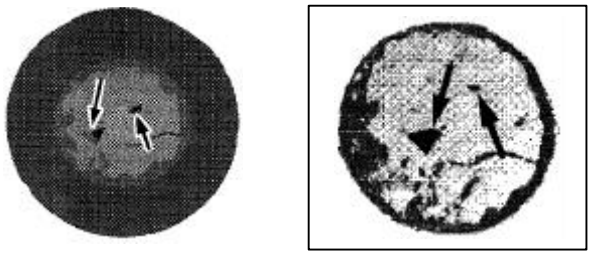
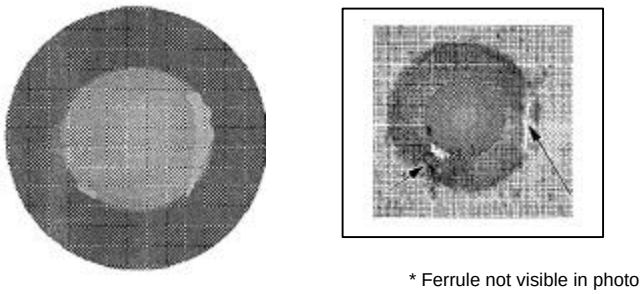
FIBER IN FERRULE BACK-LIT

PERFECT FIBER Top View  	ACCEPT Free from cracks, scratches, voids in the adhesive bond, and other anomalies; and concentric within the performance requirements.
SURFACE PITS Top View  Photo Image 	REJECT Reject/Repolish if in core or cladding.
SCRATCHES Top View  Photo Image 	REJECT Reject/Repolish if in core.

FIBER IN FERRULE - BACK-LIT - continued

CRACK Top View  Photo Image  *Ferrule not visible in photo	REJECT Reject.
EDGE CHIPS Top View  Photo Image  *Ferrule not visible in photo	REJECT May be fixable by polishing.

FIBER IN FERRULE - DIRECT-LIT, NO CORE ILLUMINATION

PERFECT  * Ferrule not visible in photo	ACCEPT Free from cracks, scratches, edge chips, hackles, pits, and other anomalies; and concentric within the performance requirements. Note: Cracks may be invisible without core illumination.
SURFACE PITS  * Ferrule not visible in photo	REJECT Reject/Repolish if in core or cladding. Confirm by backlighting.
SCRATCHES 	REJECT Reject/Repolish.
EPOXY  * Ferrule not visible in photo	REJECT Reject if epoxy is on core, cladding or ferrule. May be fixable by repolishing.

APPENDIX B - TEST METHODS FOR THE VERIFICATION OF OPTICAL FIBER FABRICATION PROCESSES

The following fiber optic test procedures should be considered for all optical fiber cable assemblies, splices, and/or connectors, as applicable:

EIA-455-1 (FOTP 1)	Cable Flexing for Fiber Optic Interconnection Devices
EIA-455-3 (FOTP 3)	Procedure to Measure Temperature Cycling Effects on Optical Fibers, Optical Cable, and Other Passive Fiber Optic Components.
EIA-455-4 (FOTP 4)	Fiber Optic Connector/Component Temperature Life.
EIA-455-5 (FOTP 5)	Humidity Test Procedure for Fiber Optic Connecting Devices
EIA-455-6 (FOTP 6)	Cable Retention Test Procedure for Fiber Optic Cable Interconnecting Devices
EIA-455-11 (FOTP 11)	Vibration Test Procedure for Fiber Optic Connecting Devices and Cable
EIA-455-12 (FOTP 12)	Fluid Immersion Test for Fiber Optic Components
EIA-455-13 (FOTP 13)	Visual and Mechanical Inspection of Fiber, Cables, Connectors etc.
EIA-455-14 (FOTP 14)	Fiber Optic Shock Test (Specified Pulse)
EIA-455-15 (FOTP 15)	Altitude Immersion
EIA-455-16 (FOTP 16)	Salt Spray
EIA-455-17 (FOTP 17)	Maintenance Aging of Fiber Optic Connectors and Terminated Cable Assemblies
EIA-455-21 (FOTP 21)	Mating Durability for Fiber Optic Interconnecting Devices
EIA-455-25 (FOTP 25)	Repeated Impact Testing of Fiber Optic Cables and Cable Assemblies
EIA-455-26 (FOTP 26)	Crush Resistance of Fiber Optic Interconnecting Devices
EIA-455-33 (FOTP 33)	Fiber Optic Cable Tensile Loading and Bending Test
EIA-455-34 (FOTP 34)	Interconnection Device Insertion Loss Test
EIA-455-36 (FOTP 36)	Twist Test for Fiber Optic Connecting Devices
EIA-455-37 (FOTP 37)	Low or High Temperature Bend Test for Fiber Optic Cable
EIA-455-39 (FOTP 39)	Fiber Optic Cable Water Wicking Test
EIA-455-41 (FOTP 41)	Compressive Loading Resistance of Fiber Optic Cables
EIA-455-42 (FOTP 42)	Optical Crosstalk in Fiber Optic Components

EIA-455-53 (FOTP 53)	Attenuation by Substitution Measurement for Multi-mode Graded-Index Optical Fibers or Fiber Assemblies Used in Long Length Communication Systems
EIA-455-57 (FOTP 57)	Optical Fiber End Preparation and Examination
EIA-455-59 (FOTP 59)	Measurement of Fiber Point Defects using an Optical Time Domain Reflectometer
EIA-455-60 (FOTP 60)	Measurement of Fiber or Cable Length Using an OTDR
EIA-455-61 (FOTP 61)	Measurement of Fiber or Cable Attenuation Using an OTDR
EIA-455-62 (FOTP 62)	Measurement of Optical Fiber Macrobend Attenuation
EIA-455-69 FOTP 69)	Test Procedure for Evaluation of the Effect of Minimum and Maximum Exposure Temperatures on the Optical Fiber
EIA-455-85 (FOTP 85)	Fiber Optic Cable Twist Test
EIA-455-88 (FOTP 88)	Fiber Optic Cable Bend Test
EIA-455-91 (FOTP 91)	Fiber Optic Cable Twist-Bend Test
EIA-455-95 (FOTP 95)	Absolute Optical Power Test for Optical Fibers and Cables
EIA-455-96 (FOTP 96)	Fiber Optic Cable Long-Term Storage Temperature Test for Extreme Environments
EIA-455-98 (FOTP 98)	Fiber Optic Cable External Freezing Test
EIA-455-171 (FOTP 171)	Attenuation by Substitution Measurement for Short-Length Multi-mode Graded-Index and Single-Mode Optical Fiber Cable Assemblies
NRL/MR/6505-92-6963	Procedure for Measuring Radiation-Induced Attenuation in Optical Fibers and Optical Cables

NASA TECHNICAL STANDARD IMPROVEMENT PROPOSAL

(See Instructions - Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
3. NAME OF SUBMITTING ORGANIZATION	
4. ADDRESS (Street, City, State, ZIP Code)	
5. PROBLEM AREAS a. Paragraph Number and Wording b. Recommended Wording: c. Rational for Recommendation:	
6. REMARKS	

7. NAME OF SUBMITTER	8. TELEPHONE NO.	9. DATE

INSTRUCTIONS

In a continuing effort to improve our NASA Technical Standards, we invite all holders to use this form for submitting comments and suggestions for improvements. All users of NASA documents are invited to provide suggestions. The form may be detached and mailed. In block 5, be as specific as possible about particular problem areas, such as wording changes, which would alleviate the problems. Enter in block 6 any remarks not related to a specific paragraph of the document. An acknowledgment will be mailed to the submitter within 30 days. Supporting data should accompany any recommendations for changes.

NOTE: ***THIS FORM MAY NOT BE USED TO REQUEST COPIES OF DOCUMENTS, NOR TO REQUEST WAIVERS, DEVIATIONS, OR CLARIFICATION OF STANDARD REQUIREMENTS ON CURRENT CONTRACTS. COMMENTS SUBMITTED ON THIS FORM DO NOT CONSTITUTE OR IMPLY AUTHORIZATION TO WAIVE ANY PORTION OF THE REFERENCED DOCUMENT(S) OR TO AMEND CONTRACTUAL REQUIREMENTS.***

Proposals may be submitted to:

NASA Technical Standards Coordinator
NASA Headquarters
Code QS
Washington, DC 20546