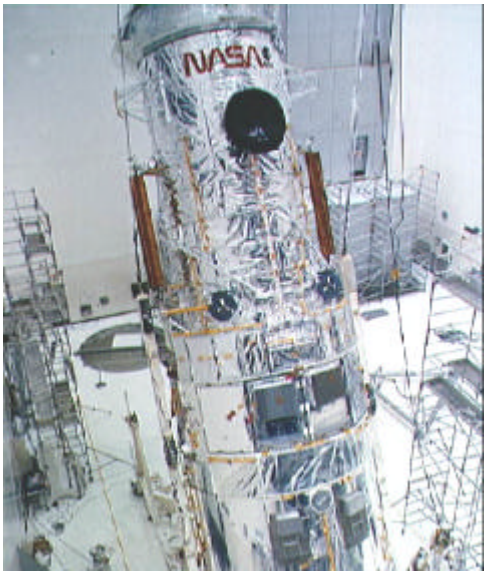
*In Accordance With*
*NASA-STD-*8739.5

# NASA Training Program




# Student Workbook for Optical Fiber Terminations

*February 1999*
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NASA

*National Aeronautics and*
*Space Administration*

In Accordance With
NASA-STD-8739.5

NASA Training Program
Student Workbook for
Optical Fiber Terminations

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# TABLE OF CONTENTS


Introduction ..... iv

Policy Matters on Training ..... iv

Completion of Training ..... v

Retraining ..... v

Guidelines to Follow ..... v

Course Requirements ..... vi

Course Objectives ..... vi

Course Agenda ..... vi

Agenda ..... vii

General Safety Requirements ..... viii

Chapter 1. Fiber Optic Overview ..... 1

Chapter 2. Course Overview ..... 10

Chapter 3. Preparing the Cable ..... 14

Chapter 4. Cleaning ..... 20

Chapter 5. Epoxy Mixing ..... 21

Chapter 6. Terminating Fiber with connectors ..... 23

Chapter 7. Polishing ..... 36

Chapter 8. Inspection ..... 39

Chapter 9. Splicing ..... 44

Chapter 10. Testing ..... 45

# INTRODUCTION

NASA has designated Goddard Space Flight Center and the Jet Propulsion Laboratory as the Training Centers for the Eastern Region and Western Region, respectively, of the United States. The NASA Training Centers specialize in the development and implementation of technical training courses for the fabrication of space flight and ground support equipment.

This course conforms to released NASA Technical Standards and is recognized by NASA.

The intent of this Fiber Optics Terminations course is to train personnel who instruct, fabricate, or inspect space flight hardware to NASA Technical Standard
NASA-STD-8739.5 Requirements for Fiber Optic Terminations. This is a hands-on course. Instruction is accomplished through written documentation, demonstrations, actual terminations of optical fiber, and testing. This document specifies the methods and techniques required producing reliable fiber optic terminations.

The purpose of this course is to assure that each individual who trains, terminates, or inspects is appropriately skilled in the types of connections involved in his/her work. This course provides the student with the theory and hands-on experience to produce or inspect quality fiber optic terminations. Hands-on training programs with qualified instructors are essential to training personnel to be able to perform these tasks consistently.

# POLICY MATTERS ON TRAINING

Questions regarding policy matters on training should be directed to the attention of the Manager of the Jet Propulsion Laboratory Training Center or the Goddard Space Flight Training Center, which ever is appropriate.

# COMPLETION OF TRAINING

Upon completion of the course, students will be issued a wallet-size card showing completion of training. A document will also be issued to the student's supervisor for employee records. All documents contain information as to the type of course, classification (operator, inspector, or instructor), date of expiration, and authorizing signatures.

The supplier based upon successful completion of training shall provide certification of personnel. See NASA-STD- 8739.5; paragraph 3N202 for further details.

# RETRAINING

Retraining is based on performance and application of theory, with passing grades of classroom work in accordance with course requirements. Retraining shall be accomplished prior to the training expiration date shown on the wallet-size identification card. Failure to successfully complete retraining requires the student to attend a full training course.

# GUIDELINES TO FOLLOW

Fiber optic terminations must perform reliably under such conditions as vibration, vacuum, radiation, and thermal cycling. General principles of assuring and controlling reliable connections are proper design; control of tools, material, and work environments; and good workmanship by trained and certified personnel. Some general factors and rules controlling reliability can be found NASA-STD-8739.5 chapter 3.

# COURSE REQUIREMENTS

Students will be required to terminate and inspect fiber optic terminations. A written examination covering materials from NASA-STD-8739.5 and from class lectures will also be given. Each student will be graded for performance of his/her work accomplished during the class. The minimum requirements to pass the course are:

| Field of Employment | Testing Activity | Grade |
|---|---|---|
| *Operators* | Fabrication | 85% |
| | Written Test | 80% |
| | Inspection | 80% |
| *Inspectors* | Fabrication | 80% |
| | Written Test | 80% |
| | Inspection | 85% |

# COURSE OBJECTIVES

At the end of class the student should be familiar with the concepts of fiber optic terminations and the requirements of NASA-STD-8739.5.

# COURSE AGENDA

The fiber optic terminations training course consists of five(5) 8 hour days for a total of 40 hours. The agenda for each day is outlined in this workbook. Retraining consists of (2) 8-hour days.

# Agenda

**Day One**

| | |
|---|---|
| 8:00 | Introduction |
| 8:15 | Background History |
| 8:30 | Basic physics and properties |
| 9:30 | *Break* |
| 9:45 | Alignment Losses |
| 11:30 | Lunch |
| 12:30 | Stripping Tools/Cable Preparation |
| 2:15 | *Break* |
| 2:30 | Cable Preparation |
| 4:00 | End of Day |

**Day Two**

| | |
|---|---|
| 8:00 | Cleaning |
| 8:30 | Epoxy Preparation |
| 9:30 | *Break* |
| 9:45 | Connector Types |
| 11:30 | Lunch |
| 12:30 | Cleaving |
| 2:15 | *Break* |
| 2:30 | Cleaving cont. |
| 4:00 | End of Day |

**Day Three**

| | |
|---|---|
| 8:00 | Connector Assembly |
| 9:30 | *Break* |
| 9:45 | Polishing |
| 11:30 | Lunch |
| 12:30 | Connector Assembly |
| 2:00 | " |
| 2:15 | " |
| 4:00 | End of Day |

**Day Four**

| | |
|---|---|
| 8:00 | Inspection |
| 9:30 | *Break* |
| 10:30 | Testing |
| 11:30 | Lunch |
| 12:30 | Splicing |
| 1:30 | " |
| 2:30 | Connector Assembly |
| 4:00 | End of Day |

**Day Five**

| | |
|---|---|
| 8:00 | Written Test |
| 9:30 | Break |
| 9:45 | Inspection Test |
| 11:30 | Lunch |
| 12:30 | Finish Connectors |
| 2:00 | Brief Students |
| 3:15 | End of Day |

# GENERAL SAFETY REQUIREMENTS

1. All students should become familiar with applicable MSDS for chemicals used in this course (IPA, Methelyne Chloride, and Tra-Con Epoxy).

2. Safety glasses and latex gloves shall be worn at all times during fabrication.

3. Slivers of bare fiber shall be disposed of accordingly.
   Use tape or fiber disposal container for disposing of fibers.

4. Processing with chemical stripper and epoxy shall be performed under a fume hood.

5. Students should keep their desk in a neat and orderly manner, by removing any excess debris, to prevent any damage to fiber assemblies.

6. No smoking in the building.

7. No drinking or eating allowed in the classroom.

8. Be familiar with emergency exits, first aid box, fire extinguisher, and eye wash station.

9. Before operating the equipment, be familiar with emergency power off button, equipment manual and operating procedures.

10. Static dissipative lab coats should be worn at all times.

# Chapter 1. Fiber Optic Overview

## History

The use of light for communication goes back to ancient times. The Greeks and Romans would light a series of signal fires on mountaintops to announce the approach of an army. Sunlight and mirrors were used to send messages over many miles such as across the English Channel. For years navy signalmen have used short and long flashes of light to communicate between ships.

The principles of transmitting light by total internal reflection were put forth in 1621. However, it wasn't until 1854 that the Englishman, John Tyndall while observing water spewing horizontally out off a rain barrel in the bright sun light, noted that the light seemed to be swept along with the water as it arced to the ground, rather than emerging from it in a straight line. He reproduced this phenomenon in his laboratory, and began to experiment with light transmission through total internal reflection. This was the basis of all fiber optic development.

One of the first practical uses of fiber optics was in the 1950's when Kapany bundled glass fibers together into a coherent arrangement to make the first fiberscope. This was used to view internal body organs. The fiberscope has found its way into many industrial and aerospace uses.

Optical fiber was not considered for use in communication because of its high attenuation until 1970 when Keck and Mauer of Corning Glass developed a stepped index fiber with a loss of no more than 20 dB per kilometer. Today, new combinations of core and cladding material have provided fiber with a loss far below Keck's "20 dB" fiber.

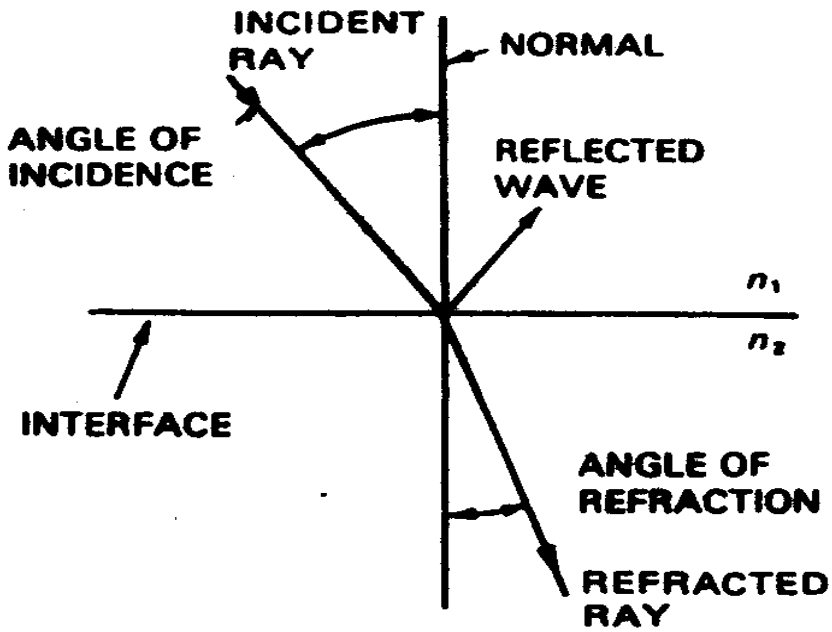
## Theory

The entire Electro-magnetic spectrum spans from a wavelength of 100 km at 3 kHz frequency (audio) to a wavelength of $10^{-4}$ nm at $10^{10}$ Hz frequency (gamma rays). The wavelength is defined as: speed of light in a vacuum/ frequency, or

$$l = \frac{c}{f} \quad where \quad c = 3.0 \times 10^{8} \ m/s$$

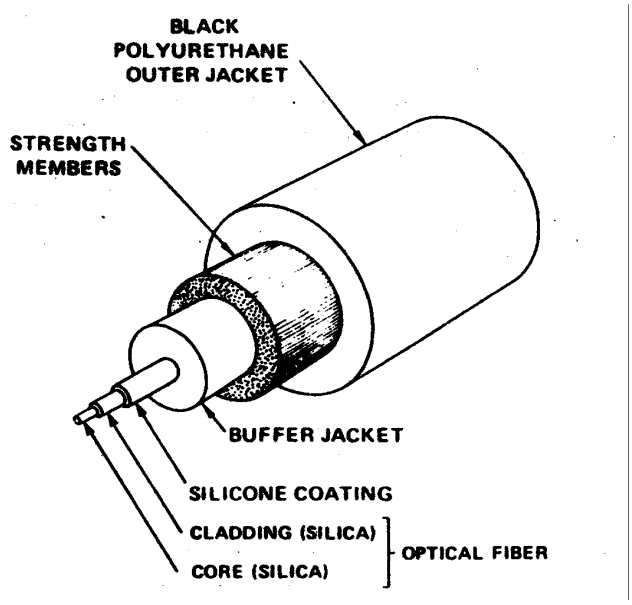
The actual visible range of the Electro-magnetic spectrum is between violet, at a wavelength of 455 nm and red, at a wavelength of 750 nm. You may still see light at 820 nm but very faintly. It is important to note that even if you do not see light in a given spectrum, you are not protected from losing your sight when looking into a laser or from looking at a reflection from a laser. In other words, always use eye protection, especially when a non-visible source is being used.

Communications are conducted at 850 nm, 1300 nm, and 1550 nm. None of which are visible. These wavelengths in which most communication applications occur in industry are known as "windows". These are the places in which light is transmitted in a fiber at low loss (see section on attenuation) or without serious compromise of the bandwidth (see section on dispersion). The bandwidth of the system defines how quickly information can be transmitted.




The index of refraction is actually the optical density of a material. It is the ratio of the velocity of light in free space (i.e. a vacuum) to the velocity of light through the transparent material. It is the quantity that measures how much light will slow down when travelling through an optically transparent material when compared to air which has an index of one, n = 1. The larger the index of refraction is, the slower light will travel through the material. The index of refraction depends on the wavelength of light. Propagating light of one wavelength may slow down more or less than light at another wavelength in the same material. Glass has an index of refraction of about 1.5.

$$\mathbf{n} = \frac{\textbf{speed of light in a vacuum}}{\textbf{speed of light in the material}} = \frac{\mathbf{c}}{\mathbf{v}}$$




## FIBER OPTIC CABLE STRUCTURE:

Fiber is made of two types of material differing only by a slight amount. The inside silica material is called the "core" and the surrounding silica material is called the "cladding". To make one different from the other, materials called "dopants" are diffused into the silica to change the index of refraction or optical density. The fact that the core index is doped such that it is only slightly larger than the index of the cladding is the mechanism that keeps light confined mainly to the core. Typically if the cladding index of refraction is 1.45 than the core index of refraction is around 1.46. For further reference purposes $n_1$ will be used to refer to the core index and $n_2$ will be used to refer to the cladding index. An outer coating protects the glass fiber (core and cladding). This coating is usually a polyamide or acrylate polymer. In spaceflight cable a loose tube buffer made of polyester elastomer surrounds the coated fiber. The strength members surrounding the buffer are made of kevlar in commercial cable but must be a Teflon/fiberglass material for spaceflight cable. Kevlar tends to hold moisture and can cause the actual silica structure to alter if exposed to water for a long enough period of time. The outside jacketing is usually made of a Tefzel material.

## BANDWIDTH:

Things that effect the rate of transmission: fiber dispersion, sources, detectors. Graded index fiber has a larger bandwidth due to the fact that it limits dispersion and therefore preserves the integrity of a pulse over a longer distance than step index fiber does. The bandwidth-length product is a number that tells what the bandwidth of the fiber is for the given length. For example if a fiber is rated at 30 MHz-km, it mean that communications at a bandwidth of 30 MHz can occur without decay of the signal from dispersion causing signal errors over a distance of 1 km. It also means that if the transmission requires 120 MHz that it can be successfully achieved for distances of 250 m.

## Dispersion

Dispersion is a broadening of a pulse as it propagates down the fiber and is due to several properties. The causes of dispersion depend on the type of application: single mode or multi mode

**Single mode fiber**: Material dispersion being in relation to the spectral width of the source and that the material will respond differently to different wavelengths of light due to the relationships between wavelength of the transmitted light and the index of refraction as a function of that light. Waveguide dispersion effects single mode applications as well. Any source will have a line width associated with it or a range of frequencies of light it produces. The pulse transmitted will spread as a result of the pulse being created by several frequencies of light. Therefore even if the index of refraction were completely the same for all frequencies, they would still travel at a slightly different velocity.

<u>Material Dispersion Limited Performance (bandwidth-length products)</u>:
Graded Index at 850 nm wavelength operation,

| | |
|---|---|
| Driven by LED with 35 nm spectral width | 150 MHz-km |
| Driven by Laser with 2 nm spectral width | 2500 MHz-km |

**Multimode fiber**: Modal dispersion being in relation to how difference modes or paths of light travel at different speeds as they propagate through the waveguide. Having a graded index in a fiber greatly reduces this dispersion effect by causing modes that take a longer path to travel faster along the edges than they would if they had traveled up the center or by the shortest path possible. In a step index multimode fiber modal dispersion can result in a delay time between modes of 50 ns/km while the delay in a graded index fiber would be .5 ns/km.

Modal dispersion limit performance (bandwidth-length products):
Step-index fiber 30 MHz-km
Graded index fiber: Research Grade 1000 MHz-km
Graded index fiber: Production Grade 400 MHz-km

## Attenuation

The amount of loss incurred as light propagates through a fiber is known as fiber attenuation. The attenuation depends on materials used as dopants and wavelength of operation.

$$\textit{Attenuation} = -10 * \log_{10}\left(\frac{I_{out}}{I_{in}}\right) \quad \textbf{(dB/km)}$$

A typical value of attenuation in step index multimode fiber is 4 dB/km at 850 nm wavelength operation with a bandwidth of 100 Hz-km, and .15 dB/km for single mode at 1500 nm wavelength operation with a bandwidth of 88 GHz-km. The large-core plastic fibers (approximate core sizes are around 200 microns) have 1000 dB/km attenuation. An excessive bend radius will increase attenuation.

## NUMERIC APERTURE:

To maintain the "weakly guiding" waveguide condition, the difference between the index in the core and the cladding must be much less than one or

$$\Delta << 1 \quad \textbf{Where} \quad \Delta = \frac{(n_{core} - n_{clad})}{n_{core}}$$

The weakly guiding condition is necessary for quantifying the light that propagates down the fiber. The numeric aperture, NA of a fiber is basically the "cone of acceptance" of the fiber in that all light entering the waveguide within the cone area defined by the NA will be guided down the fiber or will successfully propagate.

$$NA = \sqrt{\left(n_{core}^2 - n_{clad}^2\right)} \quad \text{Which is approximated by} \quad NA = n_{core}\sqrt{(2\Delta)}$$

Where Δ is the normalized difference in index of refraction between the core and the cladding:

$$\Delta = \frac{\left(n_{core} - n_{clad}\right)}{n_{core}}$$

## TYPES OF FIBER OPTICS:

**Step index multimode**: 100/140 micron, 200/230 micron (plastic)
**Graded index multimode** 100/140, 62.5/125, 50/125

### MODES AND V NUMBER

A mode is a possible path that light can take when propagating down a fiber optic. The geometry of the fiber and the wavelength of light propagating determine how many modes will propagate. Fiber that allows light to follow one single propagation path is called "single-mode" fiber. The V number is used to roughly estimate how many modes will propagate given fiber geometry and the wavelength of light. To determine how many modes will propagate in a fiber the V number is calculated by

$$V = \frac{p\ D(NA)}{l}$$

Where λ is wavelength, D is the diameter, and NA is the numeric aperture.

To achieve single mode operation or a single path of propagating light, the fiber system must have a V number less than 2.405. Therefore, the diameter will have the following constraints:

$$\boldsymbol{D} < \frac{\left(\mathbf{2.405}\ l\right)}{\left(p\ \boldsymbol{NA}\right)}$$

For operations at a wavelength of 1300 nm and an NA of .1 the diameter would need to be less than 5 microns. As the operation wavelength increases the diameter size will increase provided the NA stays constant and as the NA increases provided the wavelength remains constant the diameter will need to be smaller to maintain single mode operations.

**Wavelength vs. Core Size**: Typical NA can be in the range .1 to .15 for a steeped index single-mode fiber

To maintain single mode

NA = 0.2, Diameter must be no more than 3.8 times the wavelength
NA = 0.15, Diameter must be no more than 5 times the wavelength
NA = 0.1, Diameter must be no more than 7.6 times the wavelength

Therefore at 8 or 9-micron diameters the fiber can operate at 1300 nm for a NA of .15.

**Core Size, NA and Δ:** Since NA is related to how easy it is to couple light in to a fiber, it makes sense that large a NA fiber is sought. However, the core size must be of a manageable enough size. By adjusting the index of refraction in the core and in the cladding the NA is altered, but if you are going to use wavelengths around 1300 or 1550 nm this will adjust the core size as well. This is not the case with multimode fibers. In multimode there is no limit on the core size since the amount of modes travelling does not matter. However, the larger the Δ, the larger the modal dispersion will be due the time delay caused between the highest and lowest order modes. For single mode and multimode, $\Delta << 1$.

## TYPES OF LOSSES:

Several types of losses will lead to a diminished signal at the output end of the fiber. Some of these types will be unavoidable once given a connector and fiber combination due to tolerances, other types may be due to something actually erroneous in a system.

### 1) Alignment Losses:

When the center axes of two fiber cores are not aligned a loss due to **lateral displacement** results. If a 10 % displacement results in .5 dB of loss than for a fiber of 10 microns this would require each fiber end to only contribute to .5 microns of misalignment. In a fiber of 100-micron core diameter this would translate to a tolerance of +/- 5 microns per fiber end. This explains why in smaller diameter fiber or single mode fiber the tolerances are not easily maintained in harsh environments. It also implies that tolerances of connectors should be checked such that these misalignments are minimized. When the end faces of two fiber surfaces are not completely parallel to one another upon mating, they are said to be **angularly misaligned**. Proper fiber end polishing should ensure that the fiber end face is indeed perpendicular to the fiber center axis and therefore, parallel to the mated fiber endface.

**2) Microbend losses**:

are caused by either internal imperfections in the fiber surfaces or external forces outside of the fiber. Whichever the influence light deviates from the normal propagation path by escaping through the cladding. The result of light not staying confined to the core is a loss in poweroutput. When choosing a fiber optic connector it is important to minimize the amount of microbend losses incurred as a result of the design. For example, the crimped portion of the connector shall not inhibit the transmission signal.

**3) Macrobend Attenuation:**

Is caused by large bends in the fiber that allow light to escape through the cladding. **Bend Radius**: The bend radius should be no less than five times the cable diameter for unstressed conditions and ten times the cable diameter for stressed conditions. Besides increasing attenuation, sharp bends in the cable will also decrease the fiber tensile strength. Under normal conditions the tensile strength of fiber is greater than that of a steel fiber. A copper wire would have to be twice the diameter of a fiber to match it in tensile strength.

**4) Cracks in the Fiber**:

If there is a crack along a transmission fiber the output power will be well below acceptable levels. It is rare that a crack is present in a system that is functioning adequately. It is also the case that fiber cracks are not usually visible by magnified termination end inspections unless they are close to the terminated surface end.

**5) Air Gap**:

Air gaps or end separations are a source of loss in connector systems. Air gaps are present in flat polish systems where the light leaving the transmitter fiber experiences a change in index of refraction upon entering the gap and then again upon entering the receiver fiber. The result is back reflections from (or Fresnel's reflections) from the end face of the transmitter fiber and the end face entrance of the receiver fiber. One way to avoid the air gap losses of some connector designs is to use a physical contact polish (PC) in which the end of the fiber is terminated in a curved fashion as opposed to a flat.

**6) Fiber Mismatch**:
When two fibers are joined such that light from one core can couple into the core of the other, properties such as fiber geometry or numeric aperture must be taken into account. If the numerical aperture of the second fiber is smaller than that of the first a NA-mismatch loss is incurred. The calculation for NA-mismatch loss is

$$Loss_{NA\ Mismatch} = 10 * \log_{10}\left(\frac{NA_{rec}}{NA_{trans}}\right)^2$$

Where "rec" stands for receiving fiber and "trans" stands for transmitting fiber. Losses that occur as a result of a mismatch in fiber core diameter can be calculated by

$$Loss_{Core\ Diameter\ Mismatch} = 10 * \log_{10}\left(\frac{Diam_{rec}}{Diam_{trans}}\right)^2$$

Other types of fiber geometry mismatch losses are not as easily quantified without insertion loss testing; cladding diameter mismatch, elliptically or ovality losses (in which both cores have elliptical geometry and are misaligned), and concentricity losses in which the core is not placed directly in the center of the cladding.

**7) End face obstructions**:
Any dirt or damage on the end face of a fiber will inhibit the coupled signal. Magnified inspection of the fiber endface should ensure that the end face is free from imperfections and debris.

# Chapter 2. Course Overview

This course will introduce the student to processes required to terminate fiber optic cables. The first process will be preparing the cable for the termination. This will include techniques for removal of the jacket, buffer and coating. Second process will be assembling the connector to the cable. This process will be repeated on a variety of connections such as SMA, ST, SC, FC, and Bendix Pin/Socket Termini. The third process will be polishing and inspection. This process will introduce the student to two polishing techniques, hand and automatic. The final process will be testing of the completed assembly. All processes will be in accordance with NASA-STD-8739.5 .

## Fiber Cable

The type of fiber used in this training class is manufactured to GSFC specification S-311-339/1. This optical fiber cable contains a radiation-hardened glass fiber. Radiation hardened glass fiber must be relatively free of impurities because impurities can cause the glass to darken when it is exposed to radiation, thus causing optical performance degradation. The glass fiber is produced by Corning, Inc., and is presently one of few fibers to have passed GSFC tests for radiation hardness.

The Corning glass fiber is manufactured with a protective coating made of acrylate that surrounds the fiber. The acrylate coating (or fiber coating as it is referred to later) is chemically stripped in this training class using Methylene Chloride to prevent glass fiber nicks, which can occur during mechanical stripping processes. Nicks in the small and fragile glass fiber are difficult to detect and could result in a latent optical fiber defect. Another type of protective coating material is Polyimide. This type of coating is also chemically stripped but with boiling sulfuric acid. We will not be demonstrating this particular method in class.

The optical fiber cable was subjected to a sustained temperature exposure test. The test results indicated that there were no deleterious effects to any of the optical fiber cable components when exposed to the temperatures and duration's required in this training class.

Stripping dimensions for the optical fiber cable in this class are slightly different from the suggested terminus stripping dimensions contained in the manufacture's assembly instructions. The stripping dimensions are different mainly because the OC-1008 optical fiber cable is different from the cable shown in the manufacturer's instructions. The OC-1008 cable has an extra component, a loose tube inner jacket. In addition, the glass fiber length dimension has been controlled and specified to reduce the chance of fiber breakage when the cable is inserted into the temperature-controlled ovens.

## Epoxy

The epoxy used in class is TRA_BOND F253 and is a high-performance resin system designed by the manufacturer for optical fiber bonding with consideration given to pistoning effects.

Characteristics of the epoxy

- Short cure time (10 minutes at +125 °C), which reduces assembly time
- Wide operating temperature range (-60 °C to +175 °C), which extends beyond the optical fiber cable temperature capabilities and thus does not restrict the useful temperature range of the cable
- Substantial pot life (2 hours), which facilitates the assembly process; a BIPAX® container, which eliminates problems associated with mixing and measuring resins and hardeners
- Color-keyed cure feature, which indicates proper mixing; a relatively low viscosity, which aids in the application process
- Relatively high (>85 °C) glass transition temperature ($T_g$), which is above the maximum continuous operating temperature of the optical fiber cable
- Materials outgassing properties that meet NASA requirements.

Bubbles introduced into the F253 epoxy during the mixing process will be removed by a centrifuge.

## Equipment and Tooling

**Termination Equipment**

- Curing Oven, OFCI # 08-0028-OFC, 24 port for ST/FC/SMA/SC with adapters
- CT-9000 Hand Held Polishing Machine, GCT Technologies
- Noyes Testing Kit, with 850 nm Power Meter, 850 nm Light Source, MLP4-2.
- Buehler Fiber Termination Inspection Fibrskope Zoom 200-400X, Buehler #0801-0504.
- Buehler Fibrskope Stand, Buehler #0822-0110
- Buehler Fibrskope AC Power Adapter, Buehler # 0822-0120.
- Fusion Splicer
- OTDR

## Termination Tools

For Fabricating Terminations with all Types of Connectors on the OC-1008 Fiber Optic Cable (Spectran):

- No-Nik for stripping green loose tube buffer, NN023 (Clauss)
- Purple jacketing stripper, 45-164 (Ideal)
- Diamond Angled Scribe, 05-00010 (3M)
- Carbide Wedge Scribe, 59905-600 (Lunzer)
- Diamond Wedge Scribe, 58805-600, (Lunzer)
- Scissors, 925C, (Clauss)
- Strength Member Shears, 702SC023, (Tec Cut)
- Fiber Trash Can, FS200 (Clauss)
- Roller & Pad, MXR-1001 (Tracon)
- Epoxy Bi Pak, BAF 253 (Tracon) low outgassing for deep space applications.
- Syringe & Tip, 86710-0023, (Molex)
- Lint Free Kim Wipes
- Reservoir Bottle with alcohol
- Piano Wire
- Laser Glasses
- Methylene Chloride
- Acetone
- Polishing Pad
- Handpolishing Film: 15, 5, 3, 1, & .3 micron grits

## ST Connector Parts and Tools, AT&T

- Connector: M86522/12, /13, /14,
    1. AT&T Part Number 105-777-338 multimode, stainless steel, 100/140 micron fiber optic ST connector.
    2. AT&T Part Number 105-777-288, threaded bushing adapter

- Crimp Tool: AT&T Crimper 11-002-000 (LDC)
- ST Handpolishing Plastic Puck, 6891 (3M)
- ST/FC Handpolishing Metal Puck, 08-00082 (3M)
- Buehler Fibrskope ST Adapter, 0801-0247

## SMA Connector Parts and Tools, AMP 905

- Connector: M83522/2-04, /3-02
    1. AMP Part Number 504019-2, multimode, stainless steel, 100/140 micron fiber optic SMA connector, 905.
    2. AMP Part Number 504020-2, stainless steel SMA coupling, 905.
    3. 3M Part Number 6197, ST/SMA Coupling Adapter, 100/140 micron.
- Crimp Tool: AMP SMA Crimper, PA 1331, (Paladin)
- SMA Handpolishing Puck, 228025-1, (AMP)
- Buehler Fibrskope SMA Adapter, 0801-0203.

## FC Connector, 3M

- Connector:
    1. 3M Part Number 6206, multimode, 100/140 micron fiber optic FC connector
    2. AMP Part Number 501506-1, FC Coupling.
    3. AMP Part Number 502782-1, FC/ST Hybrid Plastic Coupling
- Crimp Tool: Paladin FC Crimper, PA 1330,
- FC Physical Contact Handpolishing Puck, 501861-1 (AMP)
- ST/FC Handpolishing Metal Puck, 08-00082 (3M)
- SC/FC Handpolishing Plastic Puck, 8892 (3M)
- Buehler Fibrskope ST Adapter, 0801-0247

## SC Connector AMP

- Connector:
    1. AMP Part Number 502883-2, multimode 100/140 micron fiber optic connector.
    2. AMP Part Number 502780-1, ST/SC Plastic Hybrid Adapter Coupling
- SC/FC Plastic Handpolishing Puck, 8892 (3M)
- Buehler Fibrskope SC Adapter, 0801-0248

## MIL-T-29504 Pin/Socket Termini, Bendix

- Termini:
    3. M29504/4-4044, Bendix Part Number CF-198036, Pin fiber optic termini
    4. M29504/5-4050, Bendix Part Number CF-198035, Socket fiber optic termini.
- Bendix Pin/Socket Hand Polishing Puck, 11-012123.
- Buehler Fibrskope Pin/Socket Adapter, 0801-0244.

# Chapter 3. Preparing the Cable

The optical fiber outer jacket, strength member, inner jacket and fiber coating components are prepared for the bonding process by stripping and cleaning in this section.

The outer jacket stripper, ceramic scissors, and inner jacket stripper tools used to cut and trim the cable can become dirty, built-up with material, dull, or damaged. Cleans tools frequently to prevent material build-up. Replace dull blades or tools when they no longer cut cable materials cleanly or easily, or when they show signs of damage. Always perform a quick visual inspection on any tool used in this section before use. Use the appropriate tool for a given task.

## Outer Jacket

Cut the required length of cable off the spool. In order for the finished length to be correct an additional 6 inches should be added to the required length to accommodate a bend that must be put in the end of the cable to hold the optical fiber in place during the first termination process. The optical fiber fits freely in a loose tube (the inner jacket) and can be pulled out of the cable readily, particularly when cable lengths are short. If the fiber is pulled slightly during the termination process, the stripped cable lengths will be out of tolerance. To prevent the fiber from being pulled out of the inner jacket, a 180 degree bend must be put into the cable approximately 3 inches from a cut end. Once the bend is made it is held in place with a tie wrap.

The outer jacket of the cable is purple in color. This outer jacket will be removed with the following procedure:

1. Using a felt tip pin, make a mark on the outer jacket in accordance with the strip dimensions for the termination being performed.

2. Using the outer jacket stripper (Ideal No. 45-164), position the cable between the tools jaws until the tool's blade is on the measured mark.

3. Allow the tool to close gently (**DO NOT FORCE**) around the outer jacket

4. Rotate the tool 360 degrees around the cable. **DO NOT ROTATE THE CABLE**

5. Open the tool and remove the cable without stripping away the outer jacket.

6. Pinch the outer jacket with your fingertips, on opposite sides of the scored area, using both hands, as close as possible to the score.

7. Bend the cable slightly at the scored area to break the outer jacket free.

8. Remove the cut portion of the outer jacket.

   **Note: Do not bend the optical fiber cable sharply while removing the outer jacket as damage to the glass fiber could occur.**

9. Using the ceramic scissors, trim the strength members' flush to the outer jacket. This will insure a uniform length necessary for achieving a proper fit on the connector.

10. Using a felt tip pin, make a mark on the outer jacket in accordance with the length of the strength members for the termination being performed.

11. Using the outer jacket stripper (Ideal No. 45-164), position the cable between the tools jaw until the tool's blade is on the measured mark.

12. Allow the tool to close gently (**DO NOT FORCE**) around the outer jacket

13. Rotate the tool 360 degrees around the cable. **DO NOT ROTATE THE CABLE**

14. Open the tool and remove the cable without stripping away the outer jacket.

15. Pinch the outer jacket with your fingertips, on opposite sides of the scored area, using both hands, as close as possible to the score.

16. Bend the cable slightly at the scored area to break the outer jacket free.

17. Remove the cut portion of the outer jacket.

18. Straighten and comb out the braid of the exposed strength member by hand.

19. Slide a pre-cut scrap piece of 1/8" diameter heat shrink tubing, down over the inner jacket so that **all** of the strength member filaments are on the **outside** of the tubing. Continue sliding the tube down, folding back the strength member filaments against the outer jacket to approximately 1/10-inch past cut edge. This keeps the strength member filaments pulled tightly back out of the way for the next operation.

## Inner Jacket

Using the inner jacket stripper (Clauss No-Nik® 0.023) remove the inner jacket with the following procedure:

Open the stripping tool and insert the cable's inner jacket between the triangular portion of the tool's jaws until the first triangular piece contacts the cable's folded strength member.
Note: The arrow on the tool's jaw will not be visible to the operator when holding the tool correctly in the right hand and the cable in the left.

To cut the inner jacket apply a light, slow, steady pressure to the tool handle until the tool stop is felt and a slight click is detected. This click is produced by the tool itself. Do not over squeeze the handle as damage to the tool and cable can result.

## Do not rotate the tool or cable.

Open the inner jacket stripper tool without stripping away the inner jacket.

Using both hands, pinch the inner jacket with your fingertips as close to the cut as possible.

Giving a quick pull in opposite directions will separate the inner jacket at the scored area.

If the inner jacket does not separate at the scored or cut area and tends to stretch, the stripper tool blades may be dull or damaged.

Note: Do not bend the optical fiber cable sharply while removing the inner jacket as damage to the glass fiber, such as cracking , could occur.

Inspect the fiber coating for any nicks or cuts. Because of the extremely small dimensions between the inner jacket and the fiber coating, the inner jacket stripper tool compresses the fiber coating slightly during the stripping operation. This slight compression should not be confused with a fiber coating nick. The compression in the fiber coating relaxes back to the original fiber coating diameter after a short period of time.

## Fiber Coating

1. Use the template and determine the length of stripped fiber required for the type of termination being performed. Place a mark on the fiber coating with a felt tip pen.

2. The chemical strip **must be shaken thoroughly** before each and every use to ensure proper chemical action and stripping times. Shake the chemical strip in a securely capped container for about 1 minute prior to use.

3. Insert the fiber into the chemical stripper (a small beaker of methylene chloride) up to the mark. Make sure not to insert past the mark or insert the strength member filaments into the chemical stripper.

4. Hold the fiber in the stripper for a minimum of two minutes.

5. Remove the fiber after the appropriate time has elapsed and proceed immediately to the next step so that the softened fiber coating does not dry out which will make it difficult to remove.

6. Hold the fiber coating firmly with one hand and with the other holding a shop wipe moistened with cleaning solvent, grasp the softened end and pull gently in opposite directions.

7. If the fiber coating does not come completely off easily, place back in stripper for an additional one-minute. Note: The strength of the chemical strip will vary over time, particularly after it has been used for many stripping operations and after it has been exposed frequently to air. If the coating is not easily and completely removed after two immersions in the chemical strip, the chemical strip is weak and must be discarded.

8. Using Shop wipes and IPA solvent, remove all residue stripper from the fiber.

   **Note: Handle carefully so as to not damage the exposed fiber. Use a wiping technique which cleans the length of the glass fiber without bending the glass.**

9. Inspect with a microscope at 50x minimum to insure all fiber coating has been removed and that there are no nicks on the outside of the fiber and no wicking of the stripping solution has occurred.

   **Note: Exercise care when handling the cable from this point on in the assembly procedure as the glass fiber is susceptible to damage without the fiber coating to protect it.**

10. Slide a pre-cut piece of heat shrinkable tubing over the cable's stripped strength members. This step ensures that the strength members are puled tightly out of the way preventing strength members from becoming saturated with cleaning solvent during the fiber coating rinse step.

11. Rinse the cable's fiber coating using a beaker of cleaning solvent. Immerse approximately 0.25 inch of the fiber coating into the cleaning solvent for 1 minute. Be careful not to let the inner jacket touch the solvent as solvent may wick up the cable and not dry out in time for the bonding operation.

12. Remove the coating from the solvent and wipe with a dry shop wipe. This step flushes the fiber coating of chemical strip residue which may be present at the very end of the cable's fiber coating after stripping.

13. Remove the scrap piece of heat shrinkable tubing from the stripped cable end.

14. Using a temperature controlled oven bake out the fiber coating for 15 minutes at 85 º C. Insert at least 1 inch of the cable's fiber coating into a middle oven cell. *Be careful not to break off the glass fiber by contacting the sides or bottom of the oven.* This step ensures that any chemical strip residue in the very end of the fiber coating is baked out thus preventing mixing of the chemical strip and the epoxy.

## In Process Verification: (3N701 (4))

Inspect the stripped cable end for defects. Use the 10X hand-held magnifier or the 50X table microscope, as specified below, to detect any nicks, cuts, cracks, residual fiber coating, or wet chemical strip under the fiber coating. Verify that 100% of the exposed strength member, fiber coating, and the glass fiber are free of defects, except as allowed below, that may have inadvertently occurred during stripping operations. Acceptance criteria shall be as follows:

a. Correct cable stripping dimensions. (10X).
b. No nicks or cuts in the fiber coating or glass fiber. (50X).
c. No nicks or cuts in the strength member filaments. (10X).
d. No cracks in the glass fiber. (50X).
e. No evidence of wet chemical strip under the fiber coating. (50X).
f. No residual fiber coating or debris on the glass fiber, except for a 0.030 inch section on the glass fiber adjacent to the fiber coating. (50X).

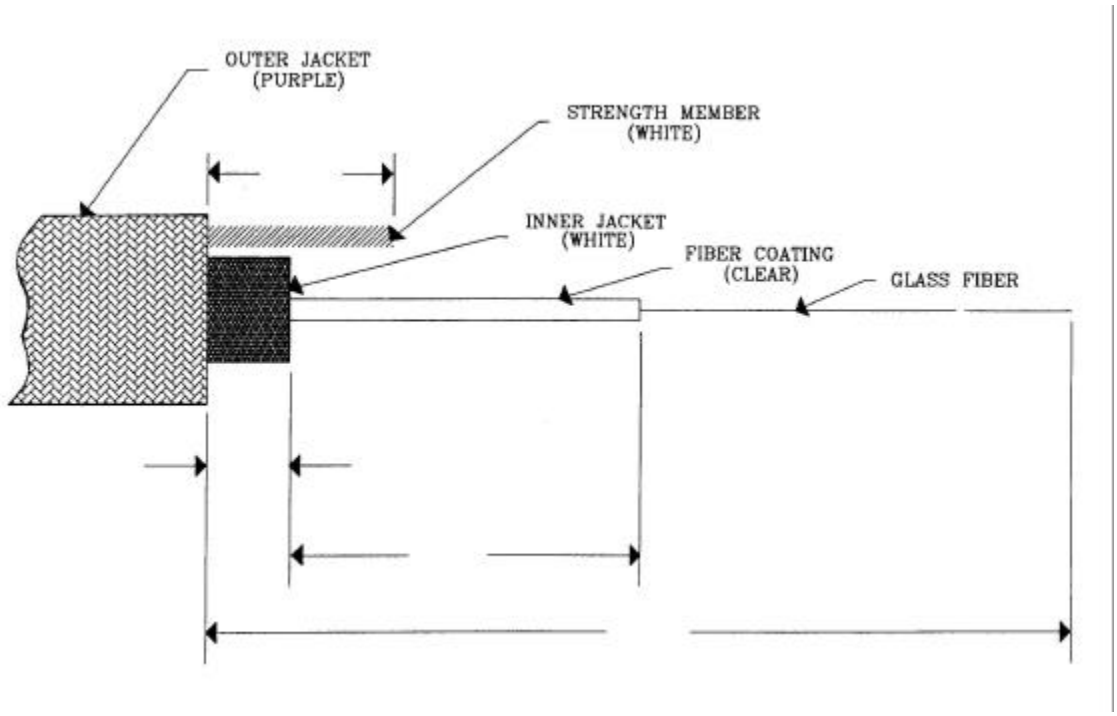
Per NASA –STD-8739.5 . As a minimum, prior to assembly, prepared fiber cable optic cables shall be subjected to documented in-process peer verification for the following:

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.

## Assignment:

Cut a piece of cable 8 to 10 inches in length. The center fiber is lose, make sure it is properly in place. Bend one end over about 1 to 2 inches down and clamp with a cable tie. This will insure the fiber will not slip within the buffer. Using the previous procedure strip fiber to the following dimensions and inspect.

Outer Jacket 1.5 ± 0.1 inch
Strength Members 0.25±0.01 inch




When the student successfully strips the piece, he/she may continue.

# Chapter 4. Cleaning

Cleaning in general is probably the single most important step in high reliability work. Contaminants (most often oil or dirt) will reduce the bond strength of epoxy. Reduction of the epoxy's bond strength will adversely affect the integrity of the terminus to cable mechanical strain relief and the glass fiber bond reliability which could result in pistoning. All components that are used in the terminating of optical fibers must be cleaned with an approved solvent prior to use. The following shall be performed:

1. All beakers shall be wiped down with clean solvent prior to use.

2. Using a wipe moistened with cleaning solvent from the solvent dispenser wipe all tweezer surfaces. This eliminates any possible contamination due to dirt or oil. Place the tweezers on a large, clean dry wipe until needed later.

3. Fill two labeled beakers with solvent as follows:
   -100 ml to beaker #1 and #2
   (The labels help to prevent cross contamination)

4. Place epoxy dispensers (syringes) in beaker #1.

5. Place in ultrasonic cleaner and operate for five minutes.

6. Set epoxy dispensers aside on clean shop wipe to dry until used.

7. When instructed to open the package of the terminus, place all parts in beaker #2. <u>IMPORTANT</u>: Only one terminus package of parts is cleaned at a time to avoid mixing parts and lot numbers from different lots.

8. Place in ultrasonic cleaner and operate for five minutes.

9. Set all terminus parts aside on clean shop wipe to dry until used.

10. Cut and pre-clean several pieces of heat shrinkable tubing. Cut several pieces of heat shrinkable tubing to 1.0 inch. Place tubing in ultrasonic cleaner for 5 minutes. This step ensures that the tubing does not contaminate the cleaned optical fiber assembly.

**IMPORTANT**: Ensure that all cleaned items are <u>completely dry</u> both inside and out by checking them visually <u>before assembly</u>. If there is any doubt whether an item is dry, sniff the item as the cleaning solvent can also be detected by smell (do not touch the item to the nose).

# Chapter 5. Epoxy Mixing

The epoxy used in class is TRA_BOND F253.

Tools Required:

Roller & Pad, MXR-1001 (Tracon)
Epoxy Bi Pak, BAF-253
Pre-Cleaned Syringe & Tip

1. Lay the pad out on top of the desk (red side up).

2. Record the following information in the shop log:
   - Epoxy Part No.
   - Epoxy Lot No.
   - Manufacturer's Expiration Date
   - Date of Entry
   - Operator's Name

3. Open the epoxy package

4. Remove the plastic clip from the middle and discard the clip. A plastic clip separates the resin from the hardener.

5. Squeeze the package to start the mixing.

6. Place the package on the pad and using the roller, roll the package 50 times (forcing resin into binder).

7. Turn the package over and using the roller again, roll the package 50 times (forcing binder into resin).

8. By this time the epoxy should be a uniform light green color.

9. Record the time and operators initials on the epoxy-mixing log.

10. Set the timer for 1 hour and 15 minutes. This is the pot life for the epoxy.

11. Place the unopened epoxy package in the centrifuge and turn on for 3 minutes. This will remove any air bubbles from the epoxy.

    **Caution: Make sure centrifuge is balanced before use.**

12. Cut the package open and pour the epoxy into a pre-cleaned syringe.

13. Insert the (epoxy) dispenser piston and plunger assembly into the barrel reservoir containing the mixed epoxy.

14. Push on the dispenser plunger so that the piston completely compresses the epoxy and expels all trapped air in the barrel reservoir. Continue to push the plunger until all trapped air is expelled, including any bubbles that may have been produced, so that only epoxy is discharged from the tip.

15. The epoxy is now ready for use. Place the assembled dispenser filled with epoxy on a clean, dry wipe. The color will change to dark green as it stands.

# Chapter 6. Terminating Fiber with Connectors

## ST Connector

With these ST connectors and the fiber the buffer will not fit into the termini.

1. Clean the entire stripped cable end (outer jacket, strength member, inner jacket, fiber coating, and glass fiber. Allow 5 minutes minimum drying time before the next step.

2. Place pre-cleaned connector boot and crimp sleeve on fiber.

3. Cut purple jacket 29 mm (1.14 in.) from end of fiber.

4. Trim strength members flush with cut end.

5. Cut purple jacket back another 9 mm (.36 in) and remove.

6. Cut buffer as close as possible to the purple jacket 3mm (.12 in).

7. Strip length of coating is 23mm (.92 in) from purple jacket

8. Insert needle tip into back side of connector body until it butts up against the ferrule and squeeze enough in until a small bead appears at the ferrule tip. The small bead of epoxy indicates that epoxy has been completely applied inside the critical ferrule area.

9. Very slowly remove the syringe tip while ensuring that the rear barrel is kept full of epoxy as the tip is completely withdrawn.

10. Blot excess epoxy from the terminus ferrule face. Using a dry wipe do not smear the epoxy by wiping; blot the epoxy away.

11. Position the connector filled with epoxy over the fiber being careful not to break the fiber. Carefully rotate and gently push the terminus onto the cable end until the glass fiber emerges from the end the of the connector. Hold the connector and cable down, so that the epoxy does not spill out of the connector when the fiber is inserted. Continue to rotate the connector until the fiber coating stops inside the connector. Rotating the connector improves the application of epoxy onto the glass fiber which also improves bonding within the ferule channel.

NOTE: Be careful as the glass fiber can easily be broken during this step. Do not apply any force to the fiber. The fiber should easily slide into and thru the hole of the connector.

12. Put a thin coat of epoxy on the outside threads of the rear connector body.

13. Slide the crimp sleeve up while still holding the connector. Make sure strength members are evenly flared around the base of the connector back body. The strength members should be distributed so that the underlying terminus rear barrel and inner jacket are not visible.

14. While holding the top of the connector on to the fiber crimp using the C setting on the crimper. (AT&T Crimper for their ST connector)(*Small setting on SMA crimper if using AMP connectors*).

15. Place into curing heater for 20 minutes at 130 - 150 degrees C.

16. Record the time and date of the start of the epoxy's cure along with the operator's name in the certification log supplement.

**Note: Do not under cure the epoxy. It will do no harm if the connector is left in the oven for longer than 20 minutes.**

17. Once cured the color of the epoxy is red/orange.

18. Record the time and date of the end of the epoxy's cure along with the operator's name in the certification log supplement.

19. Once cured scribe the fiber with a carbide wedge scribe to remove the excess fiber. Place the scribe's tip so that it is resting flat on the face of the terminus ferrule. Hold the scribe at an angle of approximately 30 degrees up from the terminus so that the scribe's chisel edge is close to the ceramic face, but not flush with the face. Let the scribe's chisel edge contact the glass fiber while continuing to hold the scribe in position. Score the glass fiber by gently drawing the scribe's chisel edge lightly, once, across the fiber. **Do not attempt to break off the glass fiber during this step**.

NOTE: This is a very important step in the procedure. If the fiber is inadvertently broken off during this step, it may crack below the required polishing surface (creating a hackle) making the terminus scrap.

20. Cleave the glass fiber. Grasp the glass fiber between the thumb and forefinger and gently pull the fiber straight away from the terminus until the fiber is detached at the scored area. **Do not push the fiber to either side to break it off**.

## Remember to place all broken fiber particles on the tape for safety purposes!

## SMA AMP 905 (commercial/NASA)

With these SMA connectors we are using a different dimension for stripping than suggested by AMP.
This is done so the connector will fit in the curing oven.

1. Clean the entire stripped cable end (outer jacket, strength member, inner jacket, fiber coating, and glass fiber. Allow 5 minutes minimum drying time before the next step.

2. Place connector boot and crimp sleeve on fiber

3. Cut purple jacket 31 mm (1.24 in) from end of fiber.

4. Trim strength members flush with cut end.

5. Cut purple jacket back another9 mm (.36 in) and remove.

6. Cut buffer 3mm ( .12 in) from purple jacket.

7. Strip length of coating is 31mm( 1.24 in) from purple jacket

8. Insert needle tip into back side of connector body until it butts up against the ferrule and squeeze enough in until a small bead appears at the ferrule tip. The small bead of epoxy indicates that epoxy has been completely applied inside the critical ferrule area.

9. Very slowly remove the syringe tip while ensuring that the rear barrel is kept full of epoxy as the tip is completely withdrawn.

10. Blot excess epoxy from the terminus ferrule face. Using a dry wipe do not smear the epoxy by wiping; blot the epoxy away.

11. Position the connector filled with epoxy over the fiber being careful not to break the fiber. Carefully rotate and gently push the terminus onto the cable end until the glass fiber emerges from the end the of the connector. Hold the connector and cable down, so that the epoxy does not spill out of the connector when the fiber is inserted. Continue to rotate the connector until the fiber coating stops inside the connector. Rotating the connector improves the application of epoxy onto the glass fiber which also improves bonding within the ferule channel.

NOTE: Be careful as the glass fiber can easily be broken during this step. Do not apply any force to the fiber. The fiber should easily slide into and through the hole of the connector.

12. Put a thin coat of epoxy on the outside threads of the rear connector body.

13. Slide the crimp sleeve up while still holding the connector. Make sure strength members are evenly flared around the base of the connector back body. The strength members should be distributed so that the underlying terminus rear barrel and inner jacket are not visible.

14. While holding the top of the connector on to the fiber crimp using the first hole (smallest) setting on the crimper. (Paladin 12-0003-PAL)

15. Place into curing heater for 20 minutes at 130 - 150 degrees C.

16. Record the time and date of the start of the epoxy's cure along with the operator's name in the certification log supplement.

**Note: Do not under cure the epoxy. It will do no harm if the connector is left in the oven for longer than 20 minutes.**

17. Once cured the color of the epoxy is red/orange.

18. Record the time and date of the end of the epoxy's cure along with the operator's name in the certification log supplement.

19. Once cured scribe the fiber with a carbide wedge scribe to remove the excess fiber. Place the scribe's tip so that it is resting flat on the face of the terminus ferrule. Hold the scribe at an angle of approximately 30 degrees up from the terminus so that the scribe's chisel edge is close to the ceramic face, but not flush with the face. Let the scribe's chisel edge contact the glass fiber while continuing to hold the scribe in position. Score the glass fiber by gently drawing the scribe's chisel edge lightly, once, across the fiber. **Do not attempt to break off the glass fiber during this step**.

20. NOTE: This is a very important step in the procedure. If the fiber is inadvertently broken off during this step, it may crack below the required polishing surface (creating a hackle) making the terminus scrap.

21. Cleave the glass fiber. Grasp the glass fiber between the thumb and forefinger and gently pull the fiber straight away from the terminus until the fiber is detached at the scored area. **Do not push the fiber to either side to break it off** .

## Remember to place all broken fiber particles on the tape for safety purposes!

**FC connector** 3M 6206 140 mm: nickel plated zinc with zirconia ferrule.

1. Clean the entire stripped cable end (outer jacket, strength member, inner jacket, fiber coating, and glass fiber. Allow 5 minutes minimum drying time before the next step.

2. Place pre-cleaned connector boot and crimp sleeve on fiber.

3. Cut purple jacket 20 mm (.79 in.) from end of fiber.

4. Trim strength members flush with cut end.

5. Cut purple jacket back another 8 mm (.32 in) and remove.

6. Cut buffer 2mm (.08 in) from the purple jacket.

7. Strip length of coating is 2mm (.08 in) from purple jacket.

8. Insert needle tip into back side of connector body until it butts up against the ferrule and squeeze enough in until a small bead appears at the ferrule tip. The small bead of epoxy indicates that epoxy has been completely applied inside the critical ferrule area.

9. Very slowly remove the syringe tip while ensuring that the rear barrel is kept full of epoxy as the tip is completely withdrawn.

10. Blot excess epoxy from the terminus ferrule face. Using a dry wipe do not smear the epoxy by wiping; blot the epoxy away.

11. Position the connector filled with epoxy over the fiber being careful not to break the fiber. Carefully rotate and gently push the terminus onto the cable end until the glass fiber emerges from the end the of the connector. Hold the connector and cable down, so that the epoxy does not spill out of the connector when the fiber is inserted. Continue to rotate the connector until the fiber coating stops inside the connector. Rotating the connector improves the application of epoxy onto the glass fiber which also improves bonding within the ferule channel.

<u>NOTE</u>: Be careful as the glass fiber can easily be broken during this step. Do not apply any force to the fiber. The fiber should easily slide into and through the hole of the connector.

12. Put a thin coat of epoxy on the outside threads of the rear connector body.

13. Slide the crimp sleeve up while still holding the connector. Make sure strength members are evenly flared around the base of the connector back body. The strength members should be distributed so that the underlying terminus rear barrel and inner jacket are not visible.

14. While holding the top of the connector on to the fiber crimp using the C setting on the crimper. (Paladin 12-0001-PAL)

15. Place into curing heater for 20 minutes at 130 - 150 degrees C.

16. Record the time and date of the start of the epoxy's cure along with the operator's name in the certification log supplement.

**Note: Do not under cure the epoxy. It will do no harm if the connector is left in the oven for longer than 20 minutes.**

17. Once cured the color of the epoxy is red/orange.

18. Record the time and date of the end of the epoxy's cure along with the operator's name in the certification log supplement.

19. Once cured scribe the fiber with a carbide wedge scribe to remove the excess fiber. Place the scribe's tip so that it is resting flat on the face of the terminus ferrule. Hold the scribe at an angle of approximately 30 degrees up from the terminus so that the scribe's chisel edge is close to the ceramic face, but not flush with the face. Let the scribe's chisel edge contact the glass fiber while continuing to hold the scribe in position. Score the glass fiber by gently drawing the scribe's chisel edge lightly, once, across the fiber. **Do not attempt to break off the glass fiber during this step**.

NOTE: This is a very important step in the procedure. If the fiber is inadvertently broken off during this step, it may crack below the required polishing surface (creating a hackle) making the terminus scrap.

20. Cleave the glass fiber. Grasp the glass fiber between the thumb and forefinger and gently pull the fiber straight away from the terminus until the fiber is detached at the scored area. **Do not push the fiber to either side to break it off** .

## Remember to place all broken fiber particles on the tape for safety purposes!

**SC AMP 502883-2**, zirconia ferrule, polymer outer shell

1. Clean the entire stripped cable end (outer jacket, strength member, inner jacket, fiber coating, and glass fiber. Allow 5 minutes minimum drying time before the next step.

2. Place pre-cleaned connector boot and crimp sleeve on fiber.

3. Cut purple jacket 37 mm (1.46 in.) from end of fiber.

4. Trim strength members flush with cut end.

5. Cut purple jacket back another 8 mm (.32 in) and remove.

6. Cut buffer 10mm (.39 in) from purple jacket

7. Strip length of coating is 15mm (.59 in) from purple jacket

8. Insert needle tip into back side of connector body until it butts up against the ferrule and squeeze enough in until a small bead appears at the ferrule tip. The small bead of epoxy indicates that epoxy has been completely applied inside the critical ferrule area.

9. Very slowly remove the syringe tip while ensuring that the rear barrel is kept full of epoxy as the tip is completely withdrawn.

10. Blot excess epoxy from the terminus ferrule face. Using a dry wipe do not smear the epoxy by wiping; blot the epoxy away.

11. Position the connector filled with epoxy over the fiber being careful not to break the fiber. Carefully rotate and gently push the terminus onto the cable end until the glass fiber emerges from the end the of the connector. Hold the connector and cable down, so that the epoxy does not spill out of the connector when the fiber is inserted. Continue to rotate the connector until the fiber coating stops inside the connector. Rotating the connector improves the application of epoxy onto the glass fiber which also improves bonding within the ferule channel.

<u>NOTE</u>: Be careful as the glass fiber can easily be broken during this step. Do not apply any force to the fiber. The fiber should easily slide into and through the hole of the connector.

12. Put a thin coat of epoxy on the outside threads of the rear connector body.

13. Slide the crimp sleeve up while still holding the connector. Make sure strength members are evenly flared around the base of the connector back body. The strength members should be distributed so that the underlying terminus rear barrel and inner jacket are not visible.

14. While holding the top of the connector on to the fiber crimp using the C setting on the crimper. (Paladin 12-0003-PAL)

15. Place into curing heater for 20 minutes at 130 - 150 degrees C.

16. Record the time and date of the start of the epoxy's cure along with the operator's name in the certification log supplement.

**Note: Do not under cure the epoxy. It will do no harm if the connector is left in the oven for longer than 20 minutes.**

17. Once cured the color of the epoxy is red/orange.

18. Record the time and date of the end of the epoxy's cure along with the operator's name in the certification log supplement.

19. Once cured scribe the fiber with a carbide wedge scribe to remove the excess fiber. Place the scribe's tip so that it is resting flat on the face of the terminus ferrule. Hold the scribe at an angle of approximately 30 degrees up from the terminus so that the scribe's chisel edge is close to the ceramic face, but not flush with the face. Let the scribe's chisel edge contact the glass fiber while continuing to hold the scribe in position. Score the glass fiber by gently drawing the scribe's chisel edge lightly, once, across the fiber. **Do not attempt to break off the glass fiber during this step**.

NOTE: This is a very important step in the procedure. If the fiber is inadvertently broken off during this step, it may crack below the required polishing surface (creating a hackle) making the terminus scrap.

20. Cleave the glass fiber. Grasp the glass fiber between the thumb and forefinger and gently pull the fiber straight away from the terminus until the fiber is detached at the scored area. **Do not push the fiber to either side to break it off** .

## Remember to place all broken fiber particles on the tape for safety purposes!

**Termini**: Amphenol
Sockets (Have springs)

1. Clean the entire stripped cable end (outer jacket, strength member, inner jacket, fiber coating, and glass fiber. Allow 5 minutes minimum drying time before the next step.

2. Put pre-cleaned heat shrink on cable.

3. Cut purple jacket 29 mm (1.16 in.) from end of fiber.

4. Trim strength members flush with cut end.

5. Cut purple jacket back another 8 mm (.34 in) and remove.

6. Cut buffer as close as possible to the purple jacket 3mm (.12 in).

7. Strip length of coating is 20mm (.82 in) from loose tube.

8. Insert needle tip into back side of connector body until it butts up against the ferrule and squeeze enough in until a small bead appears at the ferrule tip. The small bead of epoxy indicates that epoxy has been completely applied inside the critical ferrule area.

9. Very slowly remove the syringe tip while ensuring that the rear barrel is kept full of epoxy as the tip is completely withdrawn.

10. Blot excess epoxy from the terminus ferrule face. Using a dry wipe do not smear the epoxy by wiping; blot the epoxy away.

11. Position the connector filled with epoxy over the fiber being careful not to break the fiber. Carefully rotate and gently push the terminus onto the cable end until the glass fiber emerges from the end the of the connector. Hold the connector and cable down, so that the epoxy does not spill out of the connector when the fiber is inserted. Continue to rotate the connector until the fiber coating stops inside the connector. Rotating the connector improves the application of epoxy onto the glass fiber which also improves bonding within the ferule channel.

12. <u>NOTE</u>: Be careful as the glass fiber can easily be broken during this step. Do not apply any force to the fiber. The fiber should easily slide into and through the hole of the connector.

13. Apply epoxy to the exterior of the terminus rear barrel.

14. First slide and rotate the shrinkable tubing away from the cable end so that the strength members spring completely out of the tubing. Next slide the heat shrink up over the strength members and onto the rear of the terminus so that the strength members are distributed completely and evenly over the rear barrel of the terminus.

15. The heat shrink should reach to but not past the shoulder. The strength members should be distributed so that the underlying terminus rear barrel and inner jacket are not visible.

16. Shrink the heat shrinkable tubing in 125º C oven (on its side) for 15 seconds. This will shrink the sleeving down.

17. Place into curing heater for 20 minutes at 130 - 150 degrees C.

18. Record the time and date of the start of the epoxy's cure along with the operator's name in the certification log supplement.

**Note: Do not under cure the epoxy. It will do no harm if the connector is left in the oven for longer than 20 minutes.**

19. Once cured the color of the epoxy is red/orange.

20. Record the time and date of the end of the epoxy's cure along with the operator's name in the certification log supplement.

21. Once cured scribe the fiber with a carbide wedge scribe to remove the excess fiber. Place the scribe's tip so that it is resting flat on the face of the terminus ferrule. Hold the scribe at an angle of approximately 30 degrees up from the terminus so that the scribe's chisel edge is close to the ceramic face, but not flush with the face. Let the scribe's chisel edge contact the glass fiber while continuing to hold the scribe in position. Score the glass fiber by gently drawing the scribe's chisel edge lightly, once, across the fiber. **Do not attempt to break off the glass fiber during this step**.

NOTE: This is a very important step in the procedure. If the fiber is inadvertently broken off during this step, it may crack below the required polishing surface (creating a hackle) making the terminus scrap.

22. Cleave the glass fiber. Grasp the glass fiber between the thumb and forefinger and gently pull the fiber straight away from the terminus until the fiber is detached at the scored area. **Do not push the fiber to either side to break it off** .

## Remember to place all broken fiber particles on the tape for safety purposes!

**Termini**: Amphenol
Pins

1. Clean the entire stripped cable end (outer jacket, strength member, inner jacket, fiber coating, and glass fiber. Allow 5 minutes minimum drying time before the next step.

2. Put pre-cleaned heat shrink on cable.

3. Cut purple jacket 22.5 mm (.88 in.) from end of fiber.

4. Trim strength members flush with cut end.

5. Cut purple jacket back another 7 mm (.28 in) and remove (strength members should be 8 mm (.30 in) max.

6. Cut buffer as close as possible to the purple jacket

7. Strip length of coating is 8mm (.32 in) from purple jacket

8. Insert needle tip into back side of connector body until it butts up against the ferrule and squeeze enough in until a small bead appears at the ferrule tip. The small bead of epoxy indicates that epoxy has been completely applied inside the critical ferrule area.

9. Very slowly remove the syringe tip while ensuring that the rear barrel is kept full of epoxy as the tip is completely withdrawn.

10. Blot excess epoxy from the terminus ferrule face. Using a dry wipe do not smear the epoxy by wiping; blot the epoxy away.

11. Position the connector filled with epoxy over the fiber being careful not to break the fiber. Carefully rotate and gently push the terminus onto the cable end until the glass fiber emerges from the end the of the connector. Hold the connector and cable down, so that the epoxy does not spill out of the connector when the fiber is inserted. Continue to rotate the connector until the fiber coating stops inside the connector. Rotating the connector improves the application of epoxy onto the glass fiber which also improves bonding within the ferule channel.

12. <u>NOTE</u>: Be careful as the glass fiber can easily be broken during this step. Do not apply any force to the fiber. The fiber should easily slide into and through the hole of the connector.

13. Apply epoxy to the exterior of the terminus rear barrel.

14. First slide and rotate the shrinkable tubing away from the cable end so that the strength members spring completely out of the tubing. Next slide the heat shrink up over the strength members and onto the rear of the terminus so that the strength members are distributed completely and evenly over the rear barrel of the terminus.

15. The heat shrink should reach to but not past the shoulder. The strength members should be distributed so that the underlying terminus rear barrel and inner jacket are not visible.

16. Shrink the heat shrinkable tubing in 125º C oven (on its side) for 15 seconds. This will shrink the sleeving down.

17. Place into curing heater for 20 minutes at 130 - 150 degrees C.

18. Record the time and date of the start of the epoxy's cure along with the operator's name in the certification log supplement.

**Note: Do not under cure the epoxy. It will do no harm if the connector is left in the oven for longer than 20 minutes.**

19. Once cured the color of the epoxy is red/orange.

20. Record the time and date of the end of the epoxy's cure along with the operator's name in the certification log supplement.

21. Once cured scribe the fiber with a carbide wedge scribe to remove the excess fiber. Place the scribe's tip so that it is resting flat on the face of the terminus ferrule. Hold the scribe at an angle of approximately 30 degrees up from the terminus so that the scribe's chisel edge is close to the ceramic face, but not flush with the face. Let the scribe's chisel edge contact the glass fiber while continuing to hold the scribe in position. Score the glass fiber by gently drawing the scribe's chisel edge lightly, once, across the fiber. **Do not attempt to break off the glass fiber during this step**.

NOTE: This is a very important step in the procedure. If the fiber is inadvertently broken off during this step, it may crack below the required polishing surface (creating a hackle) making the terminus scrap.

22. Cleave the glass fiber. Grasp the glass fiber between the thumb and forefinger and gently pull the fiber straight away from the terminus until the fiber is detached at the scored area. **Do not push the fiber to either side to break it off**.

## Remember to place all broken fiber particles on the tape for safety purposes!

## Post Fiber Optic Connector Termination Inspection

Terminated fiber optics shall be inspected for the following:

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

2. Connector endface geometry compliant with engineering documentation.

3. 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.

4. Connector/terminus free of excess epoxy except on the ferrule which is to be polished.

5. The cable to connector/terminus bond. Check bond by gently trying to rotate the connector/terminus while holding the cable.

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

# Chapter 7. Polishing

## Coarse Polish

1. Use a 5-micron grit lapping paper to remove the protruding fiber down to the epoxy. Hold connector tip up and hold paper so that it has a slight concave radius to it. The concave radius of the lapping paper ensures that the glass fiber will not be polished flush with the ceramic ferrule face. Gently rub the protruding glass fiber in a *figure 8 pattern* on an unused portion of the lapping paper.

NOTE: Do not press or apply pressure to the lapping paper during this operation.

2. As the glass fiber is rubbed on the lapping paper, observe the mark left on the paper by the fiber and sense the change in the feel of the rubbing.

3. The mark on the lapping paper will change from a fine line to a broader line as the fiber is polished, and the feel of the rubbing will change from a sharp contact to a dull contact.

4. When a dull contact is felt and there is a broad line on the lapping paper (after approximately 25 to 30 figure 8 patterns), examine the terminus end using 10X magnifier to check that the fiber length is short enough for fine polishing.

NOTE: The glass fiber surrounded by a small bead of epoxy should just protrude from the ferrule end face and <u>must not</u> be polished flush with the ferrule face. Over polishing during this step will result in deep scratches which may not be able to be removed during the fine polish step.

## Flat Polish (SMA Connector)

1. Use the Plexiglas backing
2. Start with the 3-micron grit paper.
3. Wipe paper with a shop wipe soaked in Alcohol.
4. Using the appropriate puck, insert the connector to be polished into the puck
5. Holding the puck and supporting the connector start polishing with a figure 8 pattern.
6. Repeat polishing pattern, checking often, until there is just a thin coating of epoxy still left.
7. Remove 3-micron grit and switch to 1-micron grit paper.
8. Clean the end of the connector with shop wipe and Alcohol.
9. Wipe the paper with a clean shop wipe and Alcohol.
10. Holding the puck and supporting the connector start polishing with a figure 8 pattern.
11. Repeat polishing pattern approximately 20 times.
12. Remove 1-micron grit and switch to 0.3-micron grit paper.
13. Clean the end of the connector with shop wipe and Alcohol.
14. Wipe the paper with a clean shop wipe and Alcohol.
15. Holding the puck and supporting the connector start polishing with a figure 8 pattern.
16. Repeat polishing pattern approximately 20 times.
17. Clean the end of the connector with shop wipe and Alcohol.
18. Inspect at 200x with Fiberscope.

## Physical Contact (PC) Polish (All other connectors)

1. Use the Hard Rubber backing
2. Start with the 3-micron grit paper.
3. Wipe paper with a shop wipe soaked in Alcohol.
4. Using the appropriate puck, insert the connector to be polished into the puck
5. Holding the puck and supporting the connector start polishing with a figure 8 pattern.
6. Repeat polishing pattern, checking often, until there is just a thin coating of epoxy still left.
7. Remove 3-micron grit and switch to 1-micron grit paper.
8. Clean the end of the connector with shop wipe and Alcohol.
9. Wipe the paper with a clean shop wipe and Alcohol.
10. Holding the puck and supporting the connector start polishing with a figure 8 pattern.
11. Repeat polishing pattern approximately 20 times.
12. Remove 1-micron grit and switch to 0.3-micron grit paper.
13. Clean the end of the connector with shop wipe and Alcohol.
14. Wipe the paper with a clean shop wipe and Alcohol.
15. Holding the puck and supporting the connector start polishing with a figure 8 pattern.
16. Repeat polishing pattern approximately 20 times.
17. Clean the end of the connector with a shop wipe and Alcohol.
18. Inspect at 200x with Fiberscope.

# Chapter 8. Inspection

After polishing the terminated end, inspect with the Fiberscope at a magnification of 200X in accordance with the criteria contained in NASA-STD- 8739. 5.

Because of the high degree of magnification involved, debris or dirt on the terminus or on the microscope lens will be seen and could be mistaken for a defect. For this reason, care must be taken to ensure that the microscope lens, terminus adapter, and polished terminus are clean.

1. Ensure that the hand-held microscope, lens, and terminus adapter are clean before use.

2. Attach the terminus adapter to the hand-held microscope.

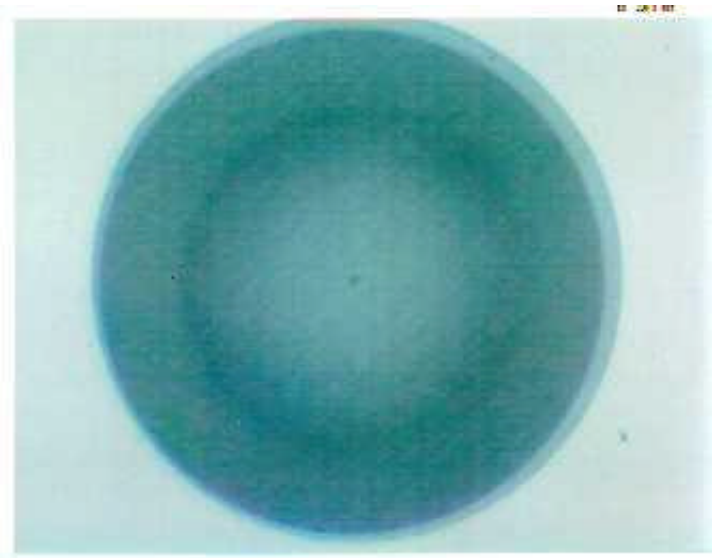
3. Clean the polished ferrule/terminus face at least two times using a wipe moistened with cleaning solvent.

4. Insert the polished connector/terminus into the microscope's adapter.

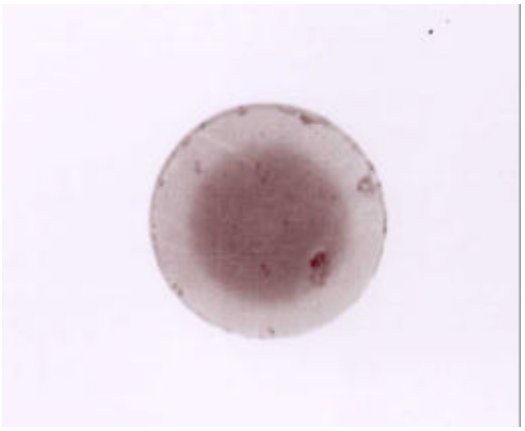
5. Turn the knob on the side of the microscope until a sharp image of the face is achieved.

## Accept Criteria:

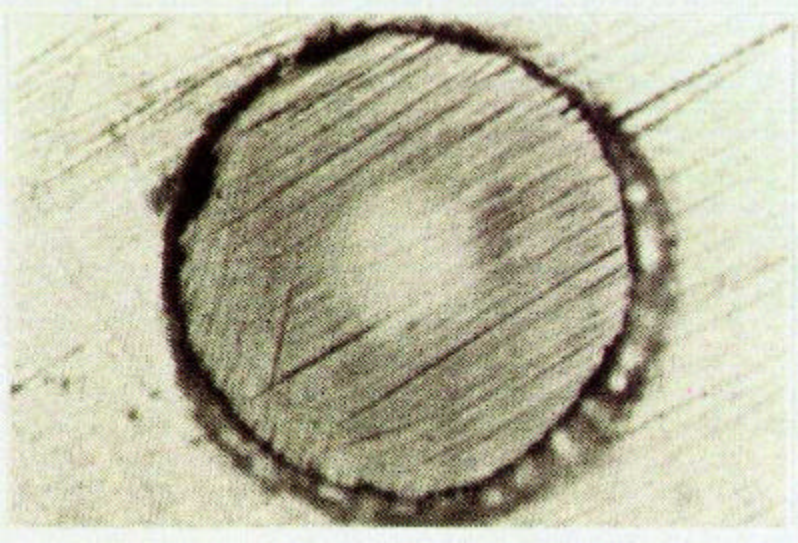
An acceptable termination will be free from cracks, scratches, edge chips, hackles, pits and other anomalies with the core clearly discerned.



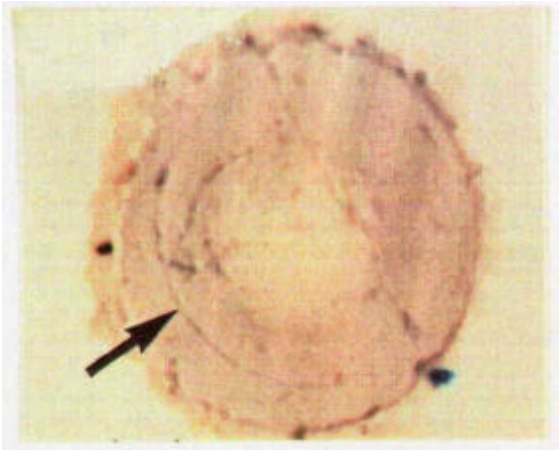
# Rejection Criteria:

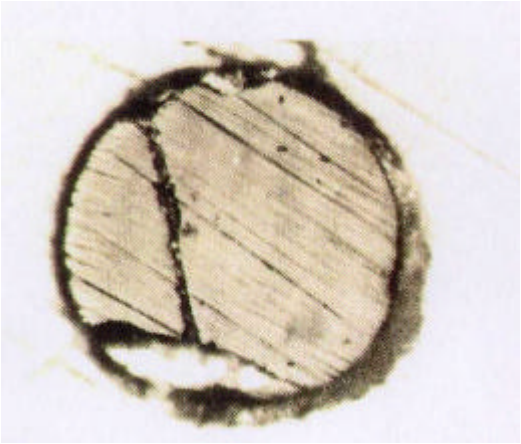


Surface Pits – Repolish if in core or cladding

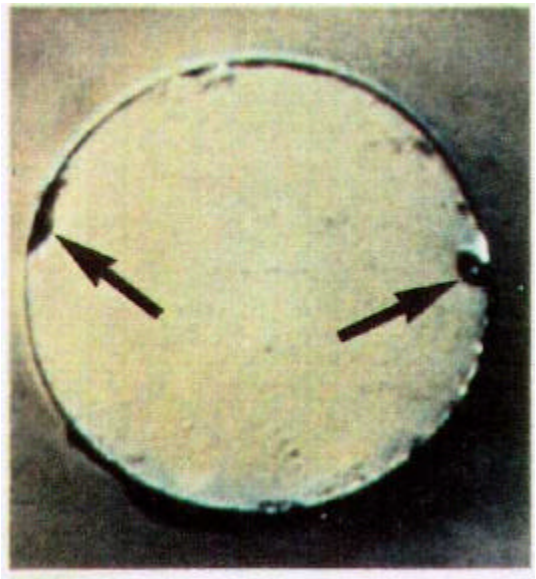


Scratches – Repolish if in core

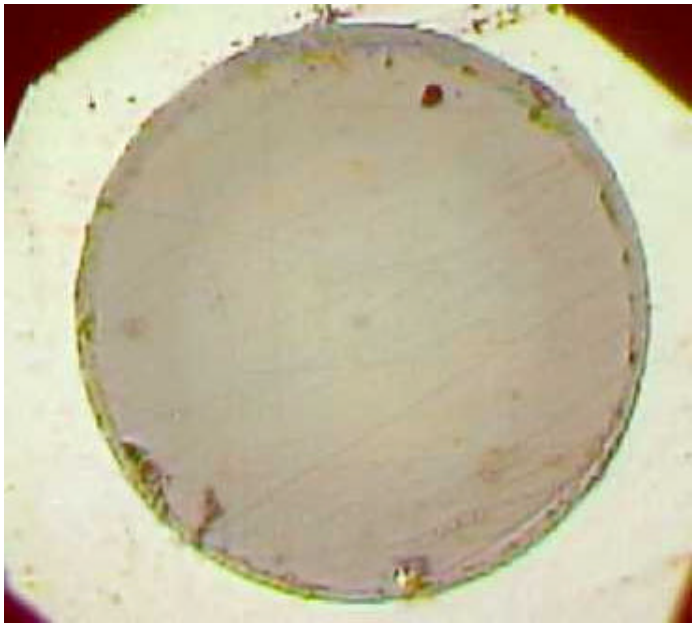




Cracks – Reject redo termination

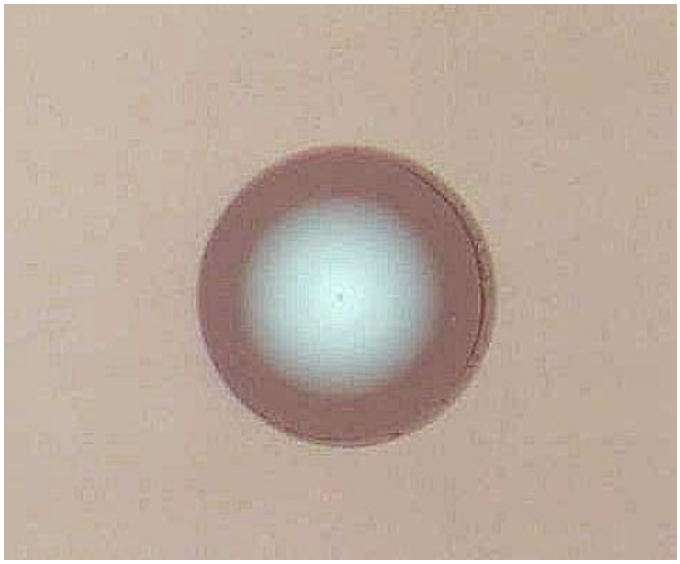


Edge Chips – May be fixable by polishing



Contamination

Hackle – May be fixable by polishing



Epoxy Separation

Epoxy – Reject if epoxy is on core, cladding or ferrule
May be fixable by polishing

# Chapter 9. Splicing

The splicing technique used in this class will be a Fusion splice. Follow the directions listed in the operating manual for the S174H Fusion Splicer from Furukawa Electric.

Note: Strip length on cable shall be 16 ± 1 mm.

# Chapter 10. Testing

## Optical Performance Verification

Note: The optical fiber cable must be terminated on both ends and have passed all acceptance criteria up to this point before beginning this section of the procedure.

Performance verification of a completely terminated optical fiber cable is performed in two steps:

1. Measurement verification of the test setup optical power level.
2. Optical power loss testing of the completely terminated optical fiber cable assembly referred to as the Unit Under Test (UUT).

SAFETY CAUTION: Care should be taken when working with optical fiber assemblies and optical fiber light sources. Optical fiber light sources may use lasers or high intensity Light Emitting Diodes (LEDs). Never look at any optical fiber light source output port, under any circumstance, as eye damage could occur. Never look at the end of any optical fiber cable or optical fiber connector or terminus that is attached to anything on the other end, as the assembly could be carrying laser light or high intensity LED light.

The test setup includes an optical light source (850nm), an optical power meter (850nm), reference cables, and the UUT. Optical loss measurements of UUT's used in spaceflight applications must be made at the same wavelength used under spaceflight conditions.

Locally fabricated reference optical fiber cables are required in the test setup. All reference cables must be of the same part number as the optical fiber cable being tested to avoid mismatches in such parameters as transmission modes, index of refraction, and numerical aperture.

Launch cables are always connected to the optical light source, and receive reference cables are always connected to the optical power meter.

## Reference Measurement

The test setup reference measurement is performed to insure that the UUT optical power loss measurements are repeatable. Debris or dirt at optical fiber connections affect optical power transmissions and produce inconsistent power level measurements. The reference measurement also ensures that there has been no degradation in the optical transmission properties of the reference cables themselves.

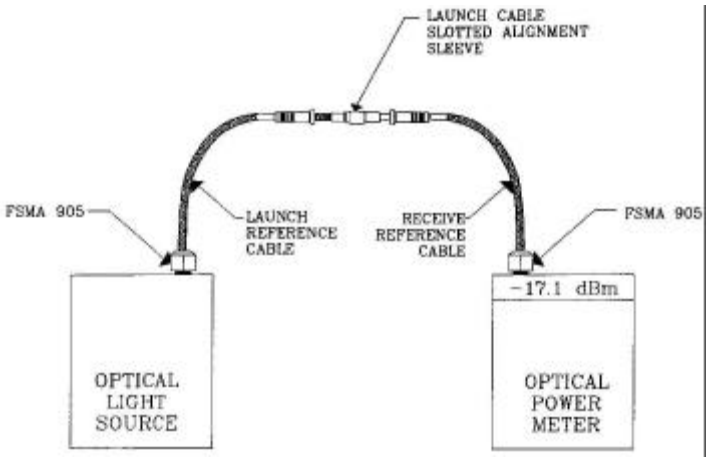
1. Ensure that the optical light source and optical power meter are calibrated.

2. Ensure that the reference cables are labeled. *Launch Reference Cable, Receive Reference Cable.*

3. Ensure that the 200X hand-held microscope, lens, connector, and launch and receive reference cables are all clean.

4. Inspect the connector/terminus for dirt or debris with the 200X hand-held microscope. Clean with wipe and solvent if necessary.

5. Connect the two reference cables together.




6. Turn on the optical light source, and let the light source stabilize for 1 minute.

7. Read the measured reference power level value from the optical power meter.

8. Record the measured reference power level in the certification log supplement. The power level on the optical power meter should be greater than –18.0 dBm (typically within the range of –17.9dBm to –15.5 dBm). If the reference power level is less than –18.0 dBm, most likely there is a problem in the test setup.

NOTE: The optical light source is rated for –20 dBm. The –20 dBm rating is for 62.5/125 micron fiber. The 100/140 micron fiber used in the procedure has a larger optical aperture than the 62.5/125 micron fiber; hence, more power is transmitted into the fiber, and the optical power meter reads a level greater than the optical source rating.

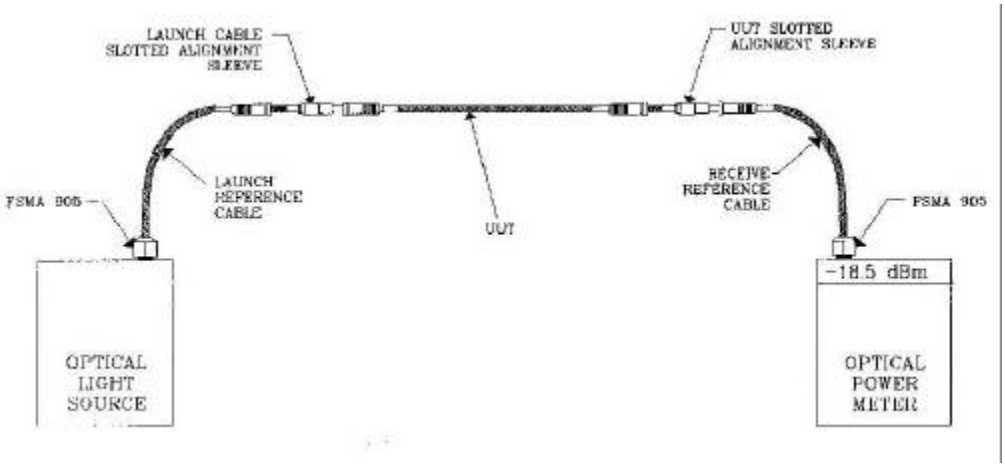
9. Turn off the optical light source and the optical power meter.

## Power Loss Measurement

The power loss measurement is performed to verify and determine the optical performance of the UUT.

10. Disconnect the launch reference cable from the receive reference cable.

11. Connect the UUT to the launch reference cable and the receive reference cable.




12. Turn on the optical power meter, and let the power meter stabilize for 1 minute. Verify that the power meter wavelength switch is set to 850nm.

13. Turn on the optical light source, and let the light source stabilize for 1 minute.

14. Read the measured UUT power level value from the optical power meter.

15. Record the measured UUT power level value in the certification log supplement.

16. Turn off the optical light source and the optical power meter.

17. Determine the UUT power loss. Algebraically subtract the measured reference power level value recorded in the certification log supplement from the measured UUT power level value recorded in the certification log supplement. Example:

    Measured UUT Power Level = -18.5 dBm
    Measured Reference Power Level = -17.1 dBm

    -18.5 dBm – (-17.1 dBm) = -1.4 dBm Loss ( Record the UUT power loss in the certification log supplement).

18. Determine the length loss acceptance value. Use the cable length value recorded in the certification log supplement. Round the cable length value to the next highest whole number. If the rounded cable length value is less than 34 feet, use –0.1 dB as the length loss acceptance value: otherewise, calculate the length loss acceptance value by multiplying the rounded cable length value by –0.003dB/foot.