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MILITARY STANDARD

FIBER OPTICS TEST METHODS AND INSTRUMENTATION

FSC 9999

DEPARTMENT OF DEFENSE
Washington, D.C. 20301

FIBER OPTICS TEST METHODS AND INSTRUMENTATION

DOD-STD-1678

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commanding Officer, Engineering Specifications and Standards Department (Code 93), Naval Air Engineering Center, Lakehurst, New Jersey 08733 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. SCOPE

1.1 Purpose. This standard gives the general physical, electrical and chemical methods for testing fiber optics cables for conformance with the requirements. It was prepared in order to eliminate unnecessary or undesirable variation in testing procedures. This standard does not include special test methods applicable to certain fiber optics cables which are described in the appropriate specifications, nor does it include all the test methods for fiber optics cable used in industry. In instance of conflict between the provisions of those test methods and those of the individual test procedures or specifications for particular material, the latter shall take precedence.

1.2 Application of test methods. Test methods contained in this standard apply to all items of equipment. WHEN IT IS KNOWN THAT THE EQUIPMENT WILL ENCOUNTER CONDITIONS MORE SEVERE OR LESS SEVERE THAN THE ENVIRONMENTAL LEVELS STATED HEREIN, THE TEST MAY BE MODIFIED BY THE EQUIPMENT SPECIFICATION.

1.3 Numbering system.

1.3.1 New methods. A method number will be assigned so that the new method is located close to the methods of similar or related tests.

1.3.2 Revision of existing methods. Revision of test methods are indicated by a letter following the method number. For example, 3111, if modified or changed, would be 3111A, the second revision, 3111B, etc.

1.4 Method of reference. Test methods contained herein shall be referenced by specifying:

a. This standard number

b. Method number. The letter following the method number shall not be used when referencing test methods. For example, use 1010, not 1010A.

c. Procedure number

d. Details required in the results paragraph of the applicable method.

e. Other data as called for in the individual test method.

2. REFERENCED DOCUMENTS

2.1 Issues of documents. The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this standard to the extent specified herein.

SPECIFICATIONS

Federal

UU-T-450	Tissue, Facial

STANDARDS

Federal

FED-STD-191	Textile Test Methods
FED-STD-228	Cable and Wire, Insulated, Methods of Testing

Military

MIL-STD-202	Test Methods for Electronic and Electrical Component Parts

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. DEFINITIONS

3.1 The following definitions listed in this military standard cover general terms. The general terms are defined in the following paragraphs.

3.1.1 Fiber. A fiber is a single discrete optical transmission element usually comprised of a fiber core and a fiber cladding.

3.1.2 Bundle. A bundle is a number of fibers grouped together.

3.1.3 Cable. A cable is a jacketed bundle or jacketed fiber in a form which can be terminated.

3.1.4 Multiple fiber cable. A multiple fiber cable is a construction in which a number of jacketed fibers are placed together in a common envelope.

3.1.5 Multiple bundle cable. A multiple bundle cable is a construction in which a number of jacketed bundles are placed together in a common cylindrical envelope.

3.1.6 Harness. A harness is a construction in which a number of multiple fiber cables or jacketed bundles are placed together in an array which contains branches. A harness is usually installed within equipment or airframe and mechanically secured to that equipment or airframe.

3.1.7 Branched cable. A branched cable consists of a cable, multiple fiber cable, or multiple bundle cable which contains one or more breakouts.

3.1.8 Branch. A branch is that portion of a cable or harness which breaks out from and forms an arm with the main cable or harness run.

3.1.9 Breakout. The point where a branch meets and merges with the main cable or harness run or where it meets and merges with another branch is called a breakout.

3.1.10 Cable or harness run. The cable or harness run is that portion of a branched cable or harness where the cross-sectional area of the cable or harness is the largest.

3.1.11 Cable core. The portion of a cable contained within a common covering is the cable core.

3.1.12 Cable assembly. A cable assembly is a cable which is terminated and ready for installation.

3.1.13 Multiple fiber cable assembly. A multiple fiber cable which is terminated and ready for installation is called a multiple fiber cable assembly.

3.1.14 Multiple bundle cable assembly. A multiple bundle cable assembly is a multiple bundle cable which is terminated and ready for installation.

3.1.15 Harness assembly. A harness assembly is a harness which is terminated and ready for installation.

3.1.16 Fiber optics. Fiber optics as applied to this standard is a general term used to describe the function where optical energy is guided to another location through fiber(s).

3.1.17 FO. FO is an abbreviation for fiber optics.

3.1.18 Acceptance pattern. The acceptance pattern of a fiber or fiber bundle is a curve of input radiation intensity plotted against the input (or launch) angle.

3.1.19 Launch angle. The launch angle is the angle between the input radiation vector and the axis of the fiber or fiber bundle.

3.1.20 Radiation pattern. The radiation pattern of a fiber or bundle is a curve of the output radiation intensity plotted against the output angle.

3.1.21 Numerical aperture, NA. The numerical aperture, NA, can be defined as follows.

3.1.21.1 Numerical aperture, NA (90% power). The numerical aperture of a fiber or bundle is defined by:

$$NA\ (90\%\ power) = \sin\theta$$

where θ is the angle between the axis of the output cone of light and the vector coincident with the surface of a cone which contains 90% of the total output radiation power,

or where θ is the angle between the axis of the input cone of light and the vector coincident with the surface of a cone which contains 90% of the total input radiation power.

3.1.21.2 Numerical aperture, NA (10% intensity). The numerical aperture of a fiber or bundle is defined by:

$$NA\ (10\%\ intensity) = \sin\theta'$$

where θ' is the angle where the measured intensity of radiation is 10% of the maximum measured intensity when plotting either the acceptance or radiation pattern.

3.1.21.3 Numerical aperture, NA (material). The numerical aperture of a fiber or bundle is defined by:

$$NA\ (material) = (n_1^2 - n_2^2)^{1/2}$$

where n_1 and n_2 are the fiber core and cladding refractive indices, respectively, for step index fibers. For graded index fibers n_1 is the maximum index in the core and n_2 is the minimum index in the clad.

3.1.22 Exit angle. The exit angle is the angle between the output radiation vector and the axis of the fiber or fiber bundle.

3.1.23 Radiant power. Φ: The time rate of flow of electromagnetic energy. unit: watts (W).

3.1.24 Radiant intensity. $I = d\Phi/d\omega$: The radiant power per unit solid angle ω in the direction considered. unit: watts per steradian (W/sr).

3.1.25 Radiance. $L = \dfrac{d^2\Phi}{d\omega dA\cos\theta} = \dfrac{dI}{dA\cos\theta}$

The radiant power per unit solid angle and per unit surface area A normal to the direction considered. The surface may be that of a source, detector or it may be any other real or virtual surface intersecting the flux; θ is the angle between the normal to the surface element dA and the direction considered. unit: watts per steradian and square meter ($W/sr\text{-}m^2$)

3.1.26 Lambertian. A radiance distribution that is uniform in all directions of observation.

3.1.27 Uniform Lambertian: A Lambertian distribution that is uniform across a surface.

3.1.28 Peak wavelength. λ_p: The wavelength at which the radiant intensity is a maximum. unit: nanometers (nm)

3.1.29 Peak radiant intensity. I_p: The maximum value of radiant intensity, I.

3.1.30 Spectral bandwidth. λ_{BW}: The difference between the wavelengths at which the radiant intensity I (λ) is 50% (unless otherwise stated) of the peak value I_p.

3.1.31 Beamwidth. θ_0: The difference between the angles at which radiant intensity I (θ) is 50% (unless otherwise stated) of the peak value I_p.

3.1.32 Radiant power ratio. R is defined as the radiant power ratio Φ_2/Φ_1, where Φ_1, and Φ_2 are the measured power before and after specimen conditioning, respectively.

3.1.33 Packing fraction. The packing fraction is the ratio of the total core area to the cross-sectional area determined from the termination inside dimensions.

3.1.34 Fiber cladding. Fiber cladding is that part of a fiber which surrounds the core of the fiber and has a lower refractive index than the core.

3.1.35 Cladding mode stripper. The cladding mode stripper is a material applied to the fiber cladding which provides a means for allowing light energy being transmitted in the cladding to leave the cladding of the fiber.

3.1.36 Fiber sheath. The word "sheath" is a general term used variously to mean cladding, buffer or jacket. The word "sheath" is not to be used in military FO specifications.

3.1.37 Fiber jacket. The fiber jacket is the material which is the outer protective covering applied over the buffered or unbuffered fiber.

3.1.38 Fiber buffer. The fiber buffer is the material which surrounds and is immediately adjacent to a fiber which provides mechanical isolation and protection. Note: Buffers are generally softer materials than jackets.

3.1.39 Fiber core. The fiber core is that part of a fiber which has a higher refractive index than the cladding which surrounds it.

3.1.40 Bundle jacket. The bundle jacket is the material which is the outer protective covering applied over a bundle of buffered or unbuffered fibers.

3.1.41 Cable jacket. The cable jacket is the material which is the external protective covering common to all internal cable elements.

3.1.42 Step index fibers. A fiber in which there is an abrupt change in refractive index between the core and cladding along a fiber diameter.

3.1.43 Graded index fibers. A fiber in which there is a designed continuous change in refractive index between the core and cladding along a fiber diameter.

4. GENERAL REQUIREMENTS

4.1 Test requirements. The requirements which must be met by the fiber optics cables subjected to the test methods described herein are specified in the individual specifications, as applicable, and the tests shall be applied as specified herein. Whenever this standard conflicts with the individual specification, the latter shall govern.

4.2 Test conditions. Unless otherwise specified herein, or the individual specification, all measurements and tests shall be made at temperatures of 15°C to 35°C, at air pressure of 650 to 800 millimeters of mercury, and relative humidity of 45 percent to 75 percent. Whenever these conditions must be closely controlled in order to obtain reproducible results; for reference purposes, temperature, relative humidity, and atmospheric pressure conditions of 23°C ± 2°C, 50 percent ± 5 percent and 650 to 800 millimeters of mercury, shall be specified.

4.2.1 Permissible temperature variation in environmental chambers. When chambers are used, specimens under test shall be located only within the working area defined as follows:

a. Time variation within working area: The controls for the chamber shall be capable of maintaining the temperature of any single reference point within the working area within ± 2°C.

b. Space variation within working area: Chambers, shall be so constructed that, at any given time, the temperature of any point within the working area shall not deviate more than 3°C from the reference point.

5. TEST METHODS

5.1 Individual methods for fiber optics testing are sectionalized.

6. NOTES

6.1 Activities outside the Federal Government may obtain copies of Federal Specifications, Standards and Handbooks as outlined under General Information in the Index of Federal Specifications and Standards and at the prices indicated in the Index. The Index, which includes cumulative monthly supplements as issued, if for sale on a subscription basis by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

6.2 Single copies of this specification and other product specifications required by activities outside the Federal Government for bidding purposes are available without charge at the General Services Administration Regional Offices in Boston, New York, Washington, D.C., Atlanta, Chicago, Kansas City, MO; Dallas, Denver, San Francisco, Los Angeles, and Seattle, WA.

6.3 Federal Government activities may obtain copies of Federal Specifications, Standards and Handbooks and the Index of Federal Specifications and Standards from established distribution points in their agencies.

Custodians:

Army - EL

Air Force - 11

Review activities:

Navy - EC, OS

Air Force - 13

Army - MI, AR

User activities :

Army - AV

Preparing activity:

Navy - AS

Project No. MISC-9999-0012

METHOD 1010

FIBER SIZE MEASUREMENTS

1. SCOPE.

1.1 This method describes a procedure for measuring the fiber diameter and the fiber core diameter.

1.2 Definitions.

1.2.1 The fiber diameter (overall diameter) D_F is defined as the diameter inclusive of the cladding and any adherent coating not normally removed during the termination process.

1.2.2 The fiber core diameter DC is defined as the diameter of the higher refractive index medium which transmits the major portion of the light flux.

1.2.3 The core/fiber area ratio of circular cross-section fibers is defined by:

$$R_a = \left(\frac{D_C}{D_F}\right)^2$$

where D_C = core diameter
D_F = fiber diameter (over cladding)

If the fiber is not circular in cross-section the core/fiber area ratio is defined by:

$$R_a = \left(\frac{A_C}{A_F}\right)$$

where A_C = core area
A_F = overall fiber area

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable. For convenience of the test, a short specimen may be used.

3. APPARATUS.

3.1 General. The illumination source shall be a white incandescent light source with adjustable intensity.

3.2 Procedure I. Optical Microscope Method.

3.2.1 Optical microscope. The optical microscope shall be a compound microscope type equipped with means for front (i.e. vertical) illumination. An inverted metalurgical microscope is suitable.

3.2.2 Micrometer eyepiece. The microscope shall be equipped with a micrometer eyepiece (often called a filar micrometer).

3.2.3 Magnification. The microscope shall be equipped with a set of objective lenses of approximately 10X, 40X and 100X magnification.

3.2.4 Reference scale. A precision scale shall be used to calibrate the microscope magnification (stage micrometer).

3.3 Procedure II. Photomicrographic Method.

3.3.1 Photomicrographic camera. The microscope described in section 3.2 (or equivalent) shall be equipped with a photomicrographic camera, preferably one which uses self-developing film.

3.3.2 Measuring scale. A suitable scale shall be used for measuring the diameters of the fiber images photographed.

4. PROCEDURES.

4.1 Procedure I. Optical Microscope Method.

Step 1 - The microscope shall be calibrated for each of the objective lenses to be used. Calibration shall be accomplished by measuring the length, L, of the image of a known scale with a precision reference scale (stage micrometer) using each objective lens (in turn) and the micrometer eyepiece (filar micrometer). The magnification is given by:

$$m = \frac{L}{l}$$

where L = the length of the known scale.
l = the length of the reference scale (portion of the stage micrometer scale used).

Step 2 - One end of the specimen shall either be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so the endfaces are perpendicular to the axis of the specimen. The other end shall either be prepared as the first or index matching fluid shall be used to couple the optical power between source and specimen.

Step 3 - A finished end of the specimen shall then be secured perpendicular to the microscope stage and an objective lens selected according to the nominal fiber size such that several fibers appear in the field of view, or in the case of a single fiber cable the one fiber appears. For most fibers, an objective lens with a magnification of approximately 40X is suitable.

Step 4 - Fibers chosen for test shall be free of chipped edges or other defects which might interfere with judging the location of the core to clad interface. The illumination source shall be attached to the free end of the specimen and the source adjusted for easily discernable fiber interfaces.

Step 5 - The overall diameter of the selected fibers shall be measured by means of the micrometer eyepiece and the known calibration. Several measurements of cladding diameter shall be made on each selected fiber and the average D_F, for each fiber shall be computed.

Step 6 - The core diameter of each of the selected fibers shall be measured in the same manner as the fiber diameter and the average core diameter, D_C, for each fiber shall be computed.

Step 7 - The core/fiber area ratio, R_a, shall be calculated for each of the measured fibers and the average computed. If the fibers are not circular, additional measurements shall be made to calculate the overall fiber area, A_F, and the core area, A_C.

Step 8 - Concentricity. The concentricity of the overall insulation or of any primary insulation, insulation coating or cladding shall be determined by locating and recording the minimum and maximum cladding thickness of the same cross section. The ratio of the minimum cladding thickness to the maximum cladding thickness shall define the concentricity.

4.2 Procedure II. Photomicrographic Method.

Step 1 - The intensity of the front and back illumination, the shutter speed and "f" stop shall be adjusted to obtain a clean photograph.

Step 2 - The image of the selected fibers shall be recorded photographically.

Step 3 - The overall image magnification shall be determined by photographing a scale of known calibration such as a stage micrometer.

Step 4 - The fiber diameter shall be determined by measuring the image diameters as described in 4.1, step 5 and dividing by the magnification as determined in 4.2, step 2. The average fiber diameter, D_F, shall be calculated for each fiber measured.

Step 5 - The core diameter of the selected fibers shall be measured as described in step 3. The average core diameter, D_C, shall be calculated for each fiber measured.

Step 6 - The core/fiber area ratio, R_a, for each fiber shall be calculated from the average of each of the measured fibers and grand average, $\overline{R_a}$, computed.

Step 7 - If the fibers are not circular, additional measurements shall be made in order to calculate the overall fiber area, A_F, and the core area, A_C.

Step 8 - Concentricity. The concentricity of the overall insulation or of any primary insulation, insulation coating or cladding shall be determined by locating and recording the thickness of the same cross section. The ratio of the minimum cladding thickness to the maximum cladding thickness shall define the concentricity.

5. RESULTS. The following details shall be specified in the equipment specification:

5.1 Procedure number

5.2 Pretest data required

5.3 Failure criteria

5.4 The type of microscope, type of objective lens, and the measured magnification

5.5 The maximum and minimum fiber and core diameter for each fiber measured

5.6 The average fiber and core diameter for each fiber measured

5.7 The calculated grand average of core/fiber area ratio, $\overline{R}_a$

5.8 The number of fibers to be measured

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METHOD 1020

FIBER BUNDLE DIAMETER MEASUREMENT

1. SCOPE.

1.1 This method measures the diameter of a tightly packed bundle of fibers exclusive of any jacketing or encapsulating materials.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable or bundle.

3. APPARATUS.

3.1 Sizing gauges. The gauges consist of funnel-shaped gauges with precisely known inside diameter. For each nominal fiber bundle diameter a series of gauges in increments of .013 mm (or other appropriate steps) both larger and smaller than the nominal diameter shall be used.

3.2 Wetting liquid. A wetting liquid may be used to wet the fibers prior to insertion into the gauge.

4. PROCEDURE.

Step 1 - The end of the fiber cable may be prepared by cutting the entire cable to obtain a fresh cross-section and then removing any jacket or extraneous material for a distance of approximately 50 mm from the end of the bundle. Care must be taken not to cut away any fibers at this step.

Step 2 - The end of the fiber bundle may be wetted by dipping into wetting liquid. This will draw the fibers together by capillary action and facilitate packing of the fibers.

Step 3 - Starting with the largest gauge of the series, the bundle shall be inserted into each progressively smaller gauge until it cannot pass into a gauge. This will also facilitate removal of excess lubricant and determine the smallest diameter circle which will accommodate the fiber bundle. The diameter of the smallest gauge which accepts the fiber bundle will define the fiber bundle diameter for the purposes of this measurement.

5. RESULTS. The following details shall be specified in the equipment specification:

5.1 Procedure number

5.2 Pretest data required

5.3 Failure criteria

5.4 The diameter of the smallest gauge into which the fiber can be fitted ("Go" Gauge)

5.5 The diameter of the next smallest gauge ("No-Go" Gauge)

5.6 The liquid used to wet the fiber

METHOD 1030

NUMBER OF FIBERS

1. SCOPE.

1.1 This method determines the total number of fibers in a fiber bundle (or multiple fiber cable) where the number of fibers is large.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optic cable. For convenience of the test, a short specimen may be used.

3. APPARATUS.

3.1 Apparatus for Procedure I.

3.1.1 Optical Microscope. An optical microscope as described in Method 1010 of DOD-STD-1678 or equal shall be used. The magnification shall be sufficient to fill a photograph with the fiber bundle image.

3.1.2 Photomicrographic Camera. A photomicrographic camera as described in Method 1010 of DOD-STD-1678 or equivalent shall be used.

3.2 Apparatus for Procedure II.

3.2.1 Laboratory Balance. A laboratory balance of reading accuracy to .1 milligram or better is required.

3.2.2 Microscope/laboratory tweezers.

4. PROCEDURES.

4.1 Procedure I.

Step 1 - Both ends of the specimen shall be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so that the endfaces are perpendicular to the axis of the specimen.

Step 2 - One end of the specimen shall be placed in the illumination source.

Step 3 - The magnification shall be adjusted and the image of the fiber bundle shall be recorded photographically.

Step 4 - The fibers in the photograph shall be counted. For convenience, it has been found useful to cross out the fiber image with an "X" or "✓" when it is counted so as not to count the same fiber more than once.

4.2 Procedure II.

Step 1 - A 130 to 150 mm length of jacketed bundle shall be carefully straightened and cut.

Step 2 - The bundle of fibers (and serving threads if present) shall be removed from their jacket and immediately placed upon the locked tray of the balance.

Step 3 - The serving threads will be carefully separated from the optical fiber elements such that no fibers are lost from the tray during this process.

Step 4 - The mass of the entire optical bundle will be taken and recorded.

Step 5 - Sequentially, individual fibers, selected at random, will be removed from the tray and the remaining bundle mass recorded.

Step 6 - A minimum of 10 fibers shall be removed from the bundle and readings taken of the reducing bundle mass after each fiber's removal from the bundle.

4.3 Procedure III.

Step 1 - The approximate number of fibers (N) in the bundle can be calculated from

$$N = .907 \left[\frac{D}{d} - 1 \right]^2$$

where d is the average fiber diameter determined according to Method 1010 and D is the fiber bundle diameter according to Method 1020.

5. RESULTS.

5.1 Results for Procedure I.

5.1.1 The type of microscope, type of objective lens, and the magnification shall be reported.

5.1.2 The total number of fibers shall be reported.

5.2 Results for Procedure II.

5.2.1 The individual fiber masses of those fibers removed from the tray will be calculated by subtracting the bundle mass after fiber removal from the bundle mass prior to removal.

5.2.2 The ten or more fiber masses tabulated in 5.2.1 will be used to calculate an average fiber mass by summation of the fiber masses and division of this value by the number of measured fibers.

5.2.3 The number of fibers within the bundle will be calculated by division of the total bundle mass measured initially by the average fiber mass calculated in 5.2.2.

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METHOD 1040

NUMBER OF TRANSMITTING FIBERS

1. SCOPE.

1.1 This method determines the number of fibers in a bundle which are transmitting light.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable.

3. APPARATUS.

3.1 Optical microscope. An optical microscope as described in Method 1010 of DOD-STD-1678 or equal shall be used. The magnification shall be sufficient to fill a photograph with the fiber bundle image.

3.2 Photomicrographic camera. A photomicrographic camera as described in Method 1010 of DOD-STD-1678 or equivalent shall be used.

3.3 Illumination source. A white incandescent light source with adjustable intensity shall be used for backlighting the specimen.

4. PROCEDURE.

Step 1 - Both ends of the specimen shall be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so that the endfaces are perpendicular to the axis of the specimen.

Step 2 - One end of the specimen shall be placed in the illuminating source. The opposite end of the specimen shall be placed in the field of view of the optical microscope.

Step 3 - The intensity of the front and back illumination, the shutter speed and "f" stop shall be adjusted to obtain a clear photograph.

Step 4 - Several photographs of the specimen shall be taken using different intensity settings of the back illuminating source. The front illumination, shutter speed and "f" stop shall not be readjusted.

Step 5 - Using Procedure I, Method 1030 of DOD-STD-1678, the number of transmitting fibers shall be determined on each photograph.

Step 6 - If the number of transmitting fibers on the photographs obtained using the two lowest intensities are different, the intensity of the back illuminating source shall be lowered and an additional photograph taken. When the number of transmitting fibers in the two photographs are the same, this number is reported.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number

5.2 Pretest data required

5.3 Failure criteria

5.4 The type of microscope, type of objective lens, and the magnification

5.5 The number of transmitting fibers obtained on the two lowest intensities

METHOD 2010

CYCLIC FLEXING

1. SCOPE.

1.1 This method describes a procedure for determining the ability of a fiber optics cable to withstand cyclic flexing.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of the fiber optics.

3. APPARATUS.

3.1 General. The apparatus shall consist of clamps, masses, mandrel assembly, drive gears and adjustment screws arranged as shown in Figure 2010-1.

3.1.1 Mandrel assembly. The mandrel assembly shall be adjustable so that the mandrels may be brought together, remain parallel and contact the fiber optics cable. The mandrel assembly shall be adjustable in reference to the axis of rotation of the cyclic arm so that during operation vertical motion of the fiber optics cable within the mandrels is a minimum.

3.1.2 Cyclic arm. The cyclic arm shall be driven by an electric motor either whose output shaft speed is adjustable or through an infinitely adjustable transmission so that the cyclic arm is driven at 30 $\pm$ 1 cycles per minute.

3.1.3 Masses. The masses shall be so designed so that the force applied to the fiber optics cable is coincident with the axis of the cable.

4. PROCEDURES.

4.1 Procedure I.

Step 1 - Unless otherwise specified, the specimen shall be preconditioned for 48 hours at 23 $\pm$ 2°C and 50 $\pm$ 5% relative humidity.

Step 2 - Prior to cyclic testing the total number of transmitting fibers shall be determined according to Method 1040.

Step 3 - The specimen shall be placed in the cyclic flexing apparatus and unless otherwise specified in the specification sheet, the bend mandrel and mass shall be chosen according to Figure 2010-1.

Step 4 - The apparatus shall be operated for the specified number of cycles.

Step 5 - The specimen shall be removed from the apparatus and the total number of transmitting fibers determined again.

4.2 Procedure II.

Step 1 - Unless otherwise specified, the specimen shall be conditioned for 48 hours at 23 ± 2°C and 50 ± 5% relative humidity.

Step 2 - Prior to cyclic testing the output power shall be determined in accordance with Method 6010.

Step 3 - The specimen shall be placed in the cyclic flexing apparatus using the specified mandrels and mass.

Step 4 - The apparatus shall be operated for the specified number of cycles.

Step 5 - The specimen shall be removed and the output power determined again.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number

5.2 Pretest data required

5.3 Failure criteria

5.4 The percentage, P_N, of the fibers broken in the cyclic test (procedure I) shall be reported and calculated from:

$$P_N = \frac{N_1 - N_2}{N_1} \times 100$$

where N_1 is the number of transmitting fibers before cycling and N_2 is the number of transmitting fibers after cycling.

5.5 The diameter of the mandrels, the mass and number of cycles (Procedure I).

5.6 The ratio (Procedure II) of output power, R, shall be reported and calculated from:

$$R = \frac{\Phi_2}{\Phi_1}$$

where Φ_1 is the output power before cyclic flexing and Φ_2 is the output power after cyclic flexing.

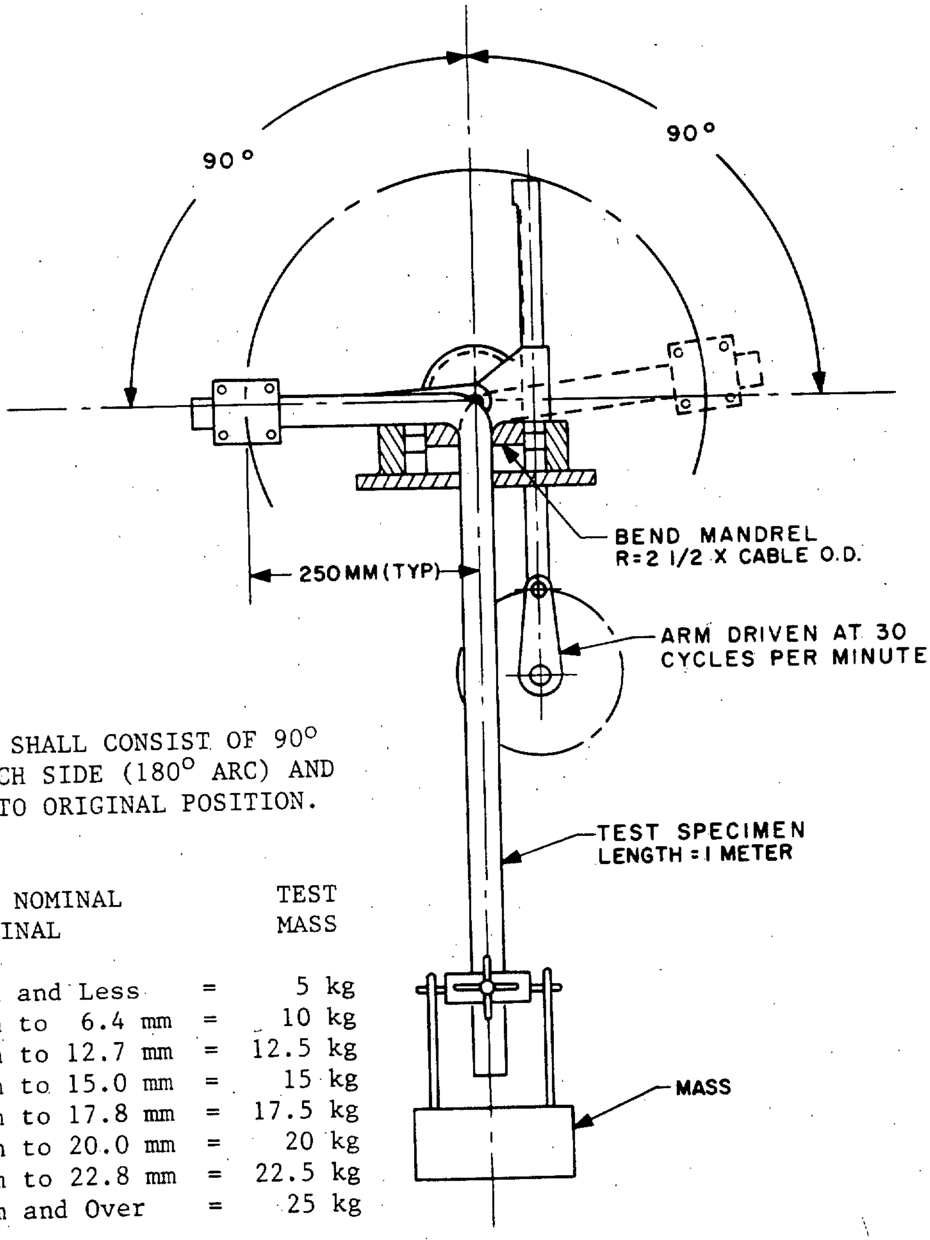
5.7 The diameter of the mandrels, the mass and number of cycles shall be reported (Procedure II).

5.8 The type, size and responsivity of the detector at the wavelength of interest (Procedure II)

5.9 The source used and launch conditions (Procedure II)

5.10 The length of the specimen.

5.11 Any visible damage to the specimen shall be reported.



NOTE:

1 CYCLE SHALL CONSIST OF 90° BEND EACH SIDE (180° ARC) AND RETURN TO ORIGINAL POSITION.

CABLE NOMINAL NOMINAL		TEST MASS
2.5 mm and Less	=	5 kg
2.6 mm to 6.4 mm	=	10 kg
6.5 mm to 12.7 mm	=	12.5 kg
14.0 mm to 15.0 mm	=	15 kg
15.3 mm to 17.8 mm	=	17.5 kg
18.0 mm to 20.0 mm	=	20 kg
20.3 mm to 22.8 mm	=	22.5 kg
22.9 mm and Over	=	25 kg

Figure 2010-1. Bend Test Fixture

METHOD 2020

LOW TEMPERATURE FLEXIBILITY (COLD BEND)

1. SCOPE.

1.1 This method describes a procedure for determining the ability of a fiber optics cable to withstand bending around a mandrel at low temperature by measuring either the fiber breakage or the transmitted power and by visual examination.

2. SPECIMEN.

2.1 The specimen shall be a representative sample of fiber optics cable whose length is at least 150 times the finished outside diameter of the cable. It shall be prepared for testing in accordance with Radiant Power Measurement, Method 6010.

3. APPARATUS.

3.1 The bending apparatus shall be as specified in Method 2011 of FED-STD-228 except for the mandrel sizes which shall be specified in the individual specification sheet. The power measurement apparatus shall be as specified in Radiant Power Measurement, Method 6010.

3.2 The test mandrels, masses, and clamping method shall be as shown in Figure 2020-1 for Procedures I and II and in Figure 2020-2 for Procedure III. The clamps shall not damage the specimen. The length of the specimen between the mandrel and the mass shall be sufficient to permit the required number of turns. (The masses shall be of values shown in Figure 2020-2.) or (The masses shall be sufficient to keep specimen taut and to permit bending without handling.)

4. PROCEDURES.

4.1 Procedure I.

Step 1 - Unless otherwise specified, the specimen shall be preconditioned for 48 hours at 23 $\pm$ 2°C and 50 $\pm$ 5% relative humidity.

Step 2 - Prior to bending the total number of transmitting fibers shall be determined according to Method 1040.

Step 3 - The specimen shall be installed on the applicable standard mandrel listed in FED-STD-228, Method 2011 and placed in the cold chamber.

Step 4 - Unless otherwise specified, the specimen shall be conditioned for 20 hours. The conditioning temperature and mass shall be as specified in the applicable specification.

Step 5 - At the end of the conditioning period and while at the conditioning temperature the specimen shall be wound at a rate of 2 turns of the mandrel per minute.

Step 6 - The specimen and mandrel shall be removed from the conditioning chamber and allowed to return to room temperature. The jacket or outer covering of the specimen shall be visually examined under 10X magnification for cracks or other defects caused by bending.

Step 7 - Within one hour from the removal from the chamber of the specimen, it shall be straightened and removed from the mandrel. The total number of transmitting fibers shall be determined again.

4.2 Procedure II.

Step 1 - Unless otherwise specified, the specimen shall be preconditioned for 48 hours at 23 ± 2°C and 50 ± 5% relative humidity.

Step 2 - Prior to bending the transmitting power, Φ_1, of the specimen shall be measured according to Radiant Power Measurement, Method 6010.

Step 3 - The specimen shall be removed from the power measurement apparatus, installed on the applicable standard mandrel listed in FED-STD-228, Method 2011 and placed in the cold chamber.

Step 4 - Unless otherwise specified, the specimen shall be conditioned for 20 hours. The conditioning temperature and mass shall be as specified in the specification sheet.

Step 5 - At the end of the conditioning period and while at the conditioning temperature the entire specimen shall be wound at a rate of 2 turns of the mandrel per minute.

Step 6 - The specimen and mandrel shall be allowed to return to room temperature. The jacket or outer covering of the specimen shall be visually examined under 10X magnification for cracks or other defects caused by bending.

Step 7 - Within one hour after reaching room temperature the specimen shall be straightened and removed from the mandrel. The transmitted power, Φ_2, of the specimen shall then be measured according to Radiant Power Measurement, Method 6010.

4.3 Procedure III.

Step 1 - Unless otherwise specified, the specimen shall be preconditioned for 48 hours at 23 $\pm$ 2°C and 50 $\pm$ 5% relative humidity.

Step 2 - Prior to bending the transmitted power, Φ_1 of the specimen shall be measured according to Radiant Power Measurement, Method 6010.

Step 3 - With the specimen connected to the power measurement apparatus, the cable shall be installed on the applicable mandrel and placed in the cold chamber. The specimen shall be clamped to the mandrel at two points adequately separated and a loop provided to avoid bending losses (see Figure 2020-1). Specimen length outside the chamber will be kept to a minimum.

Step 4 - In order to verify that the looping and clamping procedure does not cause excess loss, the transmitted power, Φ_1, shall be measured before and after installation on the mandrel.

Step 5 - Unless otherwise specified, the specimen shall be conditioned for 20 hours. The conditioning temperature and mass shall be as specified in the specification sheet.

Step 6 - At the end of the conditioning period and while at the conditioning temperature the entire specimen shall be wound at a rate of 2 turns of the mandrel per minute. The total number of turns will be specified in the specification sheet.

Step 7 - The specimen and mandrel shall be allowed to return to room temperature. The jacket or outer covering of the specimen shall be visually examined under 10X magnification for cracks or other defects caused by bending.

Step 8 - Within one hour after reaching room temperature the specimen shall be straightened and removed from the mandrel. The specimen shall not be disconnected from the power measurement apparatus. The transmitted power, Φ_2, of the specimen shall then be measured according to Radiant Power Measurement, Method 6010.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number

5.2 Pretest data required

5.3 Failure criteria

5.4 The percentage, P_N, of the fibers broken in the bending test (Procedure I) shall be reported and calculated from:

$$P_N = \frac{N_1 - N_2}{N_1} \times 100$$

5.5 The diameter of the mandrel and the mass (Procedure I).

5.6 Any cracking or splitting of the insulation (Procedure I).

5.7 The ratio (Procedure II and III) of output power, R, shall be reported and calculated from:

$$R = \frac{\Phi_2}{\Phi_1}$$

where Φ_1 is the output power before bending and Φ_2 is the output power after bending.

5.8 The length of the specimen (Procedure II and III).

5.9 The diameter of the mandrel and the mass (Procedure II and III).

5.10 Any cracking or splitting of the insulation (Procedure II and III).

5.11 The total number of turns on the mandrel.

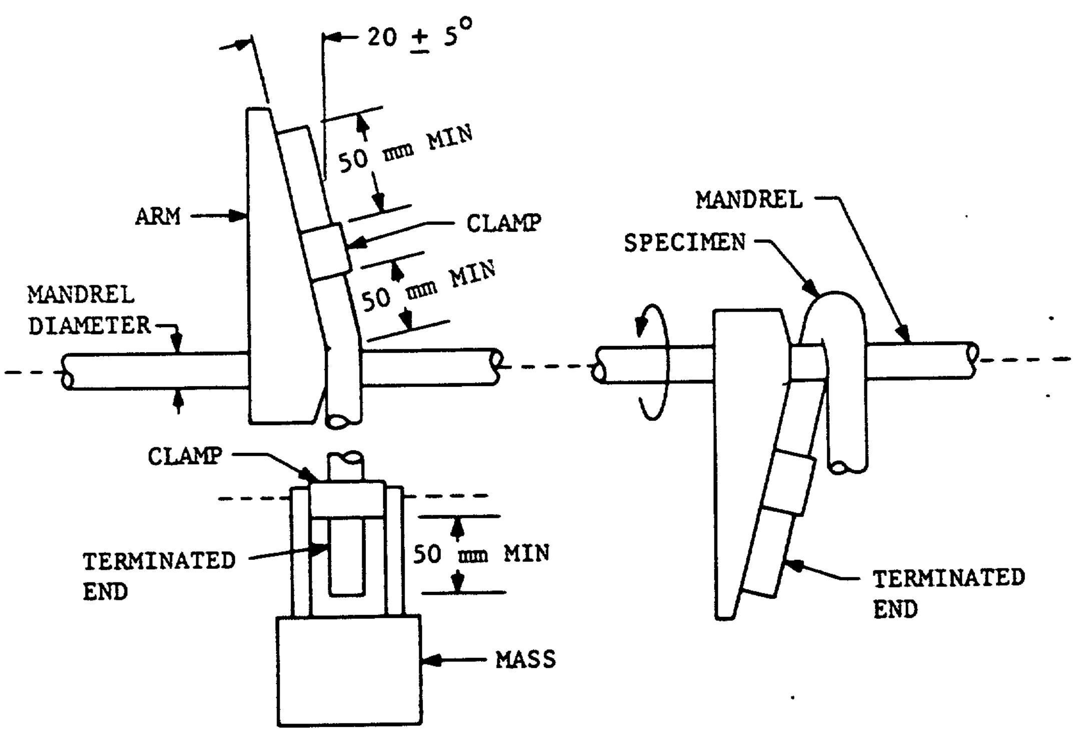
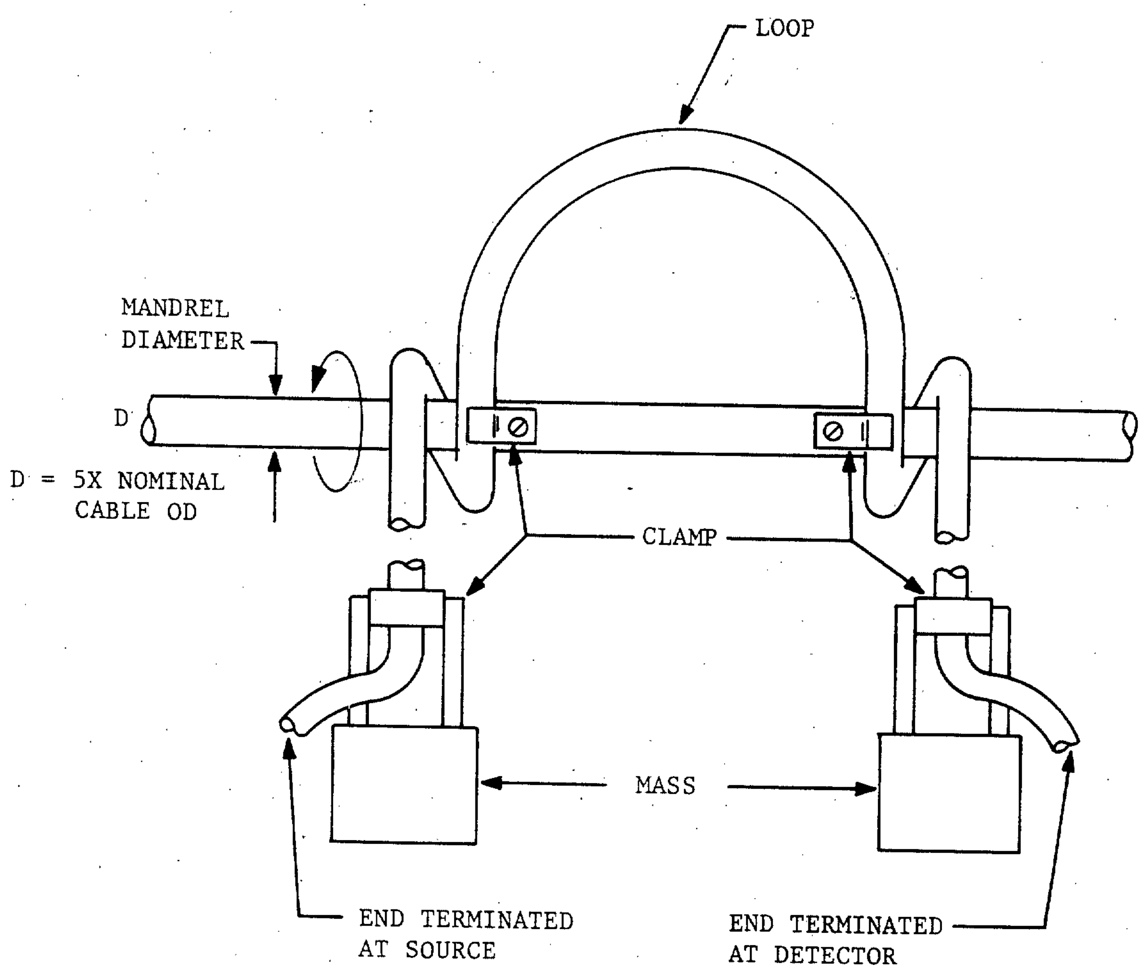


Figure 2020-1. Test Mandrels and Masses (Procedures I and II)



CABLE NOMINAL DIAMETER		TEST MASS
2.5 mm and Less	=	5 kg
2.6 mm to 6.4 mm	=	10 kg
6.5 mm to 12.7 mm	=	12.5 kg
14.0 mm to 15.0 mm	=	15 kg
15.3 mm to 17.8 mm	=	17.5 kg
18.0 mm to 20.0 mm	=	20 kg
20.3 mm to 22.8 mm	=	22.5 kg
22.9 mm and Over	=	25 kg

Figure 2020-2. Test Mandrels and Masses (Procedure III)

METHOD 2030

IMPACT TESTING

1. SCOPE.

1.1 This method determines the ability of a fiber optic cable to withstand impact loads.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of the fiber optics cable.

3. APPARATUS.

3.1 General. The apparatus shall consist of clamps, mass, drive gears, and adjustment screws arranged as shown in Figure 2030-1.

3.1.1 Drop hammer assembly. The drop hammer assembly shall be designed to permit a free vertical fall of 150 mm onto the fiber optics cable. The striking surface shall be cylindrical shaped with a minimum length of 50 mm and unless otherwise specified a radius of curvature of 10 ± .13 mm. The hardness of the striking surface and anvil shall be Rockwell RB-90, minimum. The drop hammer assembly shall be adjusted so that the axis of the striking surface will be at right angles to the axis of the cable.

3.1.2 Cyclic arm. The cyclic arm shall be driven by an electric motor whose output shaft speed is adjustable either directly or through an infinitely adjustable transmission so the cyclic arm is driven at 30 ± 1 cycles per minute.

3.1.3 Masses. The masses shall be loaded onto the hammer so that the full force is applied vertically onto the fiber optics cable unless otherwise specified.

4. PROCEDURES.

4.1 Procedure I.

Step 1 - Unless otherwise specified the specimen of the fiber optics cable shall be preconditioned for 48 hours at 50 ± 5% relative humidity and 23 ± 2°C.

Step 2 - Prior to impact testing the total number of transmitting fibers shall be determined according to Method 1040.

Step 3 - The specimen shall be placed in the impact testing apparatus and the mass of the drop hammer adjusted to the specified value by adding (or subtracting) appropriate masses.

Step 4 - The apparatus shall be operated for the specified number of cycles.

Step 5 - Unless otherwise specified, the specimen shall be removed from the apparatus and the total number of transmitting fibers determined again.

Step 6 - The specimen shall be visually inspected for any damage.

4.2 Procedure II.

Step 1 - See Step 1, Procedure I.

Step 2 - Prior to impact testing the output power shall be determined in accordance with Method 6010.

Step 3 - See Step 3, Procedure I.

Step 4 - See Step 4, Procedure I.

Step 5 - The specimen shall be removed and the output power determined again.

Step 6 - See Step 6, Procedure I.

5. RESULTS.

5.1 Results for Procedure I.

5.1.1 The percentage, P_N, of the fibers broken into the impact test shall be reported as calculated from:

$$P_N = \frac{N_1 - N_2}{N_1} \times 100$$

where N_1 is the number of transmitting fibers before impact testing and N_2 is the number of transmitting fibers after impact testing.

5.1.2 The weight applied to the drop hammer and the number of cycles shall be reported.

5.1.3 Any visible damage to the specimen shall be reported.

5.1.4 Temperature(s) at which test was performed if other than room ambient.

5.2 Results for Procedure II.

5.2.1 The ratio of output power, R, resulting from the impact test, shall be reported as calculated from:

$$R = \frac{\Phi_2}{\Phi_1}$$

where Φ_1 is the output power before impact testing and Φ_2 is the output power after impact testing.

5.2.2 The weight applied to the drop hammer and the number of cycles shall be reported.

5.2.3 Any visible damage to the specimen shall be reported.

5.2.4 The type, size and responsitivity of the detector at the wavelength of interest shall be reported.

5.2.5 The source used and launch conditions shall be reported.

5.2.6 Same as 5.1.4.

NOTE: Cable exterior deformation will not be considered as damage. However, cracking, splitting or other similar effects shall be considered as damage.

CABLE NOMINAL DIAMETER		TEST MASS
2.5 mm and Less	=	0.5 kg
2.6 mm to 6.4 mm	=	1.5 kg
6.5 mm to 12.7 mm	=	3.0 kg
12.73 mm to 13.9 mm	=	6.0 kg
14 mm to 15 mm	=	7.5 kg
15.3 mm to 17.8 mm	=	9.0 kg
18 mm to 20 mm	=	10.5 kg
20.3 mm to 22.8 mm	=	12.0 kg
22.9 mm and Over	=	13.5 kg

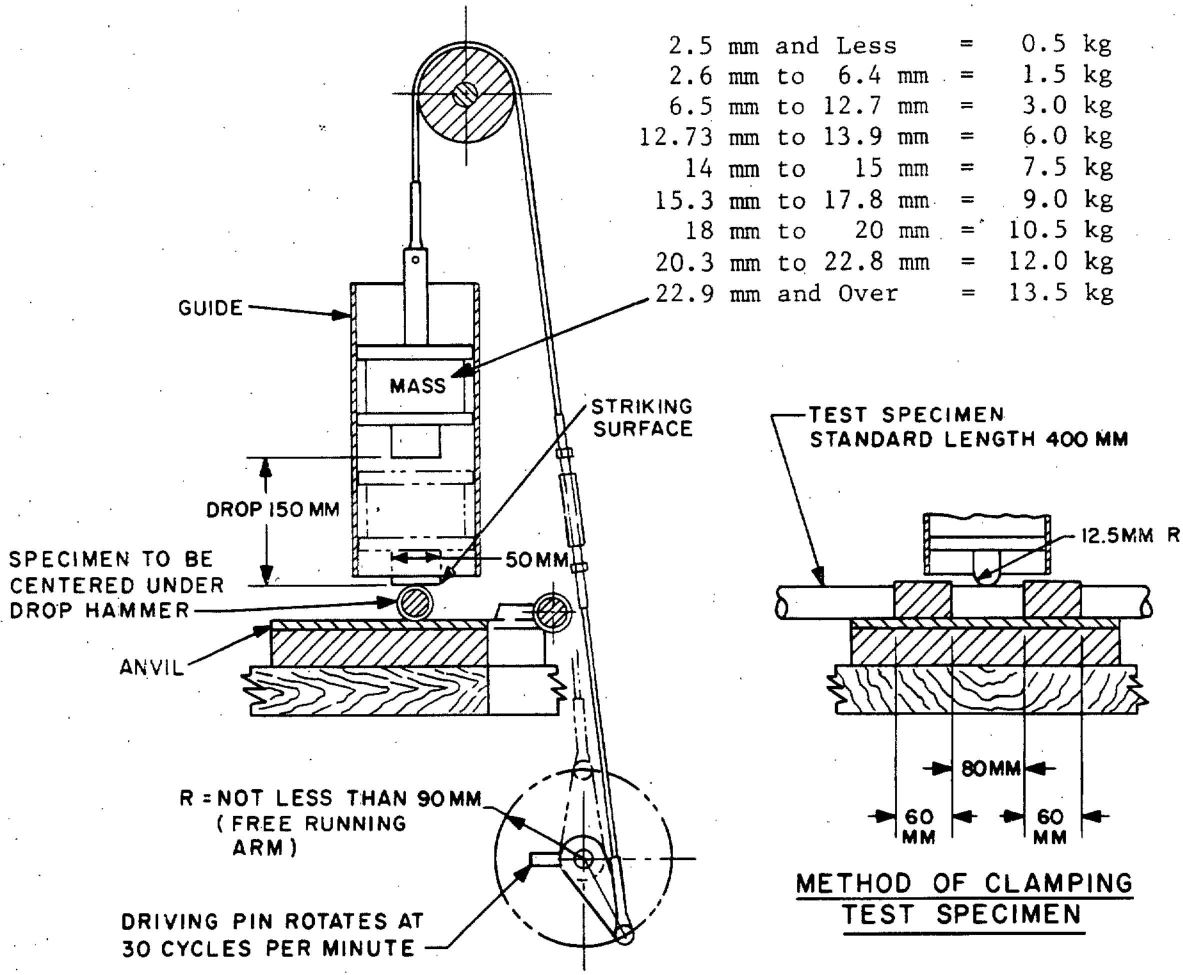


Figure 2030-1. Impact Test, Fixture Cable Testing

METHOD 2040

COMPRESSIVE STRENGTH

1. SCOPE.

1.1 This method determines the ability of a fiber optics cable to withstand slow compression or crushing.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable.

3. APPARATUS.

3.1 General. The tensile load apparatus shall be as described in Method 3001 of FED-STD-228 or shall consist of clamps, masses, drive gears and adjustment screws arranged as shown in Figure 2040-1.

3.1.1 Test fixture. The movable portion of the test fixture shall be a flat plate as shown in Figure 2040-1. The hardness of both the stationary and movable plates shall be Rockwell RB-90, minimum. The cable specimen shall be mounted so as to prevent lateral motion of the cable in the test fixture.

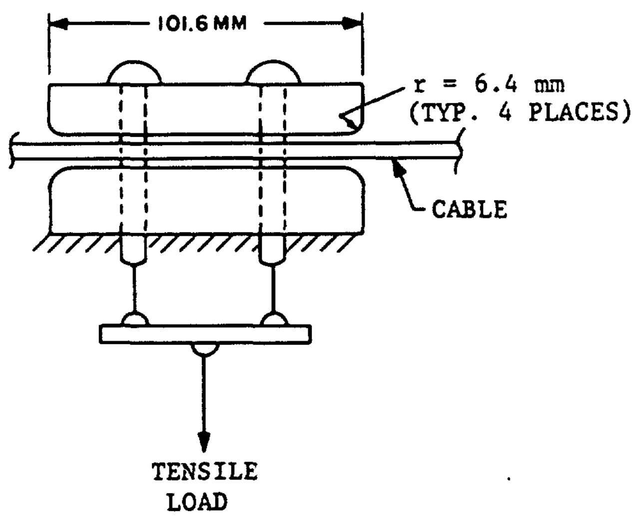


Figure 2040-1. Test Arrangements for Crush and Shear Testing

4. PROCEDURE.

4.1 Procedure I.

Step 1 - Unless otherwise specified the specimen of fiber optics cable shall be preconditioned for 48 hours at 50 ± 5% R.H. and 23 ± 2°C.

Step 2 - Prior to compressive strength testing the total number of transmitting fibers shall be determined according to Method 1040.

Step 3 - The specimen shall be placed in the test apparatus.

Step 4 - The apparatus shall be operated to apply the specified load at the specified rate.

Step 5 - Unless otherwise specified, the specimen shall be removed from the apparatus and the total number of transmitting fibers determined again.

Step 6 - The specimen shall be visually inspected for damage.

4.2 Procedure II.

Step 1 - See Step 1, Procedure I.

Step 2 - Prior to compressive strength testing the output power shall be determined in accordance with Method 6010.

Step 3 - See Step 3, Procedure I.

Step 4 - See Step 4, Procedure I.

Step 5 - The specimen shall be removed and the output power determined again.

Step 6 - See Step 6, Procedure I.

4.3 Procedure III.

Step 1 - See Step 1, Procedure I.

Step 2 - See Step 2, Procedure II.

Step 3 - See Step 3, Procedure I.

Step 4 - The output power shall be measured continuously during the application of the compressive load in accordance with Method 6010.

Step 5 - See Step 4, Procedure I.

Step 6 - See Step 5, Procedure II.

Step 7 - See Step 6, Procedure I.

5. RESULTS.

5.1 Results for Procedure I.

5.1.1 The percentage, P_N, of the fibers broken in the compressive strength test shall be reported as calculated from:

$$P_N = \frac{N_1 - N_2}{N_1} \times 100$$

where N_1 is the number of transmitting fibers before compressive strength testing and N_2 is the number of transmitting fibers after compressive strength testing.

5.1.2 The maximum load applied during the test and the loading rate shall be reported.

5.1.3 Any damage to the specimen shall be reported.

5.1.4 Temperature(s) of test if other than room ambient.

5.2 Results for Procedure II.

5.2.1 The ratio of output power, R, resulting from the compressive strength test, shall be reported as calculated from:

$$R = \frac{\Phi_2}{\Phi_1}$$

where Φ_1 is the output power before compressive strength testing and Φ_2 is the output power after compressive strength testing.

5.2.2 The maximum load applied during the test and the loading rate shall be reported.

5.2.3 Any damage to the specimen shall be reported.

5.2.4 The type, size and responsitivity of the detector at wavelength of interest shall be reported.

5.2.5 The source used and launch conditions shall be reported.

5.2.6 Same as 5.1.4

5.3 Results for Procedure III.

5.3.1 The output power Φ shall be plotted as a function of applied load.

5.3.2 The maximum load applied during the test and the loading rate shall be reported.

5.3.3 Any damage to the specimen shall be reported.

5.3.4 The type, size and responsitivity of the detector at the wavelength of interest shall be reported.

5.3.5 The source used and launch conditions shall be reported.

5.3.6 Same as 5.1.4

NOTE: Cable exterior deformation will not be considered as damage. However, cracking, splitting or similar effects shall be considered as damage.

METHOD 2050

CABLE TWIST

1. SCOPE.

1.1 This method describes a procedure for determining the ability of fiber optics cable to withstand twisting. The following parameters are either measured or observed:

a. The number of broken fibers caused by twisting

b. The change in attenuation caused by twisting

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable.

3. APPARATUS.

3.1 Suitable cable gripping blocks with supports and a torquing lever shall be used to perform the twist test.

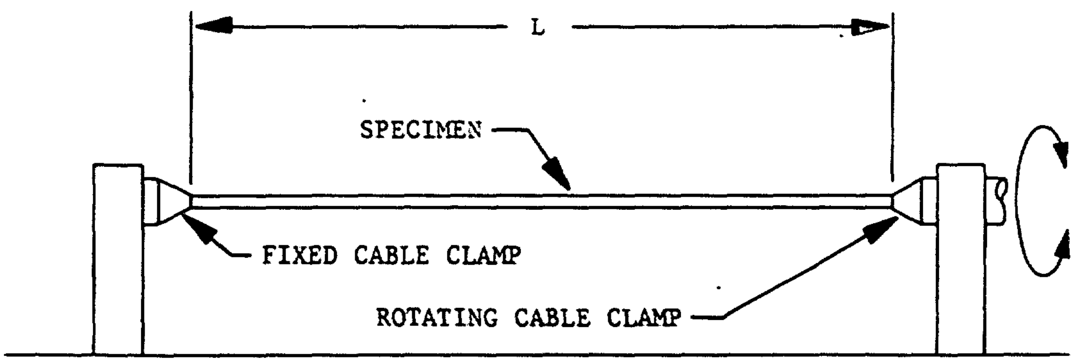


Figure 2050-1. Cable Twisting Apparatus

4. PROCEDURES.

4.1 Procedure I.

Step 1 - Prior to twisting, the number of transmitting fibers N, shall be determined in accordance with Method 1040 of DOD-STD-1678.

Step 2 - The specimen shall be installed in the apparatus with length L as specified in the applicable specification.

Step 3 - The moveable cable clamp shall be rotated 180 degrees clockwise, returned to the starting position and then rotated 180 degrees counter-clockwise and returned to the starting position. This constitutes a cycle.

Step 4 - Unless otherwise specified, Step 3 shall be repeated for a total of ten cycles. During the tenth cycle determine the number of transmitting fibers with the cable rotated 180 degrees clockwise, 180 degrees counter-clockwise and after the completion of the tenth cycle.

4.2 Procedure II.

Step 1 - Prior to twisting, the total transmitted power, Φ_1, shall be measured in accordance with Method 6010 of DOD-STD-1678.

Step 2 - The specimen shall be installed in the apparatus with length L as specified in the applicable specification.

Step 3 - Same as Step 3, Procedure I.

Step 4 - Same as Step 4, Procedure I.

5. RESULTS.

5.1 Results for Procedure I.

5.1.1 The number of transmitting fibers shall be reported before, during and after the twist test.

5.2 Results for Procedure II.

5.2.1 The ratio of output power, R, resulting from the twist test shall be reported as calculated from:

$$R = \frac{\Phi_2}{\Phi_1}$$

where Φ_1, is the output power before twisting and Φ_2 is the output power after twisting.

5.2.2 Any visible damage to the specimen shall be reported.

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METHOD 2060

CABLE TWIST-BEND

1. SCOPE.

1.1 This method describes a procedure for determining the ability of fiber optics cable to withstand twisting. The following parameters are either measured or observed.

a. The number of broken fibers caused by twisting.

b. The change in attenuation caused by twisting.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable.

3. APPARATUS.

3.1 The apparatus shall be as shown in Figure 2060-1.

4. PROCEDURES.

4.1 Procedure I.

Step 1 - Prior to twisting, the number of transmitting fibers N, shall be determined in accordance with Method 1040 of DOD-STD-1678.

Step 2 - The specimen shall be installed in the apparatus with length as specified in the applicable specification.

Step 3 - The cable shall be rotated 180 degrees clockwise, returned to the starting position and then rotated 180 degrees counterclockwise and returned to the starting position. This constitutes a cycle.

Step 4 - Unless otherwise specified, Step 3 shall be repeated for a total of 1999 cycles. During the 2000th cycle determine the number of transmitting fibers with the cable rotated 180 degrees clockwise, 180 degrees counterclockwise and after the completion of the 2000th cycle.

4.2 Procedure II.

Step 1 - Prior to twisting, the attenuation shall be measured in accordance with Method 6020 of DOD-STD-1678.

Step 2 - The specimen shall be installed in the apparatus as specified in the applicable specification.

Step 3 - Same as Step 3, Procedure I.

Step 4 - Same as Step 4, Procedure I.

5. RESULTS.

5.1 Reporting for Procedure I.

5.1.1 The number of transmitting fibers shall be reported before, during and after the twist test.

5.2 Reporting for Procedure II.

5.2.1 The ratio of output power, R, resulting from the twist test shall be reported as calculated from:

$$R = \frac{\Phi_2}{\Phi_1}$$

where Φ_1 is the output power before twisting and Φ_2 is the output power after twisting.

5.2.2 Any visible damage to the specimen shall be reported.

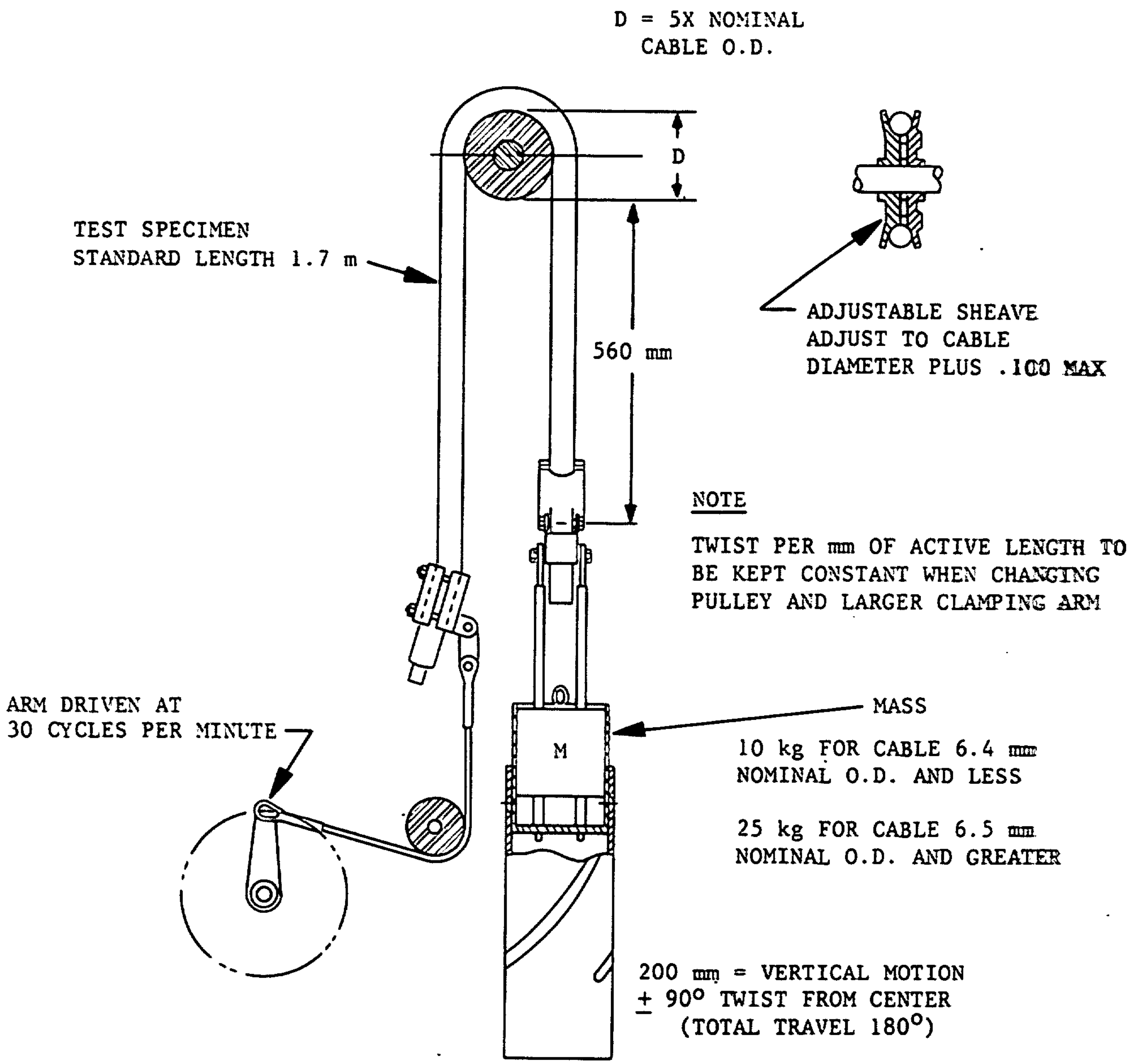

Figure 2060-1. Twist-Bend, Test, Fixture, Cable Testing

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METHOD 3010

CABLE TENSILE LOAD

1. SCOPE.

1.1 This method describes a procedure for determining the ability of fiber optics cable to withstand tensile loading. The following parameters are either measured or observed.

a. Percent increase in length under tension.

b. Percent of broken fibers caused by tension.

c. A measure of the change in radiant power caused by tension.

d. Ability of a strength member, if any, to withstand tensile load.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable.

3. APPARATUS.

3.1 The tensile load apparatus shall meet the requirements of Methods 3001 and 3016 of FED-STD-228 and as specified herein.

3.1.1 Sufficient clamps, pulleys, masses, tension measuring gauges and length measuring scales may be employed in lieu of automatic machines if 5% accuracy of measurement is maintained.

4. PROCEDURES.

4.1 Procedure I (Transmitting Fibers).

Step 1 - Unless otherwise specified the specimen shall be preconditioned for 48 hours at 50 ± 5% relative humidity and 23 ± 2°C.

Step 2 - Prior to tensile loading the number of transmitting fibers, N_1, shall be determined in accordance with Method 1040 of DOD-STD-1678.

Step 3 - The specimen shall be installed in the apparatus as specified in the applicable specification.

Step 4 - Unless otherwise specified the specimen shall be preloaded with a 4.5 kg load.

Step 5 - The length, L_1, of the specimen or strength member, as applicable, between the holding fixtures of the tensile apparatus shall be measured. This length shall be established by gauge marking the specimen (or strength member).

Step 6 - The specimen shall then be subjected to the tensile load specified in the applicable specification.

Step 7 - Unless otherwise specified the tensile load shall be maintained for 5 minutes.

Step 8 - At the end of the tensile load period and while still under tension the length, L_2, of the specimen shall be determined by measuring the distance between gauge marks. Unless otherwise specified, the number of transmitting fibers, N_2, shall be determined while the specimen is still under tension.

4.2 Procedure II (Radiant Power).

Step 1 - See Step 1, Procedure I.

Step 2 - Prior to tensile loading the radiant power, Φ_1, shall be measured in accordance with Method 6010 of DOD-STD-1678.

Step 3 - See Step 3, Procedure I.

Step 4 - See Step 4, Procedure I.

Step 5 - See Step 5, Procedure I.

Step 6 - See Step 6, Procedure I.

Step 7 - See Step 7, Procedure I.

Step 8 - At the end of the tensile load period and while still under tension the length, L_2, of the specimen shall be determined as in Step 8 of Procedure I. Unless otherwise specified, the radiant power, Φ_2, shall be measured while the specimen is still under tension.

5. RESULTS.

5.1 Results for Procedure I.

5.1.1 The percentage of fibers broken in the tensile loading shall be reported as calculated from:

$$P_N = \frac{N_1 - N_2}{N_1} \times 100$$

5.1.2 The percentage increase in length shall be reported as calculated from:

$$P_L = \frac{L_2 - L_1}{L_1} \times 100$$

5.1.3 The preload, if other than 4.5 kg, shall be reported.

5.1.4 The length, L_1, of the specimen shall be reported.

5.1.5 Any cracking or splitting of the jacket or rupture or damage to the strength member shall be reported.

5.1.6 The temperature of test, if other than room ambient, shall be reported.

5.1.7 The tensile load used shall be reported.

5.2 Results for Procedure II.

5.2.1 The ratio of output power, R, shall be reported as calculated from:

$$R = \frac{\Phi_2}{\Phi_1}$$

5.2.2 The radiation source, center wavelength(s), bandpass at the wavelength(s) and numerical aperture of the launched radiation cone shall be reported.

5.2.3 The identity and refractive index at the wavelength(s) of interest of index matching fluids, if used, shall be reported.

5.2.4 The type, size and responsivity of the detector at the wavelength(s) of interest shall be reported.

5.2.5 Same as 5.1.2

5.2.6 Same as 5.1.3

5.2.7 Same as 5.1.4

5.2.8 Same as 5.1.5

5.2.9 Same as 5.1.6

5.2.10 Same as 5.1.7

METHOD 4010

POWER TRANSMISSION VS. TEMPERATURE

1. SCOPE.

1.1 This method describes a procedure for determining the effect of the temperature upon the transmitted power of a fiber optics cable. The temperature effect on transmitted power is defined as:

$$R = \frac{\Phi_2}{\Phi_1}$$

where Φ_2 is the radiant power at temperature T_2 and Φ_1 is the radiant power at T_1 (Note: $T_2 > T_1$). Unless otherwise specified $T_1 = 25^\circ C$.

2. SPECIMEN.

2.1 The specimen shall be as specified in Radiant Power Measurement, Method 6010.

3. APPARATUS.

3.1 The apparatus shall be as specified herein and in Radiant Power Measurement, Method 6010.

3.2 Chamber. The volume of the test chamber shall be of sufficient size so that the specimen within it will not interfere with the generation and maintenance of the test conditions. The heat source shall be located so that the radiant heat will not fall directly on the specimen. Unless otherwise specified, thermocouples or equivalent temperature sensors shall be used to determine the temperature within the chamber and to control the chamber temperature.

4. PROCEDURE.

Step 1 - The output of the source shall be adjusted to the center wavelength, bandwidth and intensity of interest.

Step 2 - Both ends of a long length of the specimen shall either be prepared in accordance with Method 8040 of DOD-STD-1678 and polished so that the endfaces are perpendicular to the axis of the specimen, or index matching fluid shall be used to couple the optical power between source and specimen and specimen detector. The total length (L_4) of the specimen shall be determined.

Step 3 - The specimen shall be placed in the test chamber as shown in Figure 4010-1.

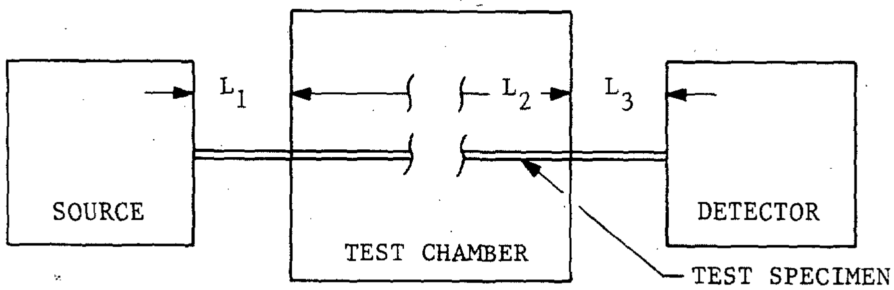

Figure 4010-1. Test Chamber

Unless otherwise specified, the length of specimen shall be loosely coiled and the diameter of the coil shall be no less than 300 mm. The coil shall be supported in such a manner as to facilitate free movement of air through it. The length, L_2, within the chamber shall be determined. The lengths, L_1 and L_3, outside the chamber shall be as short as practical.

Step 4 - One end of the specimen shall be placed in the specified radiation beam so that the entire end is uniformly illuminated with the launch cone specified in the specification sheet.

Step 5 - The other end shall be placed so that the axis of the output cone of radiation is perpendicularly incident on the detector and all of the radiation impinges on the detector. If an integrating sphere is used, the end shall be placed within the sphere.

Step 6 - A cladding mode stripper, if used, shall be applied to the fiber(s) in the specimen.

Step 7 - With the specimen and test chamber at room ambient conditions measure the temperature, T_1, of the specimen.

Step 8 - The relative (or absolute) radiant power, Φ_1, shall be measured at the specified wavelength(s). If required by the specification sheet, the number of transmitting fibers shall be determined by Method 1040.

Step 9 - The temperature of the chamber (and specimen) shall be raised to the temperature specified in the specification sheet. Unless otherwise specified, the specimen shall be conditioned for 4 hours. At the end of the conditioning period the temperature, T_2, shall be measured.

Step 10- While still within the chamber and at temperature T_2, the relative (or absolute) radiant power, Φ_2, shall be measured at the specified wavelength(s). If required by the specification sheet, the number of transmitting fibers shall be determined by Method 1040.

Step 11 The ratio of transmitted power, R, shall be calculated according to the formula in section 1 for each of the wavelengths and temperatures specified.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria

5.4 The ratio, wavelength(s) and temperature(s) where the transmitted power was measured.

5.5 The radiation source, center wavelength(s), bandpass at the wavelength(s) and numerical aperture of the launched radiation cone.

5.6 The total length of the specimen, L_4, and the length of the specimen in the conditioning chamber, L_2.

5.7 The number of transmitting fibers before and after heat conditioning if required.

5.8 The identity and refractive index at the wavelength(s) of interest of index matching fluids, if used.

5.9 The type of cladding mode stripper, if used.

5.10 The type, size and responsivity of the detector at the wavelength(s) of interest.

METHOD 4020

POWER TRANSMISSION VS. TEMPERATURE CYCLING (THERMAL SHOCK)

1. SCOPE.

1.1 This method describes a procedure for determining the effect of temperature cycling upon the transmitted power of a fiber or bundle. The temperature cycling effect on transmitted power is defined as:

$$R = \frac{\Phi_2}{\Phi_1}$$

where Φ_2 is the radiant power after temperature cycling and Φ_1 is the radiant power before temperature cycling.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable.

3. APPARATUS.

3.1 The apparatus shall be as specified herein and in Radiant Power Measurement, Method 6010.

3.2 Chamber. Temperature cycling shall be accomplished either by manually transferring the specimen or automatically transferring the specimen. The high and low temperature chamber shall meet the requirements of Method 107 of MIL-STD-202.

4. PROCEDURE.

Step 1 - The specimen shall be prepared and tested for total power transmission in accordance with Method 6010. If required, the total number of transmitting fibers shall be determined according to Method 1040.

Step 2 - Unless otherwise specified the specimen shall remain connected to the power measuring apparatus during the testing. The specimen shall be wound into a loose coil with a minimum coil diameter of 300 mm. The coil shall be supported in such a manner as to facilitate handling and free movement of air through it when it is in the conditioning chamber(s).

Step 3 - The specimen shall be subjected to thermal shock testing in accordance with Method 107 of MIL-STD-202, Test Condition B.

Step 4 - The specimen shall then be removed from the test chamber and allowed to return to room ambient conditions. The total power transmission shall be measured in the same manner as in step 1. If required, the total number of transmitting fibers shall be determined according to Method 1040.

Step 5 - The ratio of transmitted power, R, shall be calculated according to the formula in section 1 for each of the wavelengths and temperatures specified.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria

5.4 The ratio, wavelength(s) and temperature(s) where the transmitted power was measured.

5.5 The radiation source, center wavelength(s), bandpass at the wavelength(s) and numerical aperture of the launched radiation cone.

5.6 The number of transmitting fibers before and after cycling, if required.

5.7 The identity and refractive index at the wavelength(s) of interest of index matching fluids, if used.

5.8 The type of cladding mode stripper, if used.

5.9 The type, size and responsivity of the detector at the wavelength(s) of interest.

5.10 The number of temperature cycles and test condition, if not as specified in step 3, shall be reported.

METHOD 4030

POWER TRANSMISSION VS. HUMIDITY

1. SCOPE.

1.1 This method describes a procedure for determining the effect of the humidity upon the transmitted power of a fiber or bundle. The humidity effect on transmitted power is defined as:

$$R = \frac{\Phi_2}{\Phi_1}$$

where Φ_2 is the radiant power at the final condition and Φ_1 is the radiant power measured after preconditioning. Provisions are made for continuously monitoring transmitted power.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable.

3. APPARATUS.

3.1 The apparatus shall be as specified herein and in Radiant Power Measurement, Method 6010.

3.2 Chamber. The volume of the test chamber shall be such that the specimen will not interfere with the generation and maintenance of the test conditions. The heat source of the test chamber shall be so located that radiant heat will not fall directly on the specimen. The chamber shall be constructed so that condensation which may occur on the inside walls of the chamber will not drop or flow onto the specimen.

4. PROCEDURE.

Step 1 - The output of the source shall be adjusted to the center wavelength, bandwidth and intensity of interest.

Step 2 - Both ends of a long length of the specimen shall either be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so that the endfaces are perpendicular to the axis of the specimen, or index matching fluid shall be used to couple the optical power between source and specimen and specimen and detector. The total length (L_4) of the specimen shall be determined.

Step 3 - The specimen shall be placed within the test chamber as shown in Figure 4030-1 and preconditioned at 25 ± 2°C and 50 ± 5% R.H. for 48 hours.

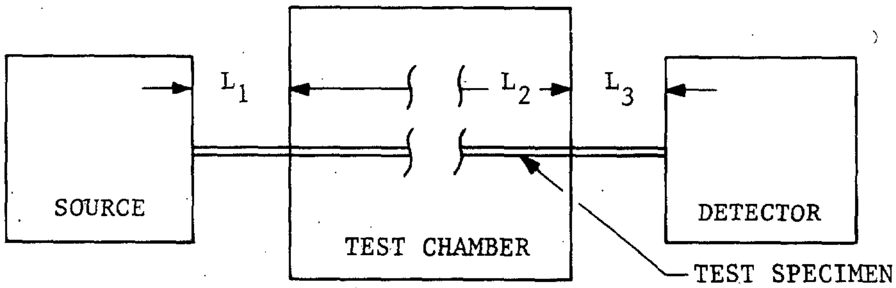

Figure 4030-1. Test Chamber

Unless otherwise specified, the length of specimen inside the chamber shall be loosely coiled and the diameter of the coil shall be no less than 300 mm. The coil shall be supported in such a manner as to facilitate free movement of air through it. The length, L_2, within the chamber shall be determined. The lengths, L_1 and L_3, outside the chamber shall be as short as practical.

Step 4 - One end of the specimen shall be placed in the specified radiation beam so that the entire end is uniformly illuminated with the launch cone specified in the specification sheet.

Step 5 - The other end shall be placed so that the axis of the output cone of radiation is perpendicularly incident on the detector and all of the radiation impinges on the detector. If an integrating sphere is used, the end shall be placed within the sphere.

Step 6 - A cladding mode stripper, if used, shall be applied to the fiber(s) in the specimen.

Step 7 - At the end of the preconditioning period the relative (or absolute) radiant power, Φ_1, shall be measured at the specified wavelengths.

Step 8 - Without removing the specimen, it shall be subjected to moisture resistance conditioning according to Method 106B of MIL-STD-202 except that the specimen shall not be vibrated.

Step 9 - At the end of the 10th cycle and while still at 25°C and 95% R.H. the relative (or absolute) radiant power, Φ_2, shall be measured. When specified, the transmitted power shall be continuously recorded throughout the 10 cycles and during an additional post-conditioning of 48 hours at 50% R.H. If required by the specification sheet, the number of transmitting fibers shall be determined by Method 1040.

Step 10- The ratio of transmitted power, R, shall be calculated according to the formula in section 1 for each of the wavelengths specified.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria.

5.4 The ratio of the transmitted power, R, and wavelength(s) where the transmitted power was measured.

5.5 The radiation source, center wavelength(s), bandpass at the wavelength(s) and numerical aperture of the launched radiation cone.

5.6 The total length of the specimen, L_4, and the length of the specimen in the conditioning chamber, L_2.

5.7 The identity and refractive index at the wavelength(s) of interest of index matching fluids, if used.

5.8 The type of cladding mode stripper, if used.

5.9 The type, size and responsivity of the detector at the wavelength(s) of interest.

5.10 If required, the minimum ratio of transmitted power, R min, shall be reported according to:

$$R\ min = \frac{\Phi\ min}{\Phi 1}$$

where Φ min is the minimum value of radiant power observed during continuous monitoring.

5.11 The relative humidity and temperature where Φ min was observed.

METHOD 4040

TENSILE LOADING VS HUMIDITY

1. SCOPE.

1.1 This method describes a procedure for measuring the effect of humidity on the tensile loading of a fiber optics cable.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable.

3. APPARATUS.

3.1 The apparatus shall be as specified in Method 3010 of DOD-STD-1678 for Procedure II and as specified herein.

3.2 Chamber. The volume of the test chamber shall be such that the specimen will not interfere with the generation and maintenance of the test conditioning. The heat source of the test chamber shall be so located that radiant heat will not fall directly on the specimen. The chamber shall be constructed so that condensation which may occur on the inside walls of the chamber will not drop or flow onto the specimen.

4. PROCEDURE.

Step 1 - Two specimens shall be tested. One specimen shall be preconditioned at 23 ± 2°C and 50 ± 5% relative humidity for 48 hours. The other shall be a reference specimen and shall be tested parallel to the humidity specimen but not subjected to humidity.

Step 2 - Both specimens shall then be subjected to tensile loading in accordance with Procedure II of Method 3010, DOD-STD-1678.

Step 3 - The ratio of transmitted power, R_1, shall be calculated for both specimens.

Step 4 - The preconditioned specimen shall then be subjected to humidity conditioning in accordance with Method 106B of MIL-STD-202 except that this specimen shall not be vibrated.

Step 5 - At the end of the 10th cycle and within 5 minutes of removal from 25°C and 95% R.H. the preconditioned specimen shall be subjected to tensile loading again.

Step 6 - For both specimens the ratio of transmitted power, R_2, shall be calculated. The final length measured shall be labeled L_4.

5. RESULTS.

5.1 Calculations (for both specimens).

5.1.1 The percent change in transmitted power ratio, P_R, shall be calculated according to the following:

$$P_R = \frac{R_1 - R_2}{R_1} \times 100$$

where R_1 and R_2 are the transmitted power ratios determined in steps 3 and 6 respectively.

5.1.2 The percent change in length, P_L, shall be calculated according to the following:

$$P_L = \frac{L_1 - L_4}{L_1} \times 100$$

where L_1 and L_4 are the original length and final length as determined in steps 3 and 6 respectively.

5.2 Reporting

5.2.1 The percent change in transmitted power ratio, P_R, shall be reported.

5.2.2 The percent change in length, P_L shall be reported.

5.2.3 The original specimen length shall be reported.

METHOD 4050

FREEZING WATER IMMERSION - ICE CRUSH

1. SCOPE.

1.1 This method describes a procedure for determining the effect of crush force caused by freezing water upon the transmitted power of a fiber optics cable immersed in the freezing water. The ice crush effect on transmitted power is defined as

$$R = \frac{\Phi_2}{\Phi_1}$$

where Φ_1 and Φ_2 are the radiant power measured before and after freezing respectively.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable.

3. APPARATUS.

3.1 The apparatus shall be as specified herein and in Method 6010.

3.2 Cable housing. The housing shall consist of a 100 mm I.D. steel pipe of 6.4 mm wall thickness. The length of the pipe shall be at least 380 mm. A 150 mm square steel flange of 6.4 mm thickness shall be welded to each end and then capped with a 150 mm square steel plate of 6.4 mm thickness bolted to it with four 6.4 mm diameter bolts. Each end cap shall have a centrally located hole of diameter slightly larger than the cable diameter to accept the cable and a grommet or similar, effective sealing device. The mating faces of the flange and plate shall be sealed using a neoprene o-ring under compression in matching circular grooves on these faces. Water shall be introduced into the housing through a 9.5 mm diameter hole in the side of the housing. This hole shall be filled with an effective sealing plug or valve.

3.3 Freezing chamber. An environmental chamber capable of maintaining the housing and specimen at the required temperature $\pm$ 1°C shall be used for temperature control.

4. PROCEDURE.

Step 1 - The output of the source shall be adjusted to the center wavelength, bandwidth and intensity of interest.

Step 2 - Both ends of the specimen shall either be prepared with standard terminations and finished so that the endfaces are perpendicular to the axis of the specimen, or index matching fluid shall be used to couple the optical power between source and specimen and specimen and detector. The total length (L_4) of the specimen shall be determined.

Step 3 - The specimen shall be placed in the cable housing and the ends and end caps sealed, see Figure 4050-1. The housing shall be completely filled with water and placed horizontally in the chamber.

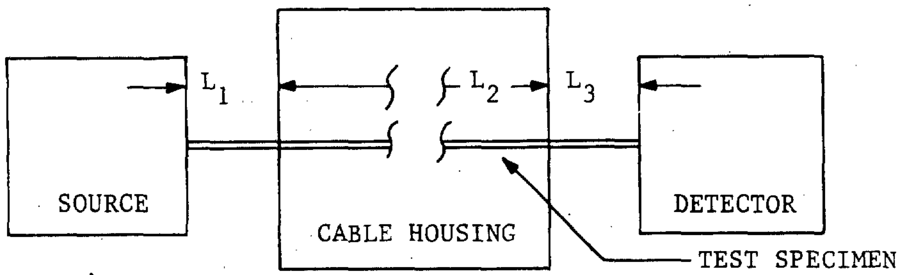

Figure 4050-1. Freezing Chamber Test Apparatus.

The length, L_2, within the housing shall be determined. The lengths, L_1 and L_3, outside the chamber shall be as short as practical.

Step 4 - One end of the specimen shall be placed in the specified radiation beam so that the entire end is uniformly illuminated with the launch cone specified in the specification sheet.

Step 5 - The other end shall be placed so that the axis of the output cone of radiation is perpendicularly incident on the detector and all of the radiation impinges on the detector. If an integrating sphere is used, the end shall be placed with the sphere.

Step 6 - A cladding mode stripper, if used, shall be applied to the fiber(s) in the specimen.

Step 7 - The radiant power, Φ_1, shall be measured in accordance with Method 6010.

Step 8 - The chamber temperature shall be lowered to -10°C at a rate of 20°C per hour. The chamber shall be maintained at that temperature for 6 hours. The temperatures shall then be raised to -2°C and maintained at that value for 1 hour.

Step 9 - The radiant power, Φ_2, shall be measured. If the specimen is a cable containing multiple fibers or multiple bundles, each fiber (or bundle) acting as a discrete optical transmission element, all transmission elements within the cable shall be tested for radiant power.

Step 10- The cable housing and specimen shall be allowed to return to room temperature. The specimen shall then be removed from the cable housing, dried and examined visually for damage.

5. RESULTS.

5.1 The ice crush effect, R, shall be reported.

5.2 The procedure used from Method 6010 to measure radiant power shall be reported.

5.3 The length of the specimen, L_2, in the cable housing shall be reported.

5.4 The temperature of test, if other than -2°C, shall be reported.

5.5 Visual observations of damage to the specimen shall be reported.

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METHOD 4060

DIMENSIONAL STABILITY

1. SCOPE.

1.1 This method describes a procedure for determining permanent dimensional changes in the jacket or covering of a fiber optics cable caused by elevated temperatures. The change is computed as a percentage as follows:

$$P_L = \frac{L_2 - L_1}{L_1} X\ 100$$

where P_L is the percentage change in jacket or covering length.

$-P_L$ is the total shrinkage of the jacket or covering

$+P_L$ is the total expansion of the jacket or covering

L_1 is the original length of the specimen.

L_2 is the length after temperature

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable.

3. APPARATUS.

3.1 Vernier caliper or equivalent shall be used to measure the shrinkage or expansion of the jacket or covering.

3.2 A meter stick or equivalent shall be used to measure the length of the specimen.

3.3 Test chamber. The volume of the test chamber shall be of sufficient size so that the specimen within it will not interfere with the generation and maintenance of the test conditions. The heat source shall be located so that the radiant heat will not fall directly on the specimen. Unless otherwise specified, thermocouples or equivalent temperature sensors shall be used to determine the temperature within the chamber and to control the chamber temperature.

4. PROCEDURE.

Step 1 - The ends of the specimen shall be cut squarely and any frayed or excess material shall be carefully removed so that all components are flush. The length of the specimen shall be as specified in the specification sheet.

Step 2 - The length, L_1, of the specimen shall be measured, see Figure 4060-1.

Step 3 - The specimen shall be placed in the temperature chamber and conditioned at the temperature and for the time specified in the specification. The specimen may be straight or coiled, but the radius of bend of the specimen shall not be less than 130 mm, if coiled.

Step 4 - After the conditioning period, the specimen shall be removed from the temperature chamber and allowed to return to room temperature.

Step 5 - The total amount of shrinkage or expansion of the jacket or covering shall be measured. The shrinkage or expansion on both ends of the specimen shall be totaled.

5. RESULTS.

5.1 The percent change in jacket or covering length, P_L, shall be reported.

5.2 The length, L_1, of the specimen shall be reported.

5.3 The time and temperature of the specimen conditioning shall be reported.

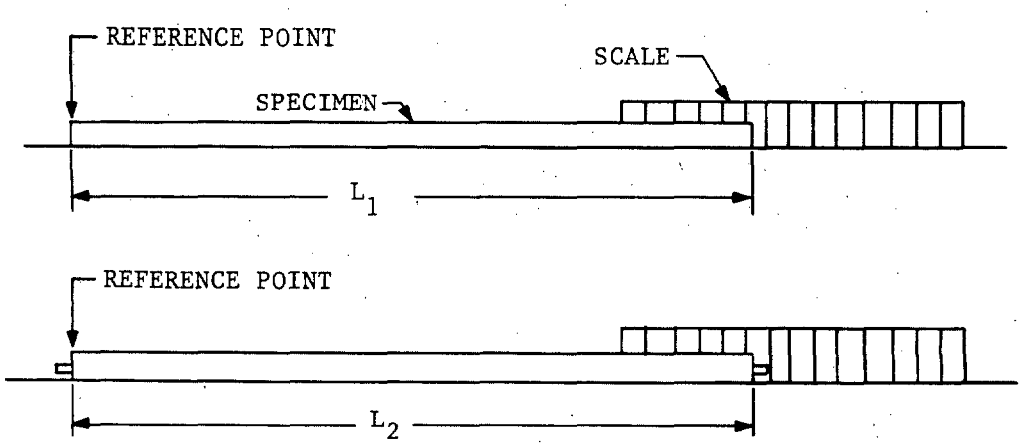


Figure 4060-1. Jacket Measuring (Shrinkage Shown).

METHOD 5010

FLAMMABILITY

1. SCOPE.

1.1 This method describes a procedure for determining the flammability of fiber optics cable.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of the fiber optics cable and shall be 600 mm in length.

3. APPARATUS.

3.1 Chamber. The test chamber shall be as described in Federal STD 191, Method 5903.

3.2 Tissue. Facial tissue conforming to Federal Specification UU-T-450.

3.3 Bunsen burner. The Bunsen burner shall have a 6.4 mm inlet, a nominal bore of 9.5 mm and a length of approximately 100 mm from top to primary inlets.

3.4 Thermocouple pyrometer.

3.5 Gas supply. Public utility or propane gas may be used.

3.6 Timepiece. A timepiece measuring seconds shall be provided to measure the duration of flame application and specimen burning time.

4. PROCEDURE.

Step 1 - The specimen shall be marked 200 mm from one end and shall be placed at an angle of 60 degrees with the horizontal, parallel to and approximately 150 mm from the front of the chamber. The bottom end of the specimen shall be that end from which the 200 mm mark has been measured.

Step 2 - The specimen shall be held tautly throughout the flammability test by clamping both ends. As an alternate, the upper end may be passed over a pulley and have attached a minimum mass necessary to hold the specimen taut.

Step 3 - The tissue shall be suspended tightly and horizontally, and centered 250 mm directly below the test mark on the specimen and at least 12.5 mm above the table top.

Step 4 - The burner shall be adjusted to produce a 75 mm high flame with an inner cone approximately one-third of the flame height. The temperature of the hottest portion of the flame, as measured with the pyrometer, shall be not less than 950°C.

Step 5 - The burner shall be positioned so that the hottest portion of the flame is applied to the test mark on the fiber optics cable. Duration of the application of flame shall be 30 seconds.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria.

5.4 The time of burning after removal of the flame.

5.5 The distance of flame travel upward along the fiber optics cable from the test mark.

5.6 Any burning particles or drippings which cause the tissue paper to burst into flame shall be reported. Charred holes or charred spots in the tissue paper caused by burning particles shall not be reported.

5.7 Specimen breakage.

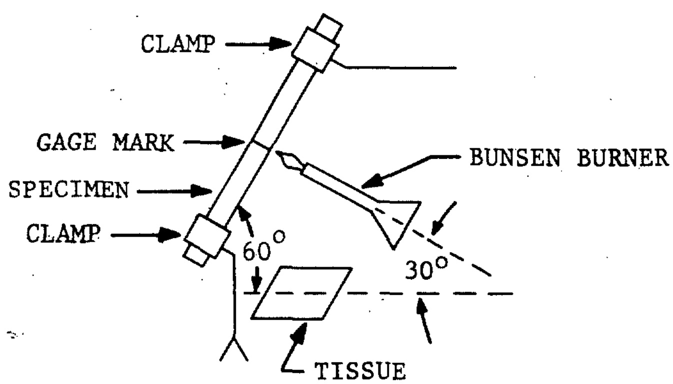


Figure 5010-1

METHOD 6010

RADIANT POWER MEASUREMENTS

1. SCOPE.

1.1 This method describes a procedure for measuring the total radiant flux (power) emanating from a source or fiber optics cable, bundle or fiber. Radiant flux is a power measurement, defined in watts where:

$$\text{Watts} = \frac{\text{Joules}}{\text{Second}} = \Phi$$

Tuned amplifier and synchronous measurement techniques are described as well as the continuous radiant power measurement. When continuous detection techniques are used, the constant value of radiant flux is measured. When synchronous or tuned amplifier techniques are used, the measured value is proportional to the total radiant flux.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of the fiber optics cable, bundle or fiber.

3. APPARATUS.

3.1 Radiation source. A suitable radiation source shall be used, such as a lamp, laser or solid state emitter. The choice of source depends upon the wavelength of radiation, launch cone and other desired characteristics. The source must be stable in intensity, uniform in intensity over the area illuminated and stable in position over a time period sufficiently long to complete the measurement procedure.

3.2 Optical filters. Optical filters may be employed with the radiation source to adjust the bandpass of the radiation.

3.3 Diffracting grating. A diffraction grating may be used to obtain the desired center frequency wavelength and bandwidth.

3.4 Iris diaphragm. An iris diaphragm may be used to define apertures and block stray radiation to the detector.

3.5 Optical lens system. An optical lens system shall be used to adjust the radiation so that the beam shape and launch pattern are repeatable.

3.6 Radiation detector. Unless an integrating sphere is used, a large area detector shall be used so that all of the radiation in the output cone is intercepted.

3.7 Integrating sphere. A properly baffled integrating sphere may be used to detect the radiant flux emanating from the specimen end. If absolute measurements of radiant flux are desired, the integrating sphere must be calibrated.

3.8 Power meter. Depending on the radiation detector used, a meter shall be used to determine the detector output parameter. The meter shall either indicate the radiant power directly or measure electrical parameter(s) so that the power may be computed from the electrical measurement(s).

3.9 Cladding mode stripper. When specified, a cladding mode stripper shall be used adjacent to the source or detector end of the specimen in order to remove radiation propagating in the fiber cladding.

3.10 Tuned amplifier. When synchronous detection techniques are used, the power meter apparatus may include a tuned amplifier capable of tuning to and locking on the light modulator frequency.

3.11 Phase lock amplifier. When synchronous detection techniques are used, the power meter apparatus may include a phase-lock amplifier capable of being synchronized and phased from the external signal supplied by a light modulator used with the radiation source.

3.12 Light modulator. When synchronous or tuned power detection techniques are employed, either the source or the radiation beam shall be modulated in such a manner as to generate a periodic radiation beam. The modulator shall supply an external signal suitable for phase locking.

4. PROCEDURES.

4.1 General.

Step 1 - The output of the source shall be adjusted to the center wavelength, bandwidth, and intensity of interest.

Step 2 - Both ends of the specimen shall be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so that the endfaces are perpendicular to the axis of the specimen, or index matching fluid may be used to couple the optical power between source and specimen and between specimen and detector. The length (L) of the specimen shall be determined.

Step 3 - One end of the specimen shall be placed in the specified radiation beam so that the entire end is uniformly illuminated with the launch cone specified in the specification sheet.

Step 4 - The other end shall be placed so that the axis of the output cone of radiation is perpendicularly incident on the detector and all of the radiation impinges on the detector. If an integrating sphere is used, the end shall be placed within the sphere.

Step 5 - A cladding stripper, if used, shall be applied to the fiber(s) in the specimen.

4.2 Procedure I. Continuous Power Measurement. (See Figure 6010-1).

Step 1 - The relative (or absolute) radiant power, Φ, shall be measured at the specified wavelength(s),

4.3 Procedure II. Tuned Power Measurement. (See Figure 6010-2).

Step 1 - The relative (or absolute) rms value of the fundamental component of the modulated radiant power, Φ, shall be measured at the specified wavelength(s).

4.4 Procedure III. Synchronous Power Measurement. (See Figure 6010-3).

Step 1 - See Step 1, Procedure II.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria.

5.4 The total power in watts and whether the power is relative or absolute (for Procedure I).

5.5 The measured rms value of the fundamental component of the modulated power and whether the power measurement is relative or absolute (for Procedure II or III).

5.6 The radiation source, center wavelength(s), bandpass at the wavelength(s) and numerical aperture of the launched radiation cone.

5.7 The type of light modulator used and the resulting waveform and modulation frequency at the input end of the specimen (when the radiation beam is modulated).

5.8 The type of tuned amplifier or phase-lock amplifier when a modulated radiation beam is used.

5.9 The length (L_1) of the specimen.

5.10 The identity and refractive index at the wavelength(s) of interest of any index matching fluids, if used.

5.11 The type of cladding mode stripper, if used.

5.12 The type, size and responsivity of the detector at the wavelength(s) of interest.

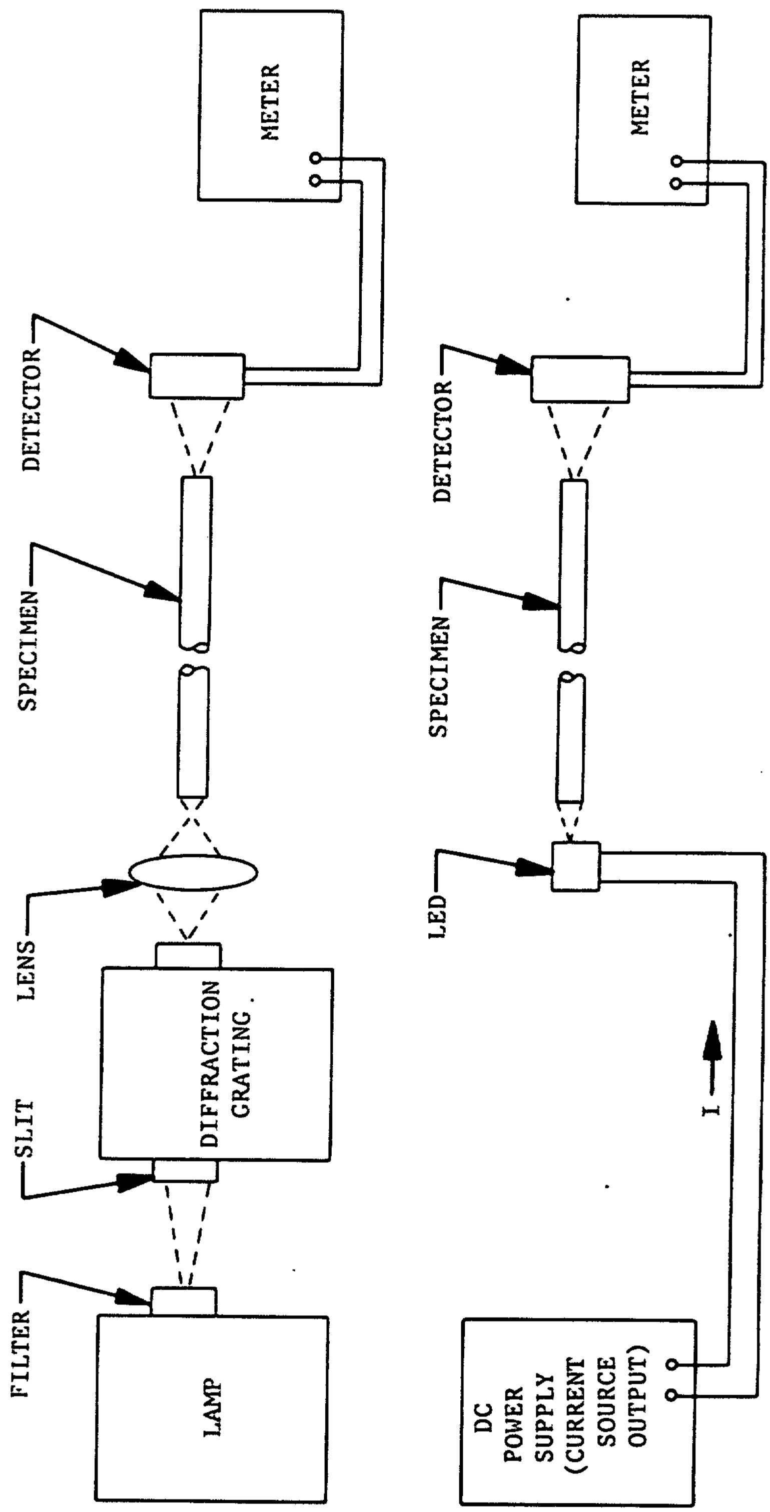


Figure 6010-1. Continuous Power Measurement (See 4.2)

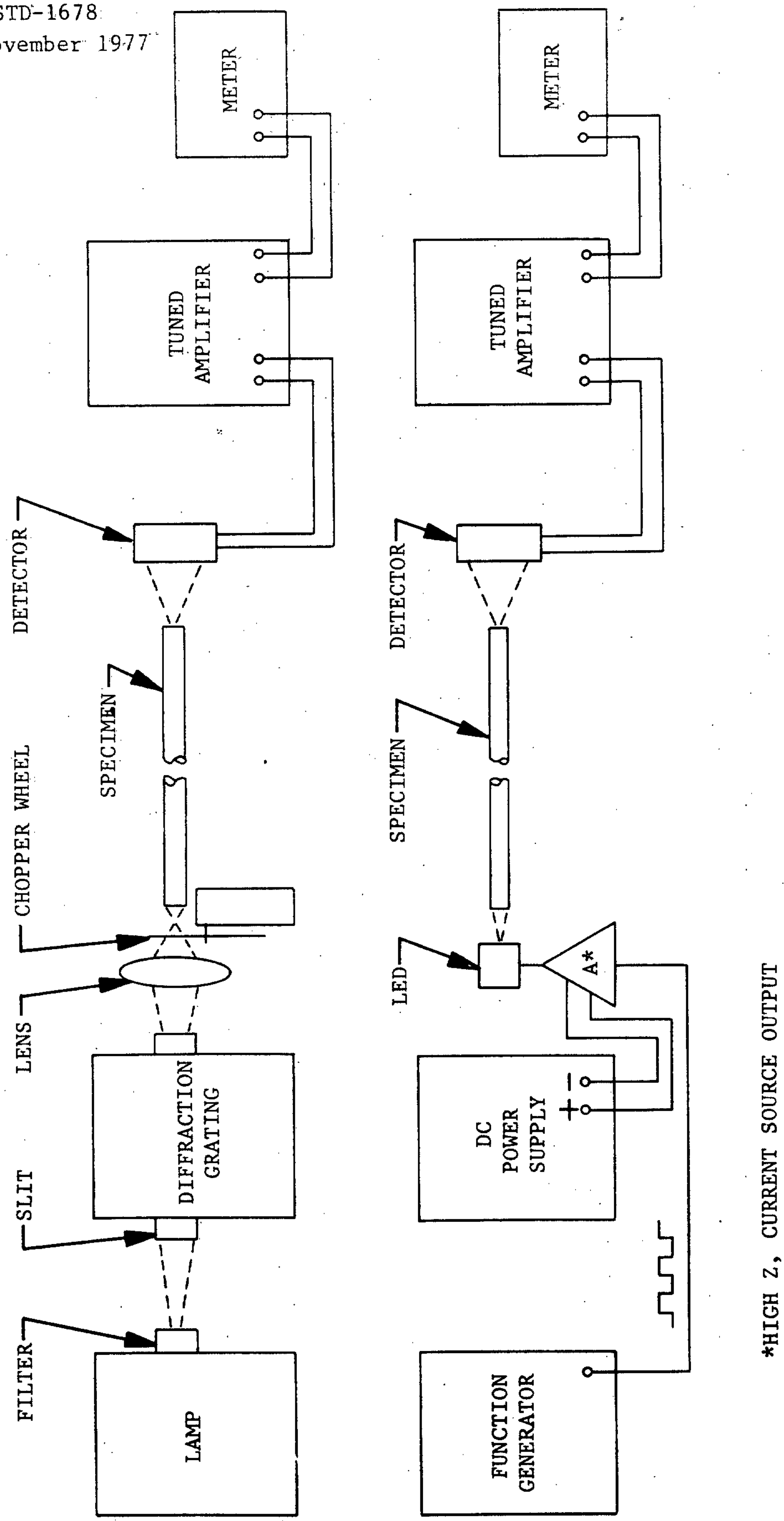
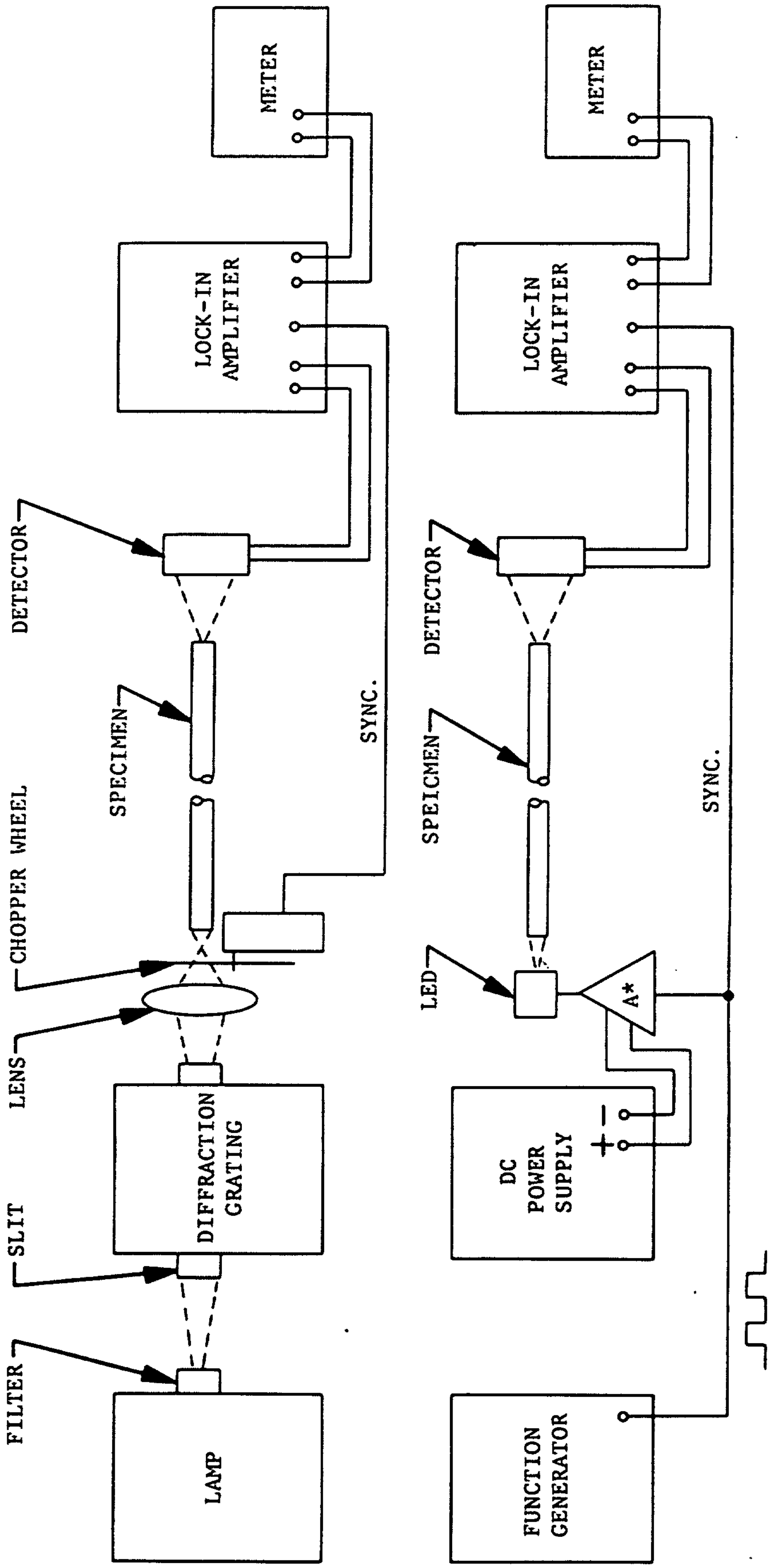


Figure 6010-2. Tuned Power Measurement (See 4.3)



*HIGH Z, CURRENT SOURCE OUTPUT

Figure 6010-3. Synchronous Power Measurement (See 4.4)

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METHOD 6020

ATTENUATION MEASUREMENT

1. SCOPE.

1.1 This method describes a procedure for measuring the optical attenuation of a specified length of fiber or bundle at specified wavelengths. It employs radiant power measurements on two known lengths of the same specimen. The optical attenuation is defined by:

$$\beta(dB/km) = \frac{-10 \text{ Log } (\Phi_1 / \Phi_2)}{\Delta L}$$

where Φ_1, is the radiant power at length L_1, Φ_2 is the radiant power at length L_2 and $\Delta L = L_1 - L_2$ (Note: $L_1 >> L_2$). The lengths are expressed in kilometers.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable, bundle or fiber. It shall be prepared for testing in accordance with Radiant Power Measurement, Method 6010 of DOD-STD-1678. The length of the specimen shall be as specified in the specification sheet.

3. APPARATUS.

3.1 The apparatus shall be as specified in Radiant Power Measurements, Method 6010.

4. PROCEDURE.

Step 1 - The output of the source shall be adjusted to the center wavelength, bandwidth and intensity of interest.

Step 2 - Both ends of a long length of the specimen shall either be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so the endfaces are perpendicular to the axis of the specimen, or index matching fluid shall be used to couple the optical power between source and specimen and between specimen and detector.

Step 3 - One end of the specimen shall be placed in the specified radiation beam so that the entire end is uniformly illuminated with the launch cone specified in the specification sheet.

Step 4 - The other end shall be placed so that the axis of the output cone of radiation is perpendicularly incident on the detector and all of the radiation impinges on the detector. If an integrating sphere is used, the end shall be placed within the sphere.

Step 5 - A cladding mode stripper, if used, shall be applied to the fiber(s) in the specimen.

Step 6 - The relative (or absolute) radiant power, Φ_1, shall be measured in accordance with Method 6010 using the procedure specified by the applicable specification and at the specified wavelength(s). If required by the specification sheet, the number of transmitting fibers shall be determined by Method 1040.

Step 7 The specimen shall be cut to the length L_2 specified in the applicable specification sheet. A new output end prepared in the same manner as in step 2.

Step 8 - The relative (or absolute) radiant power, Φ_2, shall be measured as in step 6. If required by the specification sheet, the number of transmitting fibers shall be determined by Method 1040.

Step 9 - The attenuation, β, shall be calculated according to the formula in section 1 for each of the wavelengths specified.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria.

5.4 The attenuation in dB/km and the wavelength(s) where it was measured.

5.5 The radiation source, center wavelength(s), bandpass at the wavelength(s) and numerical aperture of the launched radiation cone.

5.6 The lengths, L_1 and L_2, of the specimen tested.

5.7 If required, the number of transmitting fibers in L_1 and L_2.

5.8 The identity and refractive index at the wavelength(s) of interest of any index matching fluids, if used.

5.9 The type of cladding mode stripper, if used.

5.10 The type, size and responsivity of the detector at the wavelength(s) of interest.

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METHOD 6030

RADIATION PATTERN MEASUREMENT

1. SCOPE.

1.1 This method describes procedures for measuring the radiation pattern of a fiber, bundle or cable. In Procedures I & II, the transmitted power versus the radiation exit angle and NA (10% intensity) are determined.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber, bundle or fiber optics cable.

3. APPARATUS.

3.1 The apparatus shall be as specified herein and in Method 6010.

3.2 Radiation detector. A suitable radiation detector shall consist of either a thermopile, photomultiplier or photodiode. The choice of detector depends upon the wavelength of radiation, radiation pattern and other desired characteristics. The output signal current (or voltage) of the detector shall be proportional to the input radiant power for the wavelength interval of interest. The radiation detector may include a short length of fiber, fiber bundle or fiber optics cable. The detector aperture and distance of the detector from the finished specimen endface shall be such as to limit the half-angle of the detected cone of radiation to the maximum value specified in the specification sheet.

3.3 Radiation pattern plotter (goniometer). The radiation pattern plotter shall be a goniometer consisting of a movable arm pivoted at one end whose angular position from an arbitrary "zero" can be determined from an integral scale graduated in 1° increments with a vernier scale to estimate 10ths. Sufficient clamps, holding fixtures and alignment devices shall be used with the apparatus to insure proper physical positioning of the specimen and detector.

3.4 "X-Y" recorder. An "X-Y" recorder may be used to automatically plot the radiation detector signal vs angle.

3.5 Dark room. A dark room may be used in lieu of a filtering procedure to remove background light.

3.6 When specified, the specimen shall be wound on a holding spool or reel for test. The core diameter of the spool or reel and the tension on the specimen during winding shall be as specified.

4. PROCEDURES.

4.1 Procedure I. Finished output end, movable radiation detector.

Step 1 - The output of the source shall be adjusted to the center wavelength, bandwidth and intensity of interest.

Step 2 - Both ends of the specimen shall be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so the endfaces are perpendicular to the axis of the specimen. Index matching fluid may be used with an unpolished input end to couple the optical power between specimen and source.

Step 3 - The finished end of the specimen shall be fixed to the goniometer base and positioned such that the plane of the finished face is coincident with the axis of rotation of the movable arm. The axis of the specimen shall be coincident with the axis of radiation emanating to the detector at the arbitrary zero (see Figure 6030-1).

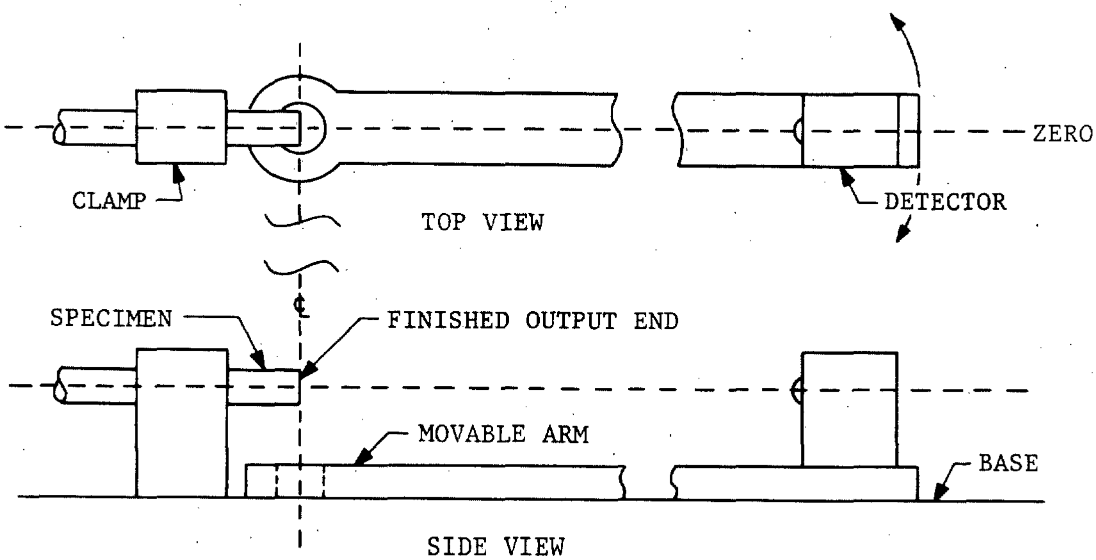

Figure 6030-1. Fixed Specimen, Movable Detector

Step 4 - The other end shall be illuminated by the source and positioned in such a manner to provide the desired launch conditions.

Step 5 - A cladding mode stripper, if used, shall be applied to the fiber(s) in the specimen.

Step 6 The detector shall be fixed to the movable end of the goniometer arm and positioned such that with the arm at the arbitrary zero it is coincident with the axis of the specimen. It shall remain at the same height relative to the base throughout the limits of rotation of the arm ($\pm$ 90^{o} from the arbitrary zero).

Step 7 The relative (or absolute) radiant power, Φ, shall be measured in accordance with Method 6010 using the procedure specified by the applicable specification and at the specified wavelength(s). The power shall be measured starting at the arbitrary zero position and at various angles (up to $\pm$ 90^{o}) from the arbitrary zero. The incremental angular steps shall be as specified in the applicable specification.

4.2 Procedure II. Fixed radiation detector, pivoting specimen output end.

Step 1 - The output of the source shall be adjusted to the center wavelength, bandwidth and intensity of interest.

Step 2 Both ends of the specimen shall be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so the endfaces are perpendicular to the axis of the specimen. Index matching fluid may be used with an unfinished end to couple the optical power between specimen and source.

Step 3 - The finished end of the specimen shall be fixed to the movable arm of the goniometer and positioned such that at the arbitrary zero the plane of the finished face is coincident with the axis of the rotation of the movable arm. The axis of the specimen shall be coincident with the axis of radiation emanating to the detector at the arbitrary zero (see Figure 6030-2).

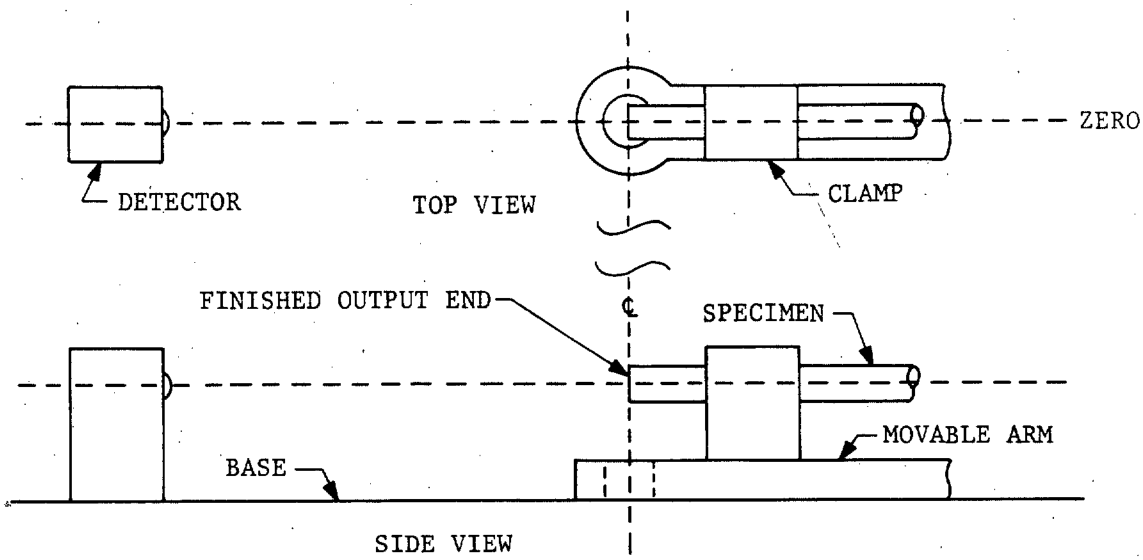

Figure 6030-2. Fixed Detector, Pivoting Specimen

Step 4 - The other end shall be illuminated by the source and positioned in such a manner to provide the desired launch conditions.

Step 5 - A cladding mode stripper, if used, shall be applied to the fiber(s) in the specimen.

Step 6 The detector shall be fixed to the base of the goniometer and positioned such that with the arm at the arbitrary zero it is coincident with the axis of the specimen.

Step 7 - The relative (or absolute) radiant power, Φ, shall be measured as in Procedure I Step 7.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria.

5.4 The type of radiation source, center wavelength and spectral bandwidth shall be reported. NOTE: If synchronous detection techniques were used, the modulation frequency shall be reported.

5.5 The type of specimen and its length.

5.6 The type of cladding mode stripper.

5.7 The numerical aperture of the launching radiation cone.

5.8 When required, the numerical aperture, NA (10% intensity) of the detected radiation cone.

5.9 The radiation pattern plot of relative radiant intensity vs angle.

5.10 The procedure (I or II) that was used.

6. NOTES.

6.1 The light source should, as nearly as practical, be Uniform Lambertian.

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METHOD 6040

ACCEPTANCE PATTERN MEASUREMENT

1. SCOPE.

1.1 This method describes a procedure for measuring the acceptance pattern of a fiber, bundle or cable by determining the total transmitted power plotted graphically against the input radiation angle. The numerical aperture NA (10% intensity) can also be determined.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber, fiber bundle or fiber optics cable.

3. APPARATUS.

3.1 The apparatus shall be as specified herein and in Method 6010.

3.2 Radiation source. The radiation source shall be as specified in Method 6010. In addition the radiation source may include a short length of fiber, fiber bundle or fiber optics cable, the fiber, bundle or cable becoming part of the source must be stable in intensity, uniform in intensity over the area illuminated and stable in position over a period sufficiently long to complete the measurement procedure. The source aperture and distance of the source from the finished specimen endface shall be such as to limit the half-angle of the input cone of radiation at the input end of the specimen to the maximum value specified in the specification sheet.

3.3 Acceptance pattern plotter (goniometer). The acceptance pattern plotter shall be a goniometer consisting of a movable arm pivoted at one end whose angular position from an arbitrary "zero" can be determined from an integral scale graduated in 1^{o} increments with a vernier scale to estimate 10ths. Sufficient clamps, holding fixtures and alignment devices shall be used with apparatus to ensure proper physical positioning of the specimen and source.

3.4 "X-Y" Recorder. An "X-Y" recorder may be used to automatically plot the radiation detector signal vs angle.

3.5 Dark room. A dark room may be used in lieu of a filtering procedure to remove background light.

3.6 When specified, the specimen shall be wound on a holding spool or reel for test. The core diameter of the spool or reel and the tension on the specimen during winding shall be as specified.

4. PROCEDURES.

4.1 Procedure I. Fixed specimen input end, movable radiation source.

Step 1 - The output of the source shall be adjusted to the center wavelength, bandwidth and intensity of interest.

Step 2 - Both ends of the specimen shall be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so the endfaces are perpendicular to the axis of the specimen. Index matching fluid may be used with an unfinished output end to couple the optical power between specimen and detector.

Step 3 - The finished end of the specimen shall be fixed to the goniometer base and positioned such that the plane of the finished face is coincident with the axis of rotation of the movable arm. The axis of the specimen shall be coincident with the axis of radiation emanating from the source (see Figure 6040-1).

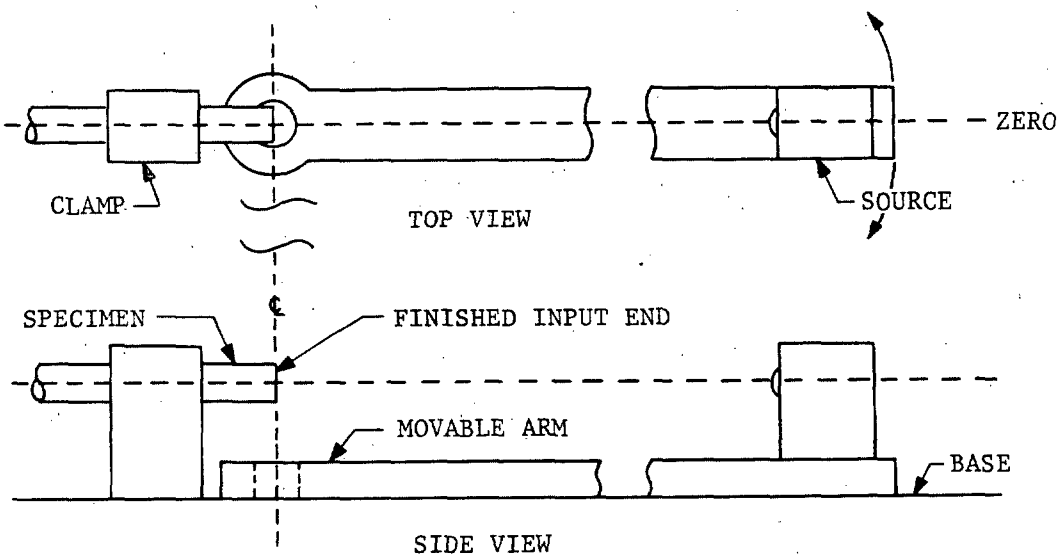

Figure 6040-1. Fixed Specimen, Movable Source

Step 4 - The other end shall be placed so that the axis of the output cone of radiation is perpendicularly incident on the detector and all of the radiation impinges on the detector, if an integrating sphere is used.

Step 5 - A cladding mode stripper, if used, shall be applied to the fiber(s) in the specimen.

Step 6 - The source shall be fixed to the movable end of the goniometer arm and positioned such that at the arbitrary zero the radiation is perpendicularly incident upon the finished face of the specimen. The radiation shall remain perpendicular to the axis of rotation of the arm throughout the limits of rotation ($\pm$ 90°) from the arbitrary zero.

Step 7 - The relative (or absolute) radiant power, Φ, shall be measured in accordance with Method 6010 using the procedure specified by the applicable specification and at the specified wavelength(s). The power shall be measured starting at the arbitrary zero position and at various angles (up to $\pm$ 90°) from the arbitrary zero. The incremental angular steps and the wavelength(s) shall be as specified in the applicable specification.

4.2 Procedure II. Fixed radiation source, pivoting specimen input end.

Step 1 - The output of the source shall be adjusted to the center wavelength, bandwidth and intensity of interest.

Step 2 - Both ends of the specimen shall be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so the endfaces are perpendicular to the axis of the specimen. Index matching fluid may be used with an unfinished output end to couple the optical power between specimen and detector.

Step 3 - The finished end of the specimen shall be fixed to the movable arm of the goniometer and positioned such that at the arbitrary zero the radiation is perpendicularly incident upon the finished face of the specimen. The radiation shall remain perpendicular to the axis of rotation of the arm throughout the limits of rotation (± 90° from the arbitrary zero).

Step 4 - The other end shall be placed so that the axis of the output cone to radiation is perpendicularly incident on the detector and all of the radiation impinges on the detector. If an integrating sphere is used, the end shall be placed within the sphere.

Step 5 - A cladding mode stripper, if used, shall be applied to the fiber(s) in the specimen.

Step 6 - The source shall be fixed to the goniometer base and positioned such that at the arbitrary zero the radiation is perpendicularly incident upon the finished face of the specimen. The axis of the specimen shall be coincident with the axis of radiation emanating from the source (see Figure 6040-2).

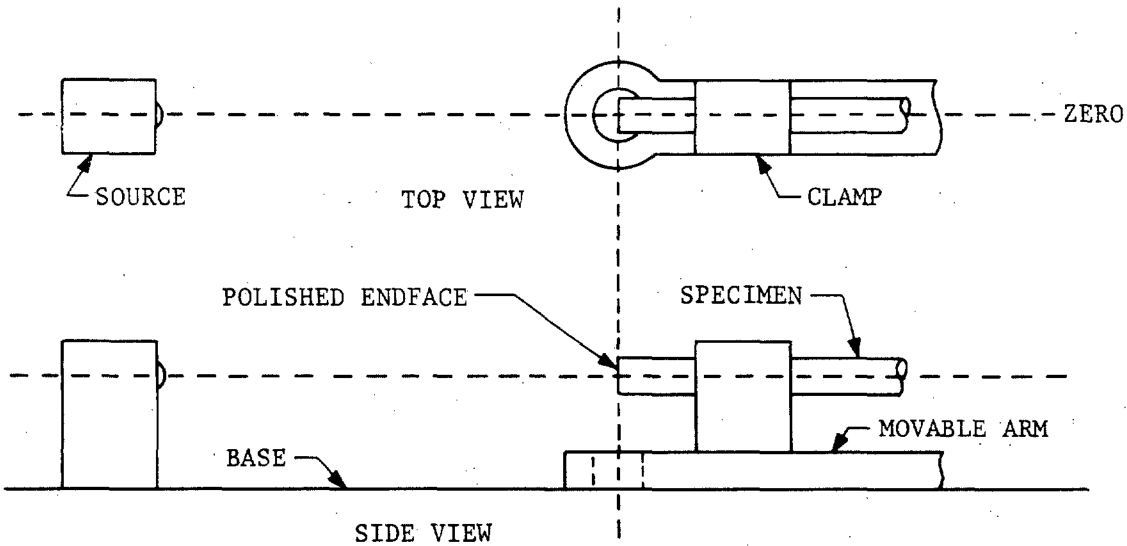

Figure 6040-2. Fixed Source, Pivoting Specimen

Step 7 - The relative (or absolute) radiant power, Φ, shall be measured as in step 7, Procedure I.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria.

5.4 The type of radiation source, center wavelength and spectral bandwidth shall be reported. If synchronous detection techniques were used, the modulation frequency shall be reported.

5.5 The type of specimen and its length.

5.6 The type of cladding mode stripper.

5.7 The source aperture and distance of the source from the finished specimen end shall be reported.

5.8 When required the numerical aperture, NA (10% intensity), of the radiation cone shall be reported.

5.9 The acceptance cone plot of relative transmitted power vs launch angle.

5.10 The procedure (I or II) that was used.

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METHOD 6050

PULSE SPREADING

1. SCOPE.

1.1 This method describes a procedure for measuring the pulse spreading (broadening) in a fiber, bundle or FO cable. The pulse spreading is defined as:

$$\tau\ (50) = \frac{(W_1{}^2 - W_2{}^2)^{1/2}}{L_1 - L_2}$$

where W_1 is the pulse width at 50% maximum pulse amplitude of the test specimen output wave form.
L_1 is the length of the test speicmen
W_2 is the pulse width at 50% maximum pulse amplitude of the reference specimen output wave form.
L_2 is the length of the reference specimen.

NOTE: $\tau(20)$ is also obtained by using W_1 and W_2 as the pulse width at 20% maximum pulse height (see Section 6).

2. SPECIMEN.

2.1 Test specimen. The test specimen shall be taken from a representative sample of fiber, bundle or FO cable.

2.2 Reference specimen. The reference specimen shall be either a short length from the same sample as the test specimen or a short length of similar fiber, bundle or FO cable, as applicable.

3. APPARATUS.

3.1 The apparatus shall be as specified herein and in Method 6010, Procedure II or III.

3.2 Beam splitter. A suitable beam splitter may be used to divide the radiation emanating from the source into two radiation beams.

3.3 Cladding mode stripper. When specified, a cladding radiation stripper shall be used adjacent to the source or detector end of the specimen in order to remove radiation propagating in the fiber cladding.

3.4 Radiation detectors. Two esentially identical detectors shall be used to detect the output radiation emanating from the test and reference specimens when the dual beam procedure is used. The spectral responsivity and response time of the detector(s) shall be compatible with the source and modulation.

3.5 Pulse recorder. A suitable pulse recorder, such as a dual beam storage oscilloscope, shall be used to display pulse amplitude versus time (pulse shape) as received at the detectors. A suitable X-Y recorder may be employed in conjunction with an oscilloscope for a permanent record of the wave forms.

3.6 Photographic camera. A suitable photographic camera may be used to obtain a permanent record of the output wave forms.

4. PROCEDURES.

4.1 Procedure I. Dual beam method.

Step 1 - The output of the source shall be adjusted, where necessary, to obtain the specified center wavelength and bandwidth. The intensity shall be adjusted to obtain sufficient detectable radiation.

Step 2 - Both ends of the test specimen and the reference specimen shall be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so that the endfaces are perpendicular to the axis of the specimen, or index matching fluid shall be used to couple the optical power between specimen and detector. The length (L_1) of the test specimen and length (L_2) of the reference specimen shall be measured.

Step 3 - One end of the test specimen shall be placed in one of the specified radiation beams so that the end is illuminated with the launch cone specified in the specification sheet. One end of the reference specimen shall be placed in the other of the specified radiation beams and likewise illuminated.

Step 4 - The other end of each specimen shall be placed so that the axis of the output cone of radiation is perpendicularly incident on their respective detectors and all of the radiation impinges on the detectors. It may be necessary to use focusing optics with small area detectors.

Step 5 - The maximum amplitude of radiation pulse shape received by the detectors shall be adjusted so that they are approximately equal and within the linear range of the detectors. This may be done by varying the beam splitting ratio or by use of an attenuator in the reference beam.

Step 6 - The output wave form from both specimens shall be recorded for a permanent record. A photograph or X-Y recording may be made of the two wave forms. Unless otherwise specified the pulse widths, W_1 and W_2, shall be measured at 50% maximum pulse amplitude (and at 20% if required). The pulse widths shall be measured in nanoseconds (ns). If $W_1 \leq 1.4\ W_2$, then the test shall be performed again after adjusting the apparatus to obtain a narrower source pulse or by using detectors with faster response or by using a longer test specimen.

Note: If none of the alternatives can, within the state of the art, satisfy $W_1 \leq 1.4\ W_2$, report this fact and report the estimate of error in the measured value of τ.

4.2 <u>Procedure II</u>. Single beam, substitution method

Step 1 - The output of the source shall be adjusted, where necessary, to obtain the specified center wavelength and bandwidth. The intensity shall be adjusted to obtain sufficient detectable radiation.

Step 2 - Both ends of the test specimen and the reference specimen shall be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so that the endfaces are perpendicular to the axis of the specimen, or index matching fluid shall be used to couple the optical power between specimen and detector. The length (L_1) of the test specimen and length (L_2) of the reference specimen shall be measured.

Step 3 - One end of the test specimen shall be placed in the specified radiation beam so that the entire end is uniformly illuminated with the launch cone specified in the specification sheet.

Step 4 - The other end shall be placed so that the axis of the output cone of radiation is perpendicularly incident on the detector and all of the radiation impinges on the detector. It may be necessary to use focusing optics with small area detectors.

Step 5 The maximum amplitude of the radiation pulse shape received by the detector shall be adjusted to a convenient height. This may be done by varying the intensity of the source.

Step 6 The output wave form shall be recorded. The pulse width, W_1, shall be measured as in Step 6 of Procedure I.

Step 7 - One end of the reference specimen shall then be placed in the specified radiation beam so that the entire end is uniformly illuminated with the same launch cone used in Step 3.

Step 8 The other end shall be placed so that the axis of the output cone of radiation is perpendicularly incident on the detector and all of the radiation impinges on the detector.

Step 9 - The maximum amplitude of the radiation pulse shape received by the detector shall be adjusted to the same height as in Step 5. The amplitude adjustment shall be made in such a way as to not alter the pulse width, W_2.

Step 10- The output wave form shall be recorded. The pulse width, W_2, shall be measured as in Step 6 of Procedure I. If $W_1 \leq 1.4\ W_2$, then the test shall be performed again using the criteria in Step 6 of Procedure I.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria.

5.4 The radiation source, center wavelength(s), bandpass at the wavelength(s) and numerical aperature of the launched radiation cone.

5.5 The length (L_1) of the test specimen and (L_2) of the reference specimen.

5.6 The identity and refractive index at the wavelength(s) of interest of any index matching fluids, if used.

5.7 The type of cladding mode stripper, if used.

5.8 The type, size and responsivity of the detector at the wavelength(s) of interest.

5.9 The test specimen configuration while under test, whether loosely coiled or wound on a reel or spool.

5.10 The pulse widths, W_1 and W_2, at 50% maximum amplitude (at 20% also when required)

5.11 The pulse spreading, τ.

5.12 The output waveform from both specimens shall be reported.

6. NOTES.

6.1 The size of spectral bandwidth depends upon whether a chromatic or monochromatic measurement is being made. The time response of the source to either internal or external modulation must be fast enough so as to approach the dispersion limits of the specimen under test.

6.2 A more accurate definition of pulse width can be given, although it is more difficult to compute.

6.2.1 Corresponding to lengths L_1 (test specimen) and L_2 (reference specimen), the pulses $S_1(t)$ and $S_2(t)$ are recorded.

6.2.2 For each pulse (K=1,2) one computes the

pulse energy $$E_K = \int S_K(t)dt$$

central time $$T_K = \frac{1}{E_K} \int t\, S_K(t)\, dt$$

RMS width $$W_K = \left[\frac{1}{E_K} \int (t-T_K)^2\, S_K(t)dt\right]^{\frac{1}{2}} = (Q_K - T_K{}^2)^{\frac{1}{2}}$$

where $$Q_K = \frac{1}{E_K} \int t^2 S_K(t)\, dt$$

6.2.3 The RMS fiber pulse spreading is determined to be

$$W = \sqrt{W_1{}^2 - W_2{}^2}$$

6.2.4 For the recorded pulses one may use a spectrum analyzer or a computer to obtain the normalized Fourier transform

$$F_K(f) = \frac{1}{E_K} \int S_K(t) \exp\,(2\pi\, ift)dt$$

where f is frequency (Hz).

6.2.5 The fiber transfer function is determined to be

$$H(f) = \frac{F_1(f)}{F_2(f)}$$

6.2.6 The fiber impulse response is determined to be

$$h(t) = \int H(f) \exp\,(-2\pi\, ift)df$$

from which various widths may be accurately recorded.

For some applications, it is desired to know the separate contributions of chromatic and monochromatic pulse spreading. The total pulse spreading is given by

$$\tau\,(\Delta\lambda) = \left[W_m{}^2 + (W_c\Delta\lambda\,)^2\right]^{\frac{1}{2}} \text{ (ns)}$$

where W_m (ns) and W_c (ns/nm) are respectively the monochromatic and chromatic contributions. If their separate evaluation is desired, pulse spreading measurements are performed with sources of two spectral widths $\Delta\lambda_1$ and $\Delta\lambda_2$ (nm). All widths are taken to be consistently 50%, 20%, or RMS as appropriate.

The chromatic pulse spreading is determined to be

$$\tau_c = \left[\frac{W^2\ (\Delta\lambda_1) - W^2\ (\Delta\lambda_2)}{(\Delta\lambda_1)^2 - (\Delta\lambda_2)^2}\right]^{1/2} \quad \text{(ns/nm)}$$

For reasonable accuracy it should be assured that $W(\Delta\lambda_1) > 3W(\Delta\lambda_2)$ otherwise the ratio $\Delta\lambda_1/\Delta\lambda_2$ must be increased, assuming the source and detector are sufficiently fast. If $W(\Delta\lambda_1) \approx W(\Delta\lambda_2)$, then this is W_m.

The monocromctic pulse spreading is determined from:

$$\tau_m = \left[\frac{W^2\ (\Delta\lambda_2) \cdot (\Delta\lambda_1)^2 - W^2\ (\Delta\lambda_1) \cdot (\Delta\lambda_2)^2}{(\Delta\lambda_1)^2 - (\Delta\lambda_2)^2}\right]^{1/2} \text{(ns)}$$

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METHOD 6060

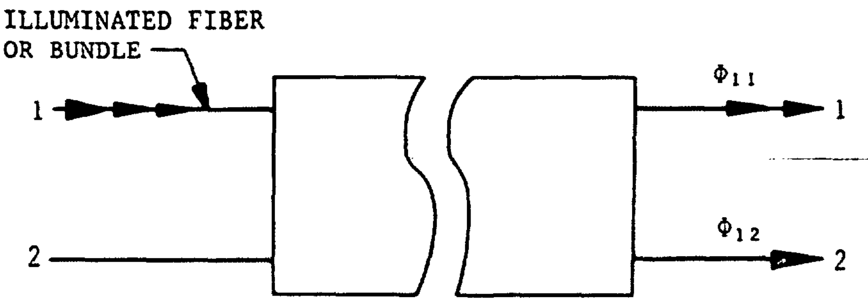
FAR-END CROSSTALK

1. SCOPE.

1.1 This method describes a procedure for measuring far-end crosstalk between two fibers (or two bundles) where each fiber (or bundle) acts as a transmission element. It employs radiant power measurements and is defined by:

$$FEXT\ (1,2) = 10 \log_{10} \ (\Phi_{11} / \Phi_{12})$$

where the first subscript represents the fiber being illuminated and the second subscript represents the fiber being monitored.



NOTE: FEXT (1,2) is the positive unit referred to as "dB down".

2. SPECIMEN.

2.1 The test specimen shall be taken from a representative sample of FO cable.

3. APPARATUS.

3.1 The apparatus shall be as specified herein and in Method 6010, Procedure II or III.

3.2 Radiation detectors. Two detectors shall be used to detect the output radiation emanating from the illuminated and neighboring fiber (bundle). The spectral responsivity and response time of the detector(s) shall be compatible with the source and modulation.

4. PROCEDURE.

Step 1 - The output of the source shall be adjusted, where necessary, to obtain the specified center wavelength and bandwidth. The intensity shall be adjusted to obtain sufficient detectable radiation.

Step 2 - Both ends of the illuminated fiber (bundle) and neighboring fiber (bundle) shall be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so that the endfaces are perpendicular to the axis of the specimen, or index matching fluid shall be used to couple the optical power between fiber (bundle) and detector. The length (L_1) of the test specimen shall be measured.

Step 3 - One end of the illuminated fiber (bundle) shall be placed in the specified radiation beam so that the entire end is uniformly illuminated with the launch cone specified in the specification sheet.

Step 4 - The other end of both the illuminated and neighboring fiber (bundle) shall be placed so that the axis of output cone of radiation is perpendicularly incident on their respective detectors and all of the radiation impinges on the detectors.

NOTE: One detector may be used and Φ_{11} and Φ_{12} measured serially (See Step 5).

Step 5 - The relative radiant power, Φ_{11}, of the illuminated fiber (bundle) and Φ_{12} of the neighboring fiber (bundle) shall be measured at the specified wavelength(s).

NOTE: If the measured value of Φ_{12} is small (less than 10 times the background noise of the dark detector) than either a shorter length of specimen or a greater source intensity should be used. It may be necessary to use calibrated attenuation in the illuminated fiber circuit.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria.

5.4 The measured power (in watts) Φ_{11} and Φ_{12}.

5.5 The radiation source, center wavelength(s), bandpass at the wavelength(s) and numerical aperture of the launched radiation cone.

5.6 The length (L_1) of the specimen.

5.7 The identity and refractive index at the wavelength(s) of interest of any index matching fluids, if used.

5.8 The far-end cross talk, FEXT (1, 2).

5.9 The pulse shape, duration and rate.

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METHOD 6070

FIBER (BUNDLE) TRANSFER FUNCTION

1. SCOPE.

1.1 This method describes a procedure for measuring the transfer function of a fiber or bundle. The transfer function is defined as:

$$FTF = H(f) = A(f)e^{i\theta(f)}$$

where A(f) is the amplitude function (ATF)
$\theta(f)$ is the phase transfer function (PTF).

2. SPECIMEN.

2.1 Test specimen. The test specimen shall be taken from a representative sample of fiber, bundle or FO cable.

2.2 Reference specimen. The reference speicmen shall be either a short length from the same sample as the test specimen or a short length of similar fiber, bundle or FO cable, as applicable.

3. APPARATUS.

3.1 The apparatus shall be as specified herein and in Method 6010, as applicable.

3.2 Sweep frequency generator. A sweep frequency generator shall be used to modulate the source.

3.3 Beam splitter. A suitable beam splitter shall be used to divide the radiation emanating from the source into two radiation beams.

3.4 Radiation detectors. Two essentially identical detectors shall be used to detect the output radiation emanating from the test and reference specimens. The spectral responsivity and response time of the detector(s) shall be compatible with the source and modulation.

3.5 Two-channel recorder. A calibrated recorder, such as a vector volt-meter or network analyzer, shall be used to measure the output of the detectors both with respect to amplitude and phase.

3.6 X-Y recorder. A suitable X-Y recorder shall be used to record the voltage vs frequency and phase angle vs frequency.

4. PROCEDURE.

Step 1 - The output of the source shall be adjusted, where necessary, to obtain the specified center wavelength and bandwidth. The intensity shall be adjusted to obtain sufficient detectable radiation.

Step 2 - Both ends of the test specimen and the reference specimen shall be prepared in accordance with Method 8040 of DOD-STD-1678 and finished so that the endfaces are perpendicular to the axis of the specimen, or index matching fluid shall be used to couple the optical power between specimen and detector. The length (L_1) of the test specimen and length (L_2) of the reference specimen shall be measured.

Step 3 - One end of the test specimen shall be placed in one of the specified radiation beams so that the entire end is uniformly illuminated with the launch cone specified in the specification sheet. One end of the reference specimen shall be placed in the other of the specified radiation beams and likewise illuminated.

Step 4 - The other end of each specimen shall be placed so that axis of the output cone of radiation is perpendicularly incident on their respective detectors and all of the radiation impinges on the detectors.

Step 5 - Prior to starting the frequency sweep, the voltage of the detectors shall be adjusted so that they are approximately equal and within the linear range of the detectors. This may be done by varying the beam splitting ratio or by use of an attenuator in the reference beam.

Step 6 - For each channel, the output amplitude $A_1(f)$, $A_2(f)$ and phase $\theta_1(f)$, $\theta_2(f)$ shall be recorded as a function of frequency f.

NOTE: The recorder or operator performs the amplitude ratio $A(f) = A_1(f)/A_2(f)$ (a subtraction on a dB scale) normalized to 1 at $f = 0$. Also performed is the phase difference $\theta(f) = \theta_1(f) - \theta_2(f)$ normalized to 0 at $f = 0$.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria.

5.4 The radiation source, center wavelength(s), bandpass at the wavelength(s) and numerical aperture of the launched radiation cone.

5.5 The length (L_1) of the test specimen and (L_2) of the reference specimen.

5.6 The identity and refractive index at the wavelength(s) of interest of any index matching fluids, if used.

5.7 The type of cladding mode stripper, if used.

5.8 The type, size and responsivity of the detectors.

5.9 The test specimen configuration while under test, whether loosely coiled or wound on a reel or spool, shall be reported.

5.10 The fiber transfer function shall either be reported as a curve of voltage and phase angle vs frequency or shall be computed at specified frequencies according to the formula in Section 1.

6. NOTES.

6.1 In most instances the source should be uniform Lambertian. The size of spectral bandwidth depends upon whether a chromatic or monochromatic measurement is being made. The time response of the source to either internal or external modulation must be fast enough so as to approach the dispersion limits of the specimen under test.

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METHOD 6080

REFRACTIVE INDEX PROFILE (INTERFEROMETRIC METHOD)

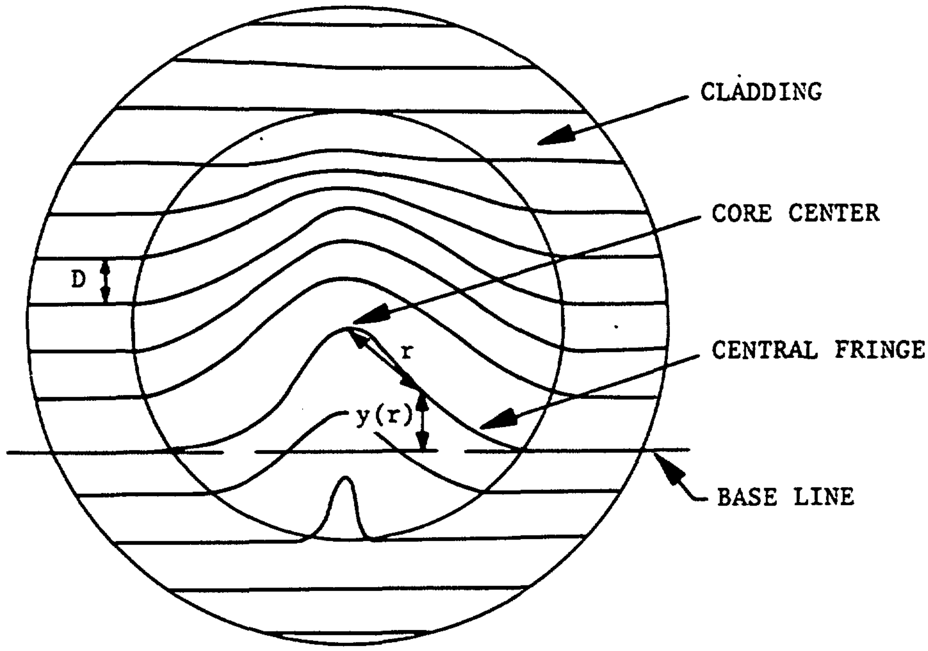
1. SCOPE.

1.1 This method determines the refractive index profile of a graded index fiber by an interferometric procedure.

1.1.1 The refractive index profile is obtained from the change in refractive index from the cladding value as given by:

$$\Delta n(r) = \frac{y(r) \cdot \lambda}{D \cdot T}$$

where $\Delta n(r)$ is the index change at distance r from the core center
$y(r)$ is the central fringe deviation at distance r as measured from the baseline connecting the same cladding fringe on both sides of the core (see diagram)
D is the parallel fringe spacing in the cladding
λ is the wavelength
T is the thickness of the fiber specimen



2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber, bundle or cable.

3. APPARATUS.

3.1 Interference microscope. A Mach-Zehnder type microscope or equal shall be used. The microscope shall be equipped with a monochromatic light source.

3.2 Photomicrographic camera. A photomicrographic camera, preferably one which uses self developing film, shall be used in conjunction with the microscope to provide a permanent record of the fringe pattern.

3.3 Photodensitometer. A photodensitometer may be used to scan the fringes to establish maxima and minima intensities.

4. PROCEDURE.

Step 1 - The fiber specimen shall be bonded into a suitable capillary tube, cut and finished so that the endfaces are flat within $\lambda/10$, parallel within 5 arc minutes and perpendicular to the axis of the specimen within 1.5 degrees. The specimen shall be several times thinner than 2.3A/NA where A is the core radius and NA is numerical aperture. This ensures that ray focusing effects are negligible. The specimen shall be prepared in accordance with Method 8040, Procedure II.

Step 2 - The thickness, T, of the fiber specimen is approximately given by $T = nZ$ where: n = index of refraction of the specimen and Z = the distance of lens travel determined by focusing the microscope at the top and bottom surfaces of the specimen.

Step 3 - The specimen shall be observed with the microscope operated in a tilted wavefront configuration.

Step 4 - The parallel fringe spacing observed in the specimen shall be adjusted to a value convenient for visual or photodensitometer scanning.

Step 5 - The central fringe deviation y(r) from the base line and the corresponding distance r from the center shall both be measured for a number of positions along the base line.

Step 6 - The specimen may then be rotated in the microscope specimen holder and the fringe deviation determined again along another fiber diameter.

5. RESULTS.

5.1 The refractive index change, $\Delta n(r)$, shall be reported.

5.2 The thickness, T, shall be reported.

5.3 The wavelength, λ, shall be reported.

5.4 The magnification of the microscope shall be reported.

5.5 Any departure from radially symmetric profiles shall be reported.

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METHOD 6090

REFRACTIVE INDEX PROFILE
(NEAR FIELD METHOD)

1. SCOPE.

1.1 This method determines the refractive index profile of a graded or step index fiber by a near field procedure.

1.1.1 For short specimens (L $\simeq$ 100 mm) the refractive index along a given fiber radius $\hat{r}$, is given by:

$$n(r) = \left[(NA)^2 \cdot \frac{I(\hat{r})}{I(o)} \left(1 - (\frac{r}{a})^2 \right)^{\frac{1}{2}} + n^2(a) \right]^{\frac{1}{2}}$$

where NA is the numerical aperture, NA (10% intensity)
- $I(\hat{r})$ is the intensity (or power) of the radiation measured at a distance $\hat{r}$ from the pattern center
- $I(o)$ is the intensity (or power) maximum of the pattern center
- $\hat{r}$ is the radius at which I $(\hat{r})$ is measured, $\hat{r}$ = Mr
- M is the magnification
- $r = \hat{r}/M$
- a is the radius of core
- n(r) is the index of refraction at point r (core)
- n(a) is the index of refraction at point a (cladding)

1.1.2 For long specimen (L $\simeq$ 2000 mm) the refractive index along a given fiber radius, r, is given by:

$$n(r) = \left[(NA)^2 \cdot \frac{I(\hat{r})}{I(o)} + n^2 (a) \right]^{\frac{1}{2}}$$

2. SPECIMEN.

2.1 The specimen shall either be a short length of fiber, Procedure I, or long length of fiber, Procedure II.

3. APPARATUS.

3.1 The apparatus shall be as specified herein and in Method 6010, Procedure II or III.

3.2 Input launch system. The input radiation used shall either be Lambertian or adjusted to Lambertian by optical means. The launch system shall be capable of filling the entire numerical aperture (NA) of the specimen.

3.3 Output launch system. An output launch system shall be employed to focus the image of the output end of the specimen onto a plane.

3.4 Radiation detector. A scanning detector, such as a movable p-n junction photodiode shall be used. Its motion shall be fixed within the focal plane of the specimen image. The wavelength responsivity shall be compatible with the source. The NA of the detector shall be no smaller than the NA of the output launch system.

3.5 "X-Y" recorder. An "X-Y" recorder may be used to automatically plot the radiation detector signal vs detector position.

4. PROCEDURE.

Step 1 - The NA (10% intensity) of the fiber shall be determined in accordance with Method 6030 or 6040.

Step 2 - The detector scanning apparatus shall be positioned so that the detector lies in the focal plane of the specimen image throughout the scanning distance.

Step 3 - The radiant power shall be measured in accordance with Method 6010, Procedure II or III, while the detector is traversed across the diameter of the specimen image.

Step 4 - The radiant power shall be recorded as a function of detector position, $\hat{r}$.

Step 5 - The specimen shall then be rotated.

Step 6 - The radiant power shall be measured while the detector is traversed across another diameter of the specimen image.

Step 7 - The radiant power shall be recorded as in Step 4.

Step 8 - Calculate the refractive index, n(r) by the appropriate equation.

5. RESULTS.

5.1 The refractive index, n(r), shall be reported for both the diameter scans as a function of r.

5.2 The type and size of the detector shall be reported.

5.3 The length, NA (10% intensity) and diameter(s) of the specimen shall be reported.

METHOD 6100

REFRACTIVE INDEX PROFILE
(REFLECTION METHOD)

1. SCOPE.

1.1 This method determines the refractive index profile of a graded or step-index fiber by a reflection procedure.

1.1.1 The refractive index profile is given by

$$n(r) = \left[\frac{1 + S(r)}{1 - S(r)}\right] n_I$$

where

$$S(r) = \frac{n(a) - n_I}{n(a) + n_I} \sqrt{\frac{P(r)}{P(a)}}$$

Here $n(r)$ is the refractive index at distance r from the core center
$n(a)$ is the cladding refractive index (at distance a)
n_I is the refractive index of the coupling fluid
$P(r)$ is the power reflected at distance r
$P(a)$ is the power reflected at distance 'a'

2. SPECIMEN.

2.1 The specimen shall be prepared from a representative sample of fiber.

3. APPARATUS.

3.1 The apparatus shall be as specified herein and in Method 6010, Procedure I or II. See Figure 6100-1.

3.2 Plane polarizer. A plane polarizer shall be used if the source is not already plane polarized.

3.3 Beam splitter. A beam splitter shall be used to divide the source radiation into a beam incident upon the fiber and a detected reference beam. It also serves to split off the retroreflected beam to a detector. The polarization properties of the light must be preserved.

3.4 Circular polarizer. A circular polarizer, such as a quarter wave plate operating upon the plane polarized light, shall be used to eliminate polarization reflectivity effects in the incident and retroreflected beams.

3.5 Optical lens system. A lens system shall be used to focus the incident beam to a small spot on the fiber end surface and to accept the beam retroreflected from the fiber. An immersion fluid (or air) of index n_I may be used between the lens system and the fiber specimen face.

3.6 Difference amplifier. The signals from the reference and reflection detectors may be compared as by a difference amplifier.

4. PROCEDURE.

Step 1 - The short fiber specimen (~ 100 mm) has its smooth end face mounted on an x-y positioner. To reduce extraneous backreflections from inside the fiber, the fiber opposite end may be inserted in an index fluid.

Step 2 - The source and lens system are adjusted so that a uniformly small spot is incident upon the movable fiber face.

Step 3 - The difference amplifier is adjusted so that the detected power P(a) reflected off the core is cancelled by the reference signal.

Step 4 - As the light spot scans along a fiber diameter, both the distance from the center r and the change in reflected signal P(r) are recorded. Note, $P(r) + P(a) = \Delta P(r)$.

Step 5 - The scan may be repeated along another diameter.

5. RESULTS. The following details shall be as specified in the equipment specification.

5.1 Procedure number.

5.2 Immersion fluid (if any) refractive index n_I.

5.3 Cladding refractive index n(a).

5.4 Calculated index profile n(r).

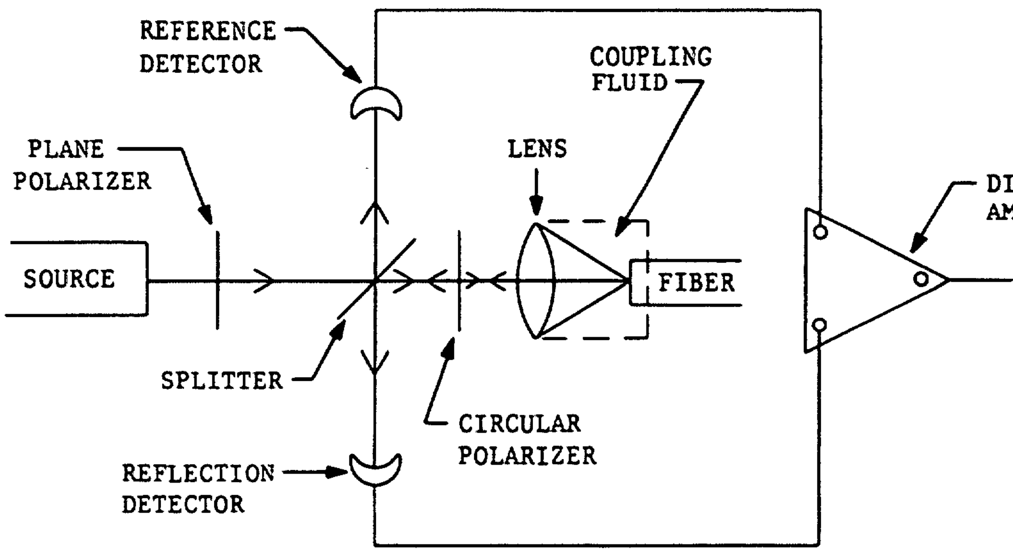

Figure 6100-1.

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METHOD 8010

INSULATION BLOCKING, FIBER OPTICS CABLE

1. SCOPE.

1.1 This method describes a procedure for determining the ability of the jacket insulation or outer covering of a fiber optics cable to withstand elevated temperature for prolonged periods without sticking to itself on adjacent turns or layers.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable whose length is at least 1500 times the finished diameter of the cable (see step 2).

3. APPARATUS.

3.1 Metal spool. A metal spool with a barrel diameter of 40 times the outside diameter of the fiber optics cable shall be used. The flanges of the spool shall be made such that the ends of the specimen can be attached to them.

3.2 Chamber. The volume of the test chamber shall be of sufficient size so that the specimen within it will not interface with the generation or maintenance of the test conditions. The heat source shall be located so that the radiant heat will not fall directly on the specimen. Unless otherwise specified, thermocouples or equivalent temperature sensors shall be used to determine the temperature within the chamber and to control the chamber temperature.

4. PROCEDURE.

Step 1 - One end of the specimen shall be attached to the one flange of the spool.

Step 2 - Three layers of the specimen shall be wound upon the spool with a minimum of three close turns on each layer. Care shall be exercised to ensure that the individual turns are in intimate contact with the adjacent turn(s). Tension for winding shall be 1 kg.

Step 3 - After winding, the remaining end of the specimen shall be attached to the other flange and secured in such a manner as to ensure that no unwinding or loosening of the specimen has occurred.

Step 4 - The specimen and spool shall be placed in the test chamber for the time and temperature specified.

Step 5 - After conditioning, the specimen and spool shall be removed from the conditioning chamber and allowed to return to room temperature. The specimen shall be un wound manually, and examined visually for evidence of adhesion (blocking) of the adjacent turns.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria

5.4 The extent of adhesion shall be reported according to the following:

Results	Extension of Adhesion
No adhesion	None
Mild adhesion, specimen easily removed, cosmetic damage only	Mild
Moderate adhesion, specimen removed with some difficulty, damage consists of pieces removed so that cross-sectional area is altered	Moderate
Severe adhesion, specimen cannot be removed without catastrophic damage	Severe

METHOD 8020

WICKING

1. SCOPE.

1.1 This test method measures the wicking characteristics of fiber optic cables.

2. SPECIMEN.

2.1 Specimen. The test specimen shall be 150 ± 1.5 mm long with square ends and shall be a representative sample of the fiber optics cable.

3. APPARATUS.

3.1 Standard test tube.

3.2 Scale, balance or platform, accurate to ± .05 milligram.

3.3 Ultraviolet light source.

3.4 Standard dye solution. The dye solution shall be prepared as follows:

Ethyl alcohol	30 ml
Rhodamine B dye	20 mg
Aerosol OT	3 ml
Distilled water to make	2 liters

The dye shall be dissolved in the ethyl alcohol before adding to the water. The solution shall be kept stoppered and a fresh solution shall be prepared every 30 days. A new portion of the solution shall be used for each test conducted.

4. PROCEDURE. Wicking shall be determined by Procedure I or II as specified in the applicable specification sheet.

Procedure I.

Step 1 - The specimen shall be weighed accurately to the nearest 0.1 milligram.

Step 2 - The weighed specimen shall be vertically immersed with the lower 50 mm in distilled water in an open test tube and shall be conditioned thus for 24 hours at room temperature in a draft-free area.

Step 3 - The specimen shall then be removed from the distilled water, the surface of the insulation shall be wiped free of excess moisture with a clean, dry, lint free cloth, and, within 5 minutes after removal from the water, the specimen shall be weighed again to the nearest 0.1 milligram.

4.2 Procedure II.

Step 1 - The procedure shall be identical with Procedure I except that standard dye solution (3.4) shall be substituted for the distilled water of Procedure I.

Step 2 - Immediately after the final weighing, the specimen shall be observed under ultraviolet light to determine, to the nearest 1.27 mm, the distance the dye solution has traveled in the fibers or any part of the jacket by wicking action. The layer(s) of jacket may be dissected away with a sharp blade, working from the upper end of the specimen, to facilitate observation.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria.

5.4 The change in mass, calculated to percent of the original specimen weight.

5.5 The distance the dye solution has traveled beyond the 50 mm immersion level.

METHOD 8030

FLUID IMMERSION

1. SCOPE.

1.1 This method describes a procedure for determining the effect on jacket and fiber materials subjected to immersion in specific fluids. It uses dimensional change of the jacket as one measure of effect. The other is the effect on transmitted power as defined by:

$$R = \frac{\Phi_2}{\Phi_1}$$

where Φ_2 is the radiant power at the final condition and Φ_1 is the radiant power measured after preconditioning.

2. SPECIMEN.

2.1 The test specimen shall be taken from a representative sample of the fiber optics cable.

3. APPARATUS.

3.1 The apparatus shall be as specified herein and in Radiant Power Measurement, Method 6010.

3.2 Micrometer caliper.

3.3 Stainless steel fluid pans of suitable volume.

3.4 Timer.

3.5 Thermometer, 0 to 100°C

3.6 Test fluids. The test fluids shall be as specified.

3.7 Hot plate or equivalent heat source.

4. PROCEDURE.

Step 1 - The specimen shall be preconditioned at $23 \pm 2^\circ C$ and $50 \pm 5\%$ relative humidity for 48 hours and the diameter, D_1, measured.

Step 2 - The output of the source shall be adjusted to the center wavelength, bandwidth and intensity of interest.

Step 3 - Both ends of the specimen shall either be prepared with standard terminations and finished so that the endfaces are perpendicular to the axis of the specimen, or index matching fluid shall be used to couple the optical power between source and specimen, and specimen and detector.

Step 4 - The central portion of the specimen shall be formed into a loop such that 600 mm minimum can be immersed. The loop or coil shall have a radius between 10X and 20X the measured diameter of the cable.

Step 5 The radiant power, Φ_1, shall be measured at the specified wavelength(s).

Step 6 - The central portion of the specimen shall be immersed in the fluid for the time and at the temperature specified. Care shall be exercised in supplying adequate ventilation and protection for hazardous or flammable fluids.

Step 7 - At the end of the immersion time the specimen shall be removed from the test fluid and allowed to remain in free air at room temperature for one hour.

Step 8 - Within one additional hour the radiant power, Φ_2, and diameter, D_2, of the cable where immersed shall be determined.

Step 9 - The specimen shall then be visually examined for damage.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria.

5.4 The percent change in diameter of the specimen.

5.5 Cracks, splits, voids or other damage to the specimen.

5.6 The effect on transmitted power, R.

METHOD 8040

FIBER AND BUNDLE END PREPARATION

1. SCOPE.

1.1 This method describes procedures for finishing the ends of a fiber or bundle so that end losses can be reduced in testing the optical parameters of the fiber or bundle.

2. SPECIMEN.

2.1 The specimen shall be a representative sample of fiber, bundle or FO cable.

3. APPARATUS.

3.1 Scribe. A suitable tool shall be used as a glass scribe.

3.2 Bending tool. The bending tool shall be either a mandrel or two shallow "V" grooved blocks hinged together.

3.3 Optical microscope. An optical microscope as described in Method 1010 of DOD-STD-1678 or equal shall be used. The magnification shall be sufficient to examine the fiber or bundle image.

3.4 Terminator. A ferrule type terminator shall be used of the type and size specified in the applicable specification.

3.5 Cleaning fluid. A suitable solvent, such as acetone, methylene chloride or methyl ethyl ketone, shall be used as cleaning fluids.

3.6 Wetting liquid. Ethyl or methyl alcohol may be used as a wetting liquid.

3.7 Bonding agent. Epoxy or other suitable plastic bonding systems may be used as adhesive bonding agents.

3.8 End finishing apparatus. When end finishing requires polishing, MDR Manufacturing Co. Model 8826-4 or equivalent apparatus shall be used.

3.8.1 Termination holder. The apparatus shall provide means of reproducibly holding the end termination perpendicular to the grinding or polishing surface.

3.8.2 Grinding compound. If large amounts of material are to be removed from the end face, 600 mesh diamond or similar abrasive shall be used as the grinding compound.

3.8.3 Final polishing. Final polishing may be accomplished using either Linde "A" compound, dry polishing discs of equal fineness or equivalent methods.

4. PROCEDURE.

4.1 Procedure I. Scribe and break, single fiber, glass core and glass cladding.

Step 1 - When the mandrel is chosen as the bending tool, the fiber shall be formed and secured to the mandrel. Using the scribe, a small notch is scratched perpendicular to the fiber axis on the top of the fiber. Since the fiber is under tension at the notch it should break as soon as the notch is made. If not, a slightly deeper notch or slightly smaller mandrel or slightly increased tension or a combination of these is needed. Using the hinged "V" blocks as the bending tool, the fiber shall be placed in the "V" groove and secured to the "V" blocks. Using the scribe, a small scratch is made perpendicular to the fiber axis on the top of the fiber. The scratch should be in the area of the hinge fulcrum. The "V" blocks are then bent to apply stress to the scratch. The fiber should break. If not, then a deeper scratch or smaller bend radius is needed.

Step 2 - The end face of the fiber shall then be examined microscopically. The end face should be flat and perpendicular to the axis of the fiber (see Figure 8040-1). If the end face is not acceptable then the procedure shall be repeated.

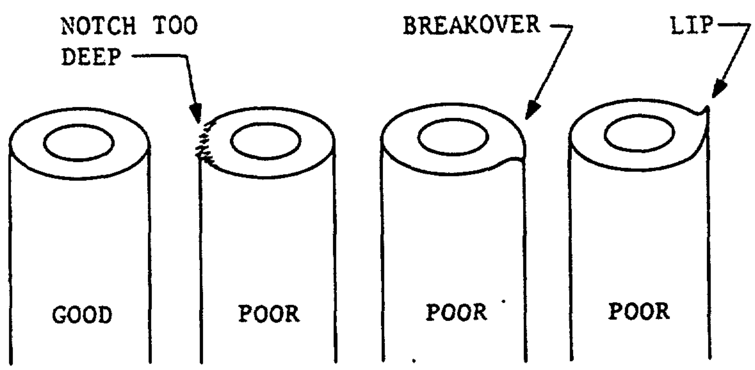

Figure 8040-1. Fiber End Face Appearance

NOTE: The ability to obtain a proper notch will require some practice; each tool will differ. It is preferable to try increasingly smaller bend radii rather than deeper notches to effect a proper end face.

4.2 Procedure II. Scribe and break, single fiber, glass core and plastic cladding.

Step 1 - The fiber may be hung on a cylindrical mandrel covered with "Teflon" tape. One end should be clamped to prevent motion, and the other end should be held in a weighted clamp below the axis of the mandrel. (eg., for clad fibers with a silica core of 200 µm diameter, a mandrel of 150 mm diameter and a weighted clamp of 650 g are suitable.) A tiny notch should be scribed in the fiber perpendicular to the fiber axis, at a point on the mandrel 45° down from the top of the mandrel. One of three scribing methods may be used.

a. Move and push a silicon carbide or diamond blade gently across and into the plastic cladding surrounding the silica fiber. When the blade reaches the fiber, cleavage should take place.

b. For harder plastic claddings, a heated silicon carbide blade may be used. Heat the blade to the lowest temperature that gives good results.

c. The cladding may be removed mechanically or with solvents in order to cleave the bare (unclad) fiber end.

Step 2 - The end face of the fiber shall then be examined microscopically. The end face of the fiber itself (not necessarily of the cladding) should be flat and perpendicular to the axis of the fiber (see figure 8040-2). If the end face is not acceptable then the procedure shall be repeated.

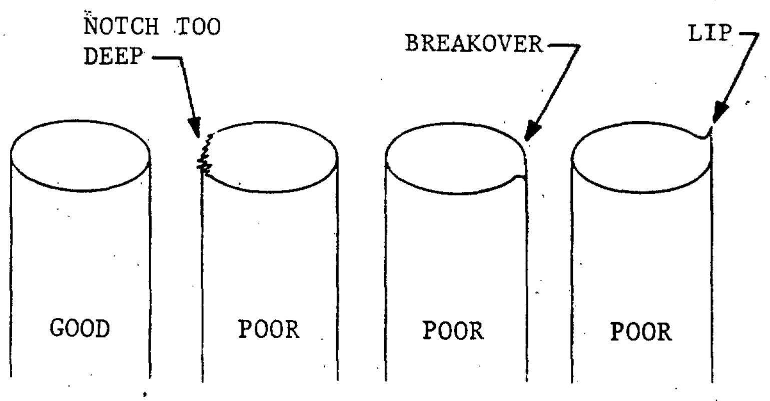

Figure 8040-2. Plastic Clad Silica Fiber End Face Appearance (Cladding Around the Fiber Not Shown)

NOTE: For a method to calculate the proper bend radius and weight, see D. Gloge, et al., Bell System Technical Journal 52, p. 1579 (1973).

4.3 Procedure III. (Cut, single fiber or bundle, all plastic)

Step 1 - Oil, or foreign material, shall be removed from the specimen in the area chosen for termination. Any solvent used must not damage the plastic core or cladding.

Step 2a - If a plastic swage-end ferrule is used, insert the plastic fiber or bundle into the connector, then crimp, and swage by screwing down the polishing bushing. Skip to Step 6.

Step 2b - If the fiber or bundle is to be bonded into the ferrule with a bonding agent, the bonding agent must not damage the plastic core or plastic cladding. A solventless epoxy resin (100% solids) may be suitable.

Step 3 - The terminator shall be slid back to expose the fiber ends and the bonding agent applied to the fiber(s). Sufficient bonding agent shall be used to fill the interstices between fibers and between fibers and terminator.

Step 4 - The terminator shall then be moved over the area where bonding agent has been applied and positioned such that a short length of the fiber(s) protrude from the end of it.

Step 5 - The bonding agent shall be cured for maximum hardness for the applicable time and temperature consistent with the limitation of the FO cable insulation systems if any. Care shall be exercised in choosing the proper bonding agent. The bonding agent shall be of such hardness as to resist the embedment of grinding and polishing compound.

Step 6 - The plastic fiber(s) shall be cut off flush with the front of the ferrule, by a stroke with a sharp blade such as a new razor blade. The blade should be stroked across the diameter of the fiber(s), and not be sawed back and forth.

Step 7 - The end face of the fiber (bundle) shall then be examined microscopically. The end face should be flat and perpendicular to the axis of the fiber (bundle) and should be free of deep scratches. A razor-cut end will generally be suitable for routine measurements of transmitted power.

4.4 Procedure IV. Terminate and polish, fiber or bundle (both glass clad, glass core and plastic clad, silica case)

Step 1 - Oil, sizing, or foreign material shall be removed from the specimen in the area chosen for termination. It may be necessary to flare the fibers while washing with solvent.

Step 2 - The bundle may then be dipped into the wetting liquid and inserted into the specified terminator. The terminator and bundle shall be allowed to dry.

Step 3 - The terminator shall be slid back to expose the fiber ends and the bonding agent applied to the fiber(s). Sufficient bonding agent shall be used to fill the interstices between fibers and between fibers and terminator.

Step 4 - The terminator shall then be moved over the area where bonding agent has been applied and positioned such that a short length of the fiber(s) protrude from the end of it.

Step 5 - The bonding agent shall be cured for maximum hardness for the applicable time and temperature consistent with the limitation of the FO cable insulation systems if any. Care shall be exercised in choosing the proper bonding agent. The bonding agent shall be of such hardness as to resist the embedment of grinding and polishing compound.

Step 6 - Excess fiber length protruding from the terminator shall be removed in such a manner as not to cause damage to the fibers, terminator or bonding within the terminator.

Step 7 - After cooling to room temperature the terminated end shall be mounted in the end finishing apparatus. Using grinding compound, the exposed fibers shall be ground down flush with the end of the terminator.

Step 8 - The terminated end (without removal from the end polishing apparatus) shall then be polished to remove scratches and surface defects caused by the grinding operation.

Step 9 - The end face of the fiber (bundle) shall then be examined microscopically. The end face should be flat and perpendicular to the axis of the fiber (bundle) and free of scratches. If the end face is not acceptable then the polishing step shall be repeated.

5. RESULTS. The following details shall be as specified in the equipment specification:

5.1 Procedure number.

5.2 Pretest data required.

5.3 Failure criteria.

5.4 The procedure used to prepare the end face of the fiber or bundle.

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METHOD 8070

JACKET FLAW DETECTION
AND LEAK

1. SCOPE.

1.1 This method describes procedures for determining the integrity of a jacket applied to a fiber optics cable.

1.1.1 Procedure I is a water submersion type vacuum method.

1.1.2 Procedure II is a gas detection type vacuum method.

2. SPECIMEN.

2.1 The specimen shall be taken from a representative sample of fiber optics cable.

3. APPARATUS.

3.1 Vacuum chamber. A vacuum chamber shall be used which is capable of maintaining an absolute pressure of 38.1 mm of mercury and have a minimum volume of 5×10^7 mm^3.

3.2 Vacuum pump. A suitable vacuum pump shall be used.

3.3 Vacuum gauge. A suitable vacuum gauge, such as a Baratron®, manometer, or thermocouple gauge, shall be used to measure the pressure of the chamber. When a Baratron is used it shall be accurate within ± 0.001 mm Hg.

3.4 Sample tube. The sample tube volume shall be sufficient to hold the specified specimen and shall not have an empty volume more than 30% greater than the volume of the specimen being tested. It shall be equipped with a window by which to view the specimen.

4. PROCEDURES.

4.1 Procedure I (see Figure 8070-1).

Step 1 - The sample tube shall be filled with distilled water to a sufficient depth whereby to cover the specimen.

Step 2 - The sample tube with water shall be subjected to an absolute pressure of 38.1 mm of mercury for sufficient time to degas the water.

Step 3 - The sample tube with water shall then be returned to room ambient pressure and the specimen submerged in the water to a depth of at least 25 mm.

Step 4 - The sample tube, water and specimen shall then be subjected to an absolute pressure of 38.1 mm of mercury and held for 1 minute and then the pressure reduced to 63.5 mm of mercury.

Step 5 - The specimen shall be observed usually for evidence of a continuous stream of bubbles emanating from the surface of the specimen.

4.2 Procedure II (see Figure 8070-2).

Step 1 - Place the specimen in the sample tube. Seal the chamber and shut the isolator valve.

Step 2 - Close the vent valve and start the evacuation of the bell jar with the mechanical pump. Evacuation shall continue until the pressure in the bell jar reaches 10^{-4} mm of Hg or less.

Step 3 - The pressure in the sample tube shall be atmospheric pressure. Record pressure reading.

Step 4 - The isolation valve shall be opened for 1 to 2 seconds and then shall be closed. The test period shall start at the time, (t_o), when the isolation valve is closed. At the same time, the starting pressure, (P_o), shall be read on the Baratron. Record t_o and P_o.

Step 5 - At periodic intervals for the duration of the test, the pressure (P_x) shall be read at the Baratron and the time (t_x) shall be recorded to the nearest second. A minimum of three readings shall be made with an approximate elapsed time of 5 minutes between each reading. Readings at shorter intervals may be required to ascertain leakage rates on specimens less than 914 mm in length.

Step 6 The vapor leakage rate, (K), for the specimen shall be calculated by the following formula:

$$K(mm^3/sec) = \frac{(P_x - P_o)(V_2 - V_x)}{P_o \; (t_x - t_o)}$$

where:
- P_o = Starting pressure (in mm Hg)
- P_x = Pressure (in mm Hg) at time t_x
- t_o = Starting time (in secs) at which P_o was read
- t_x = Time (in secs) at which P_x was read
- V_2 = Sample tube volume (in mm^3)
- V_x = Test sample volume (in mm^3)

Step 7 - When a multi-port connection is used, each sample shall be subjected to the procedure described in 4.2 Step 3 through 4.2 Step 6.

Step 8 - If the quantity (P_x - P_o) remains constant throughout the test period, a gross leak may exist. The suspect test sample shall be removed from the chamber and shall be visually inspected for seal ruptures. If none are found, the test sample shall be set aside for a period of time, at least equal to the time the specimen was subjected to the reduced pressure, prior to retesting.

5. RESULTS.

5.1 Results for Procedure I.

5.1.1 Evidence of a continuous stream of bubbles emanating from the specimen shall be reported.

5.1.2 The submersion depth of the specimen, the amount of pressure reduction and the time of the reduced pressure exposure shall also be reported.

5.2 Results for Procedure II.

5.2.1 The leakage rate of the specimen shall be reported, including the pressures, times and calculations of leakage rate.

5.2.2 If the quantity (P_x - P_o) remained constant throughout the test period, the results of the visual examination for seal rupture shall be reported as well as the results of retesting.

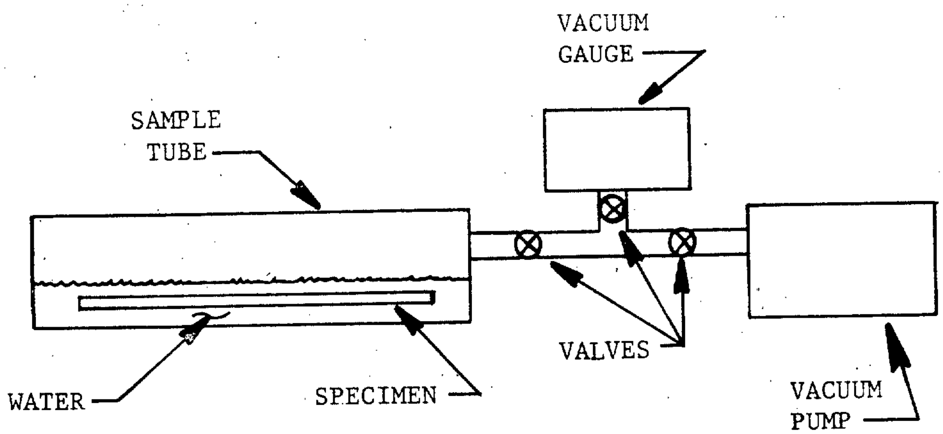

Figure 8070-1. Procedure I, Test Equipment Arrangement

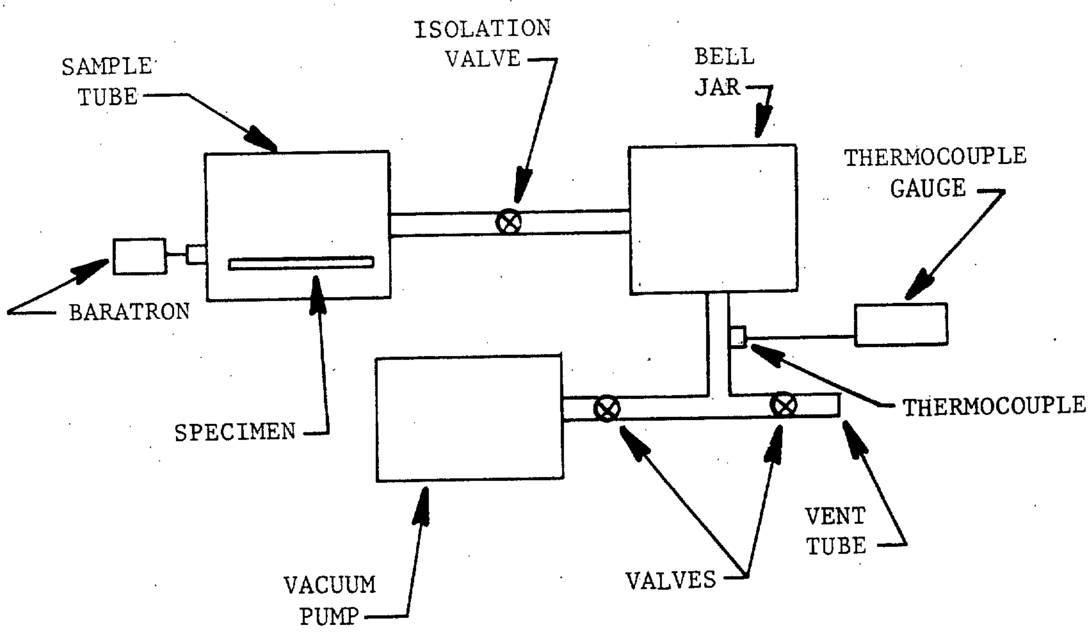

Figure 8070-2. Procedure II, Test Equipment Arrangement

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