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Superseding AS16781	

Fiber Optics Test Methods and Instrumentation

FSC 9999

RATIONALE

Technical evaluation indicates that AS16781 procedures are out of date by current accepted practices. In finding MIL-STD-1678 still an active MIL spec and updated to current practices, the SAE AE-8D committee recommends cancellation of AS16781.

CANCELLATION NOTICE

This document has been declared "CANCELLED" as of July 2011. By this action, this document will remain listed in the Numerical Section of the Aerospace Standards Index.

NOTICE

This document has been taken directly from U.S. Military Specification DOD-STD-1678, Notice 1 and contains only minor editorial and format changes required to bring it into conformance with the publishing requirements of SAE technical standards. The initial release of this document is intended to replace DOD-STD-1678, Notice 1. Any part numbers established by the original specification remain unchanged.

The original Military Specification was adopted as an SAE standard under the provisions of the SAE Technical Standards Board (TSB) Rules and Regulations (TSB 001) pertaining to accelerated adoption of government specifications and standards. TSB rules provide for (a) the publication of portions of unrevised government specifications and standards without consensus voting at the SAE Committee level, and (b) the use of the existing government specification or standard format.

Under Department of Defense policies and procedures, any qualification requirements and associated qualified products lists are mandatory for DOD contracts. Any requirement relating to qualified products lists (QPL's) has not been adopted by SAE and is not part of this SAE technical document.

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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 covers 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 by 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 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 consist 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 arness 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 (95% power): The numerical aperture of a fiber or bundle is defined by:

$$\text{NA (95\% power)} = \sin\ \theta$$

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 95% of the total 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 95% of the total input radiation power.

3.1.21.1 Numerical aperture, NA (5% intensity): The numerical aperture of a fiber or a bundle is defined by:

$$\text{NA (5\% intensity)} = \sin\ \theta'$$

where θ' is the angle where the measured intensity of radiation is 5% 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:

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

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-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 values 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 issue, 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.

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 metallurgical 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).

4.1 (Continued):

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.

4.2 (Continued):

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

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.

METHOD 1040.1
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 illuminating the specimen on the front and back. A diffusion plate shall be used between the illumination source and specimen back.

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 illuminated by the back illuminating source. The opposite end of the specimen shall be placed in the field of view of the optical microscope and illuminated at an oblique angle to the specimen face.

Step 3 - The intensity of the front and back illumination, the front illumination angle, the shutter speed and “F” stop shall be adjusted to obtain a clear photograph and to obtain maximum contrast between transmitting and non-transmitting fibers.

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.

4. (Continued):

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

NOTE: If the number of transmitting fibers is large compared to the number of non-transmitting fibers, the number of non-transmitting fibers shall be counted. This presupposes that the total number of fibers is known.

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:

5.1 Reporting:

The following information shall be reported with each test:

a. Operator and date.
b. Specimen identification.
c. Specimen length.
d. The number of transmitting fibers obtained on the two lowest intensities.

5.2 Documentation:

The following information shall be recorded and shall be made available upon request:

a. The type of microscope, type of objective lens, and magnification.
b. Date of last equipment calibration and when calibration is next due.

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 ± 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 ± 2°C and 50 ± 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.

4.1 (Continued):

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.

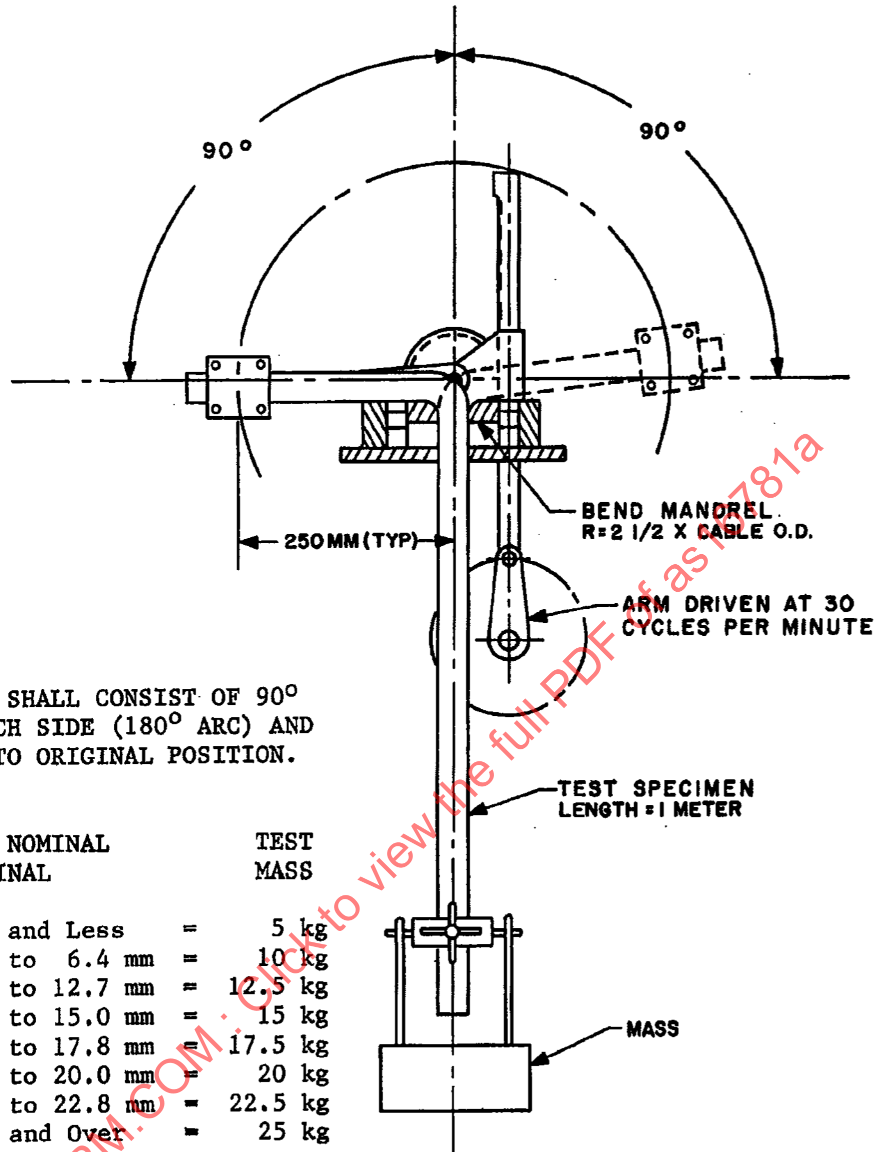
5.7 The diameter of the mandrels, the mass and number of cycles shall be reported (Procedure II).

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 ± 2°C and 50 ± 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.

4.1 (Continued):

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 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 ± 2°C and 50 ± 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.

4.3 (Continued):

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.

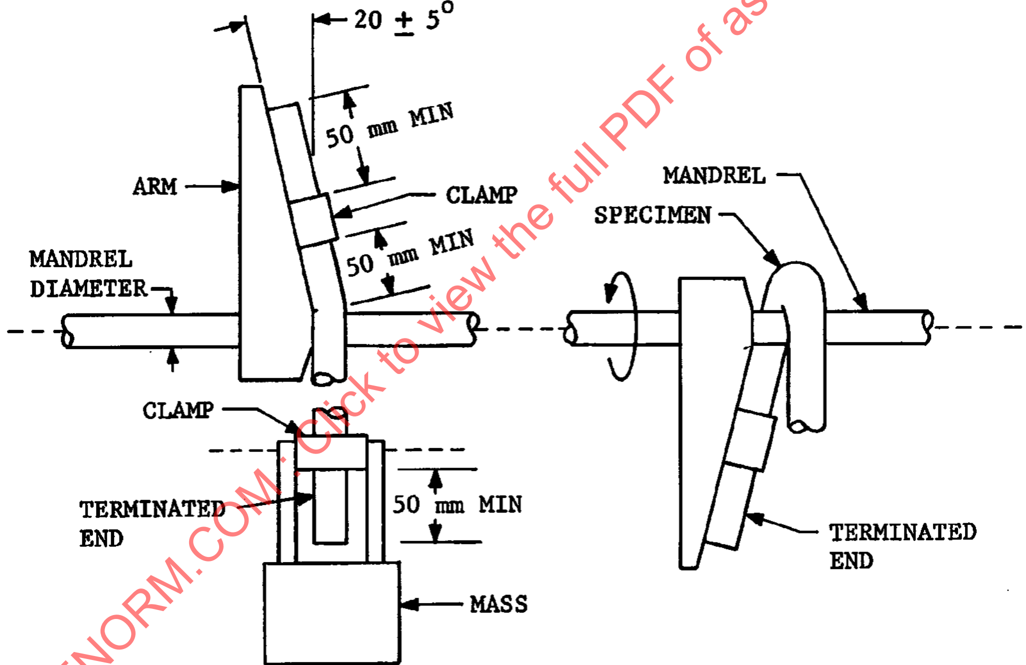
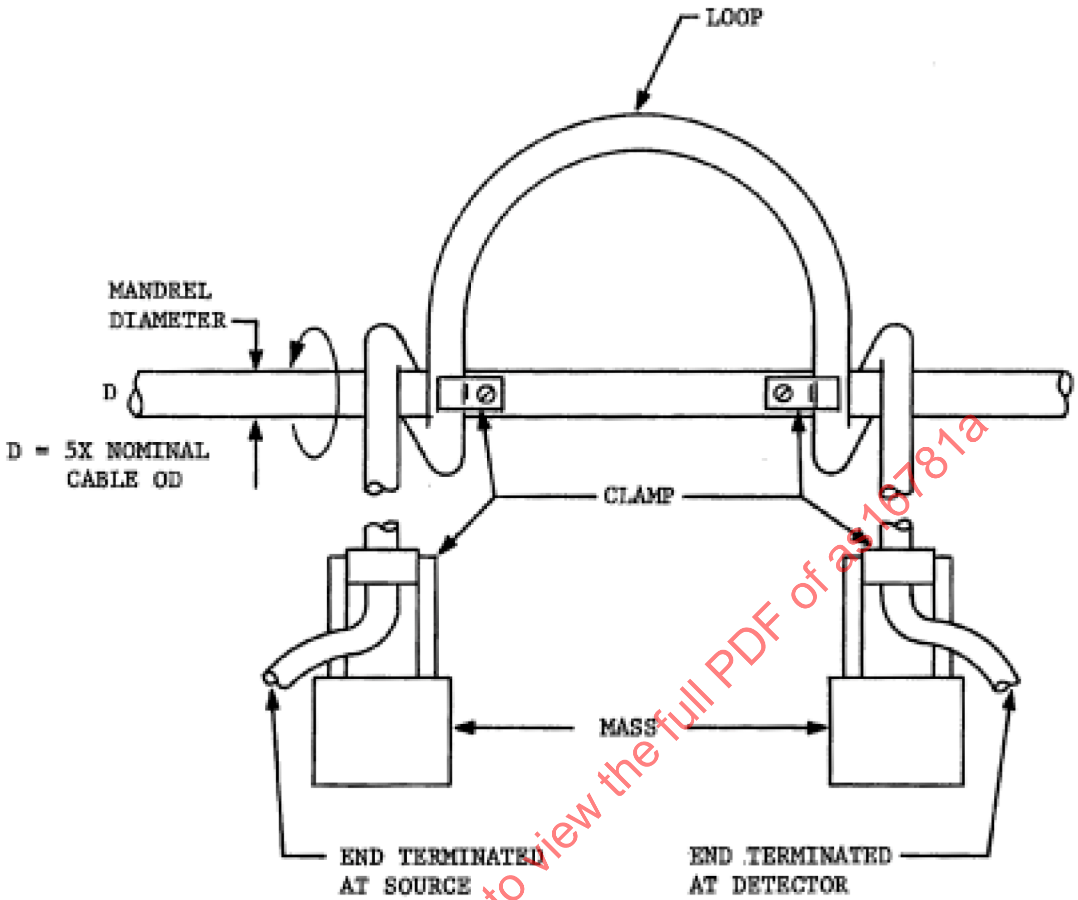


Figure 2020-1. Test Mandrels and Masses (Procedures I and II)



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 so the specified value by adding (or subtracting) appropriate masses.

4.1 (Continued):

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

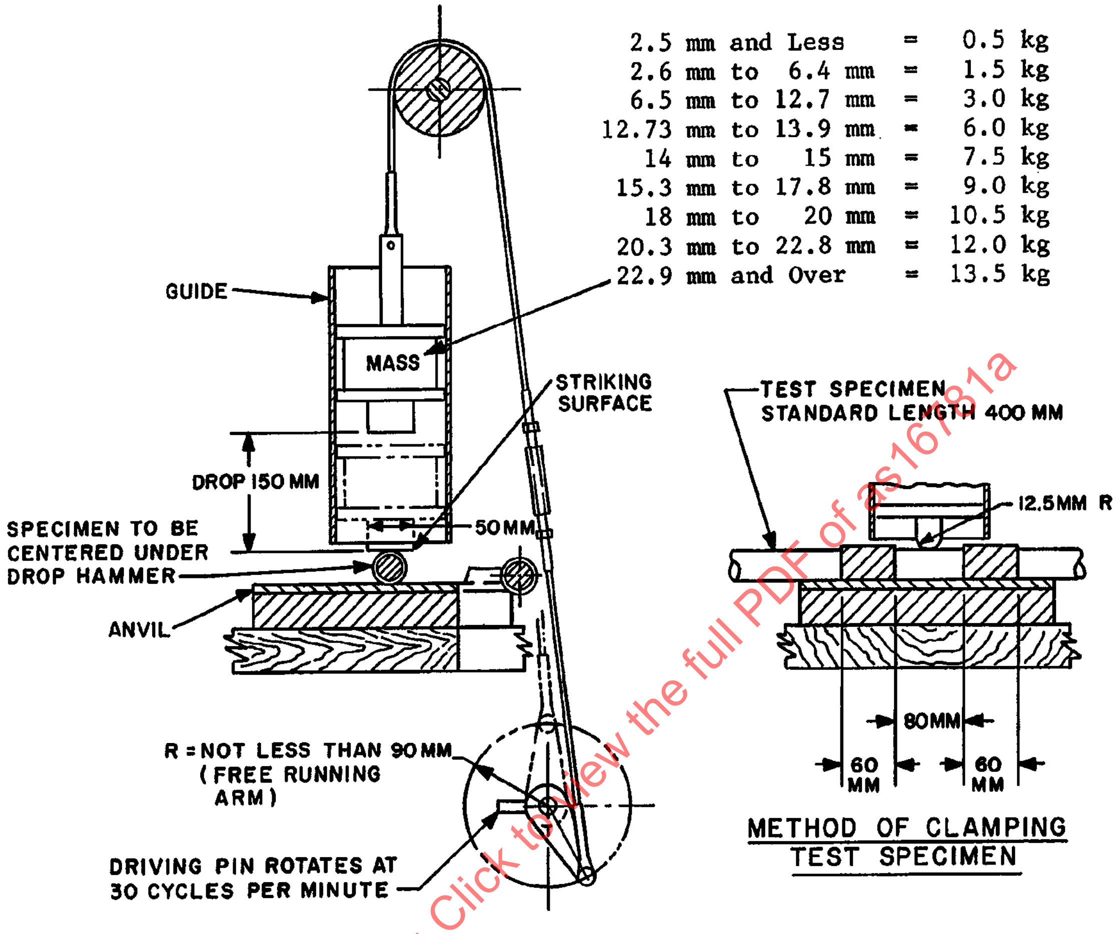


Figure 2030-1. Impact Test, Fixture Cable Testing

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.

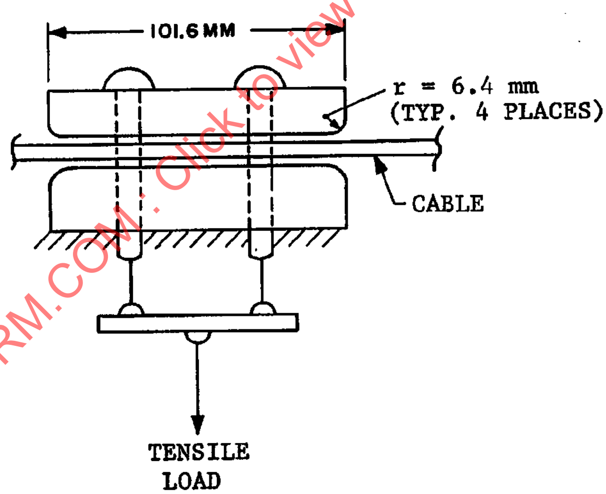


Figure 2040-1. Test Arrangements for Crush and Shear Testing

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.

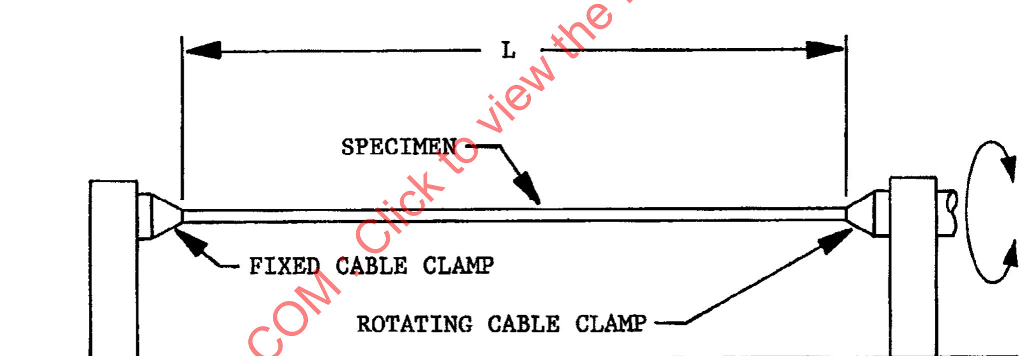


Figure 2050-1. Cable Twisting Apparatus

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 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 ten cycles. During the tenth cycle determine the number of transmitting fibers with the cable rotated 180 degrees clockwise, 180 degrees counterclockwise 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.

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.

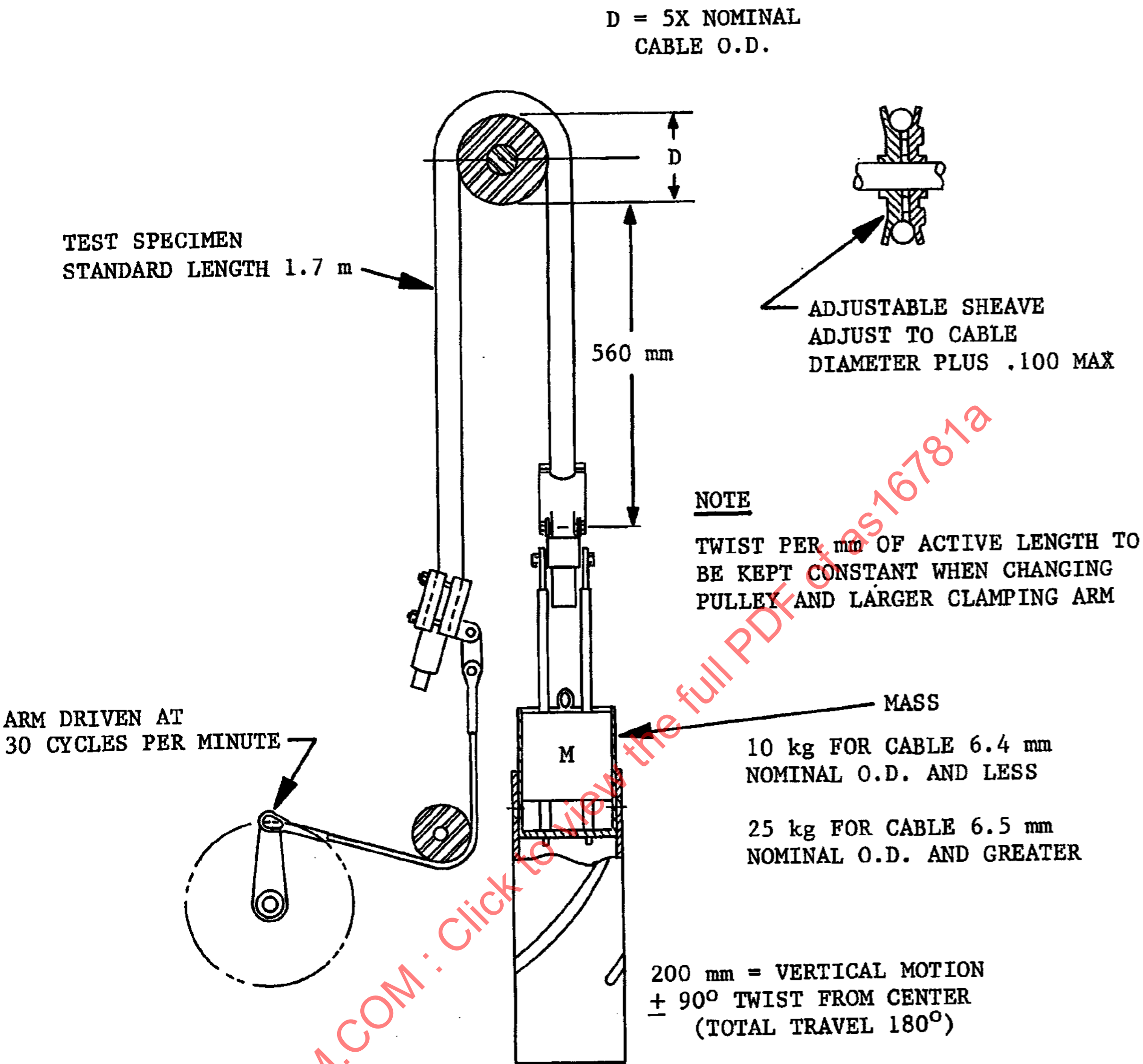


Figure 2060-1. Twist-Bend, Test, Fixture, Cable Testing

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).

4.1 (Continued):

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°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.

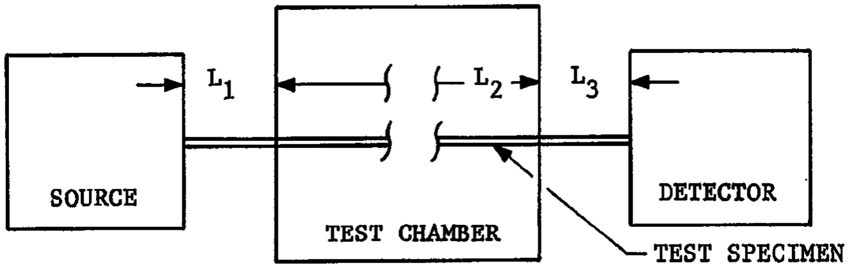


Figure 4010-1. Test Chamber

4. (Continued):

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.

4. (Continued):

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.

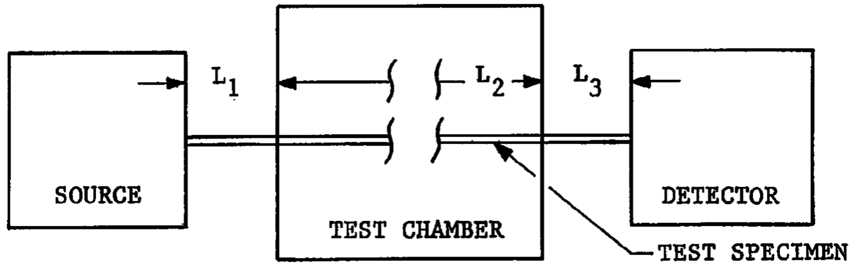


Figure 4030-1. Test Chamber

4. (Continued):

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 ± 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.

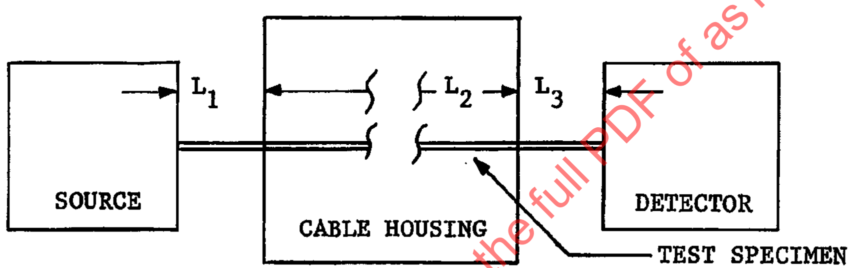


Figure 4050-1. Freezing Chamber Test Apparatus.

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.

4. (Continued):

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.

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:

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

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.

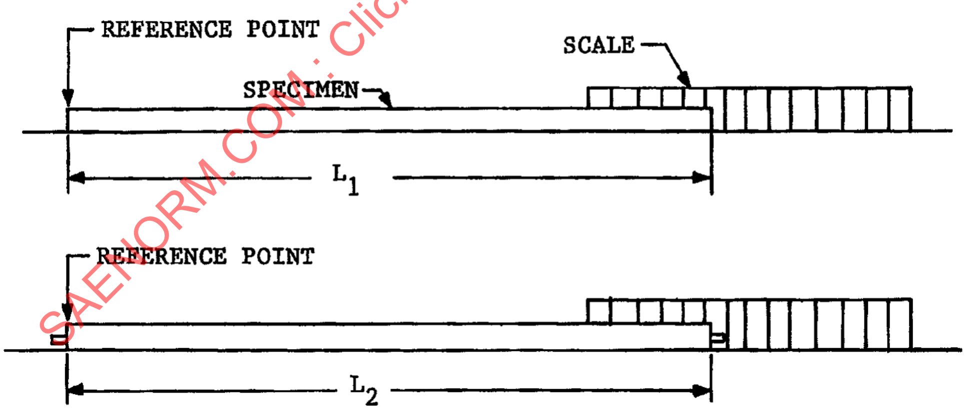


Figure 4060-1. Jacket Measuring (Shrinkage Shown).

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.

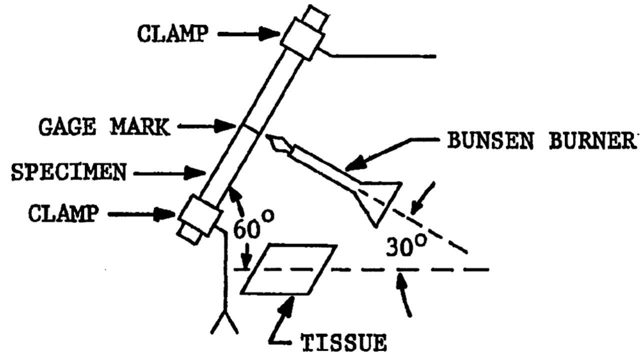


Figure 5010-1

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.

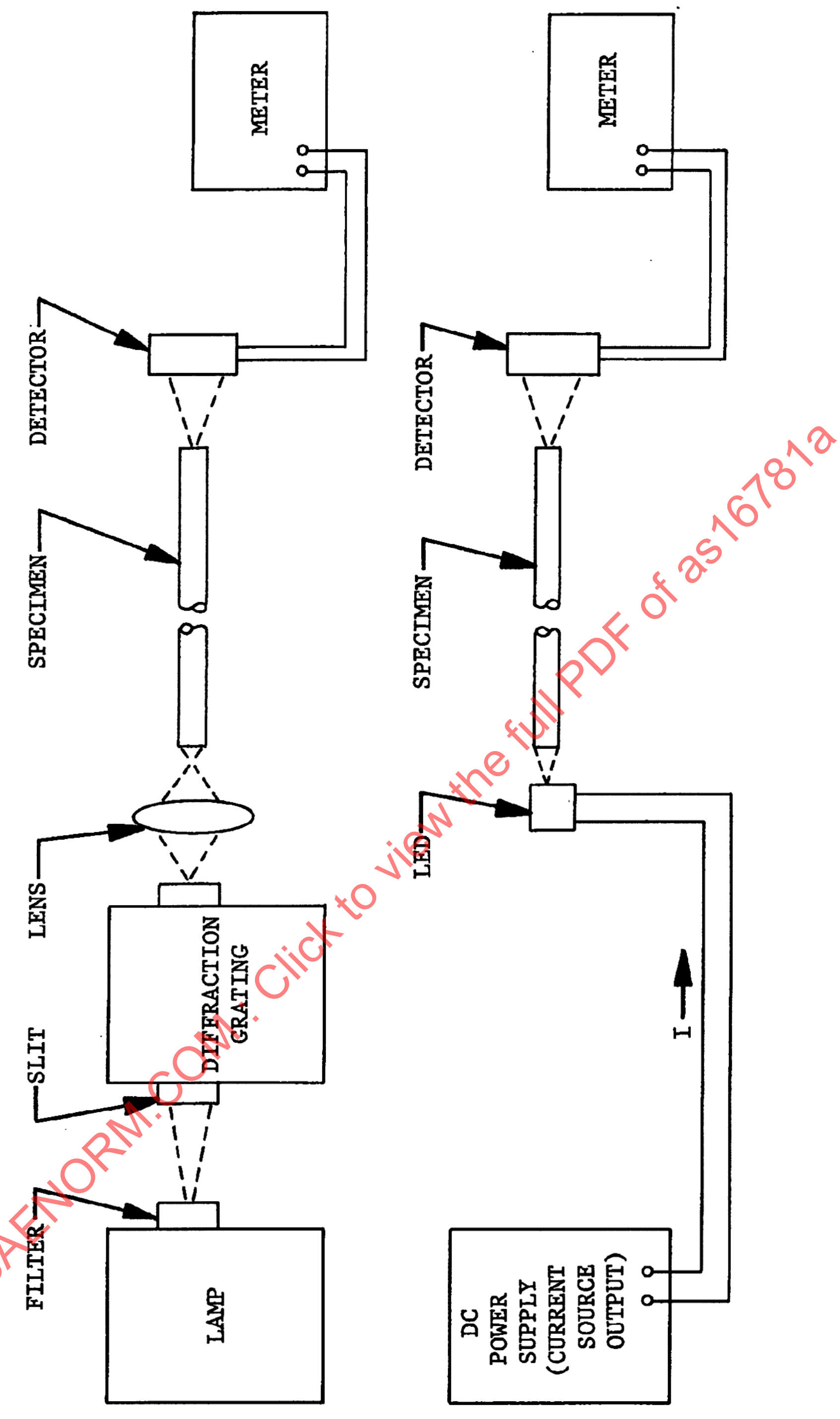


Figure 6010-1. Continuous Power Measurement (See 4.2)

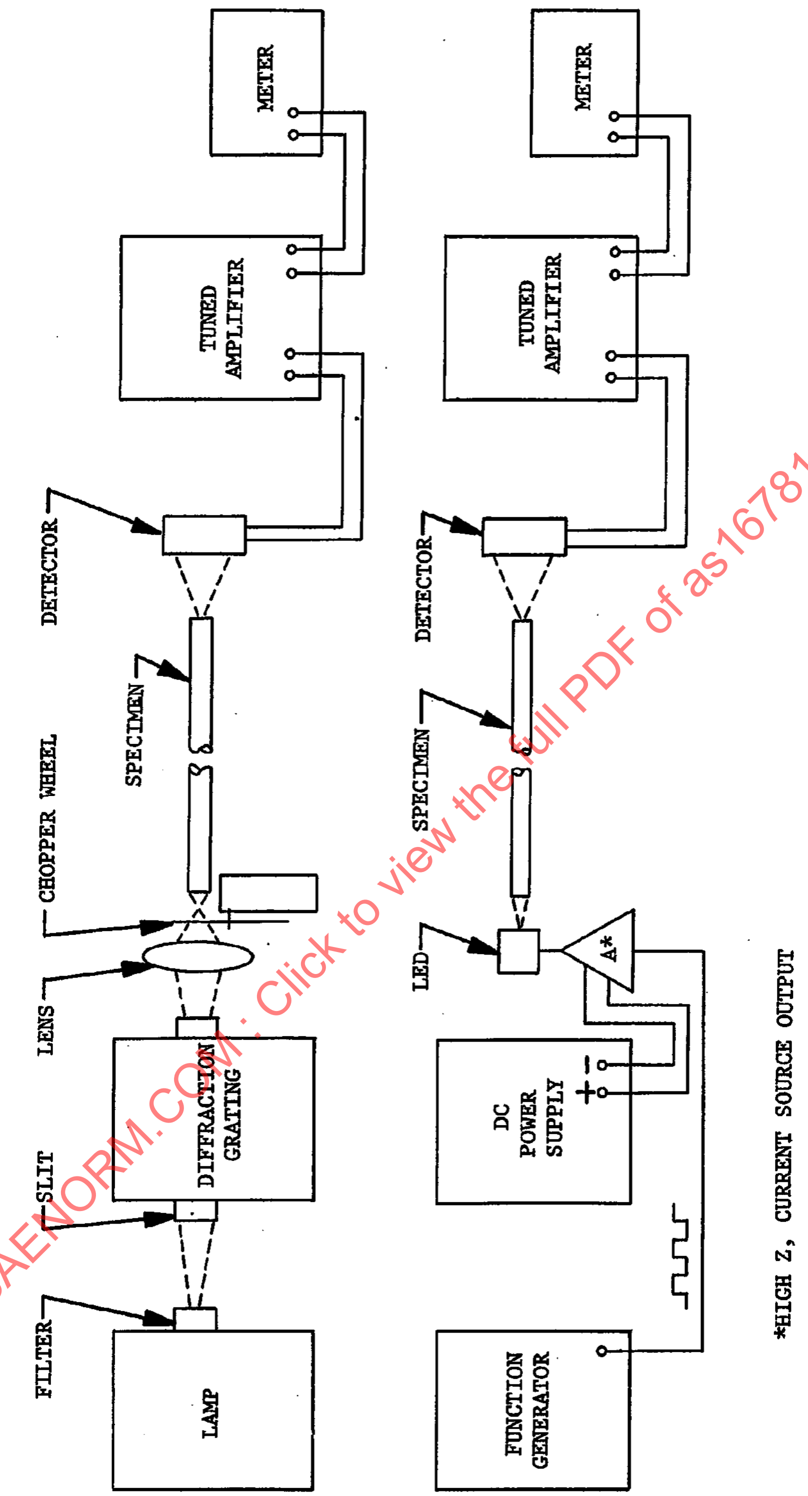


Figure 6010-2. Tuned Power Measurement (See 4.3)

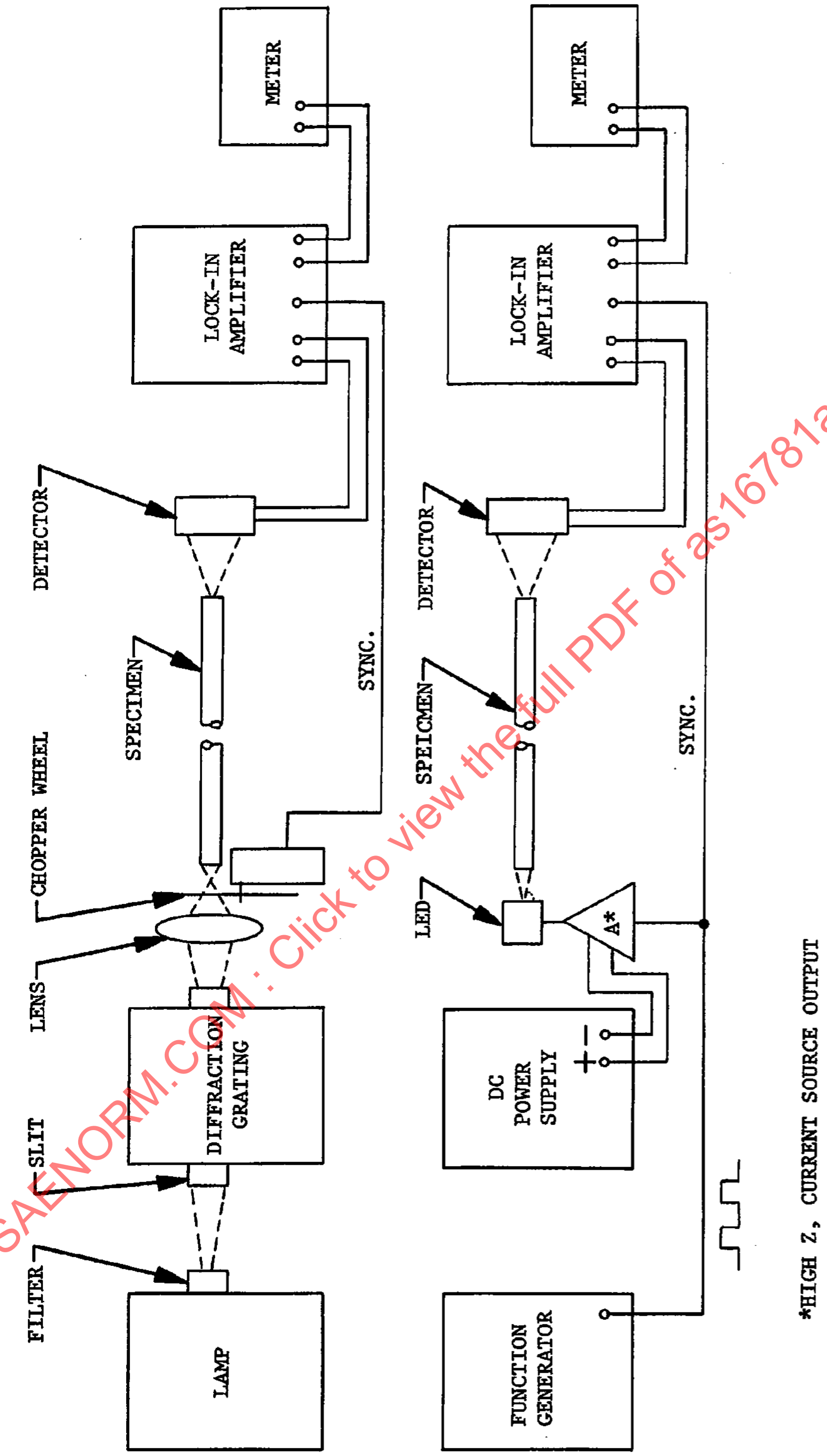


Figure 6010-3. Synchronous Power Measurement (See 4.4)

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:

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

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 sphered 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.

4. (Continued):

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.

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).

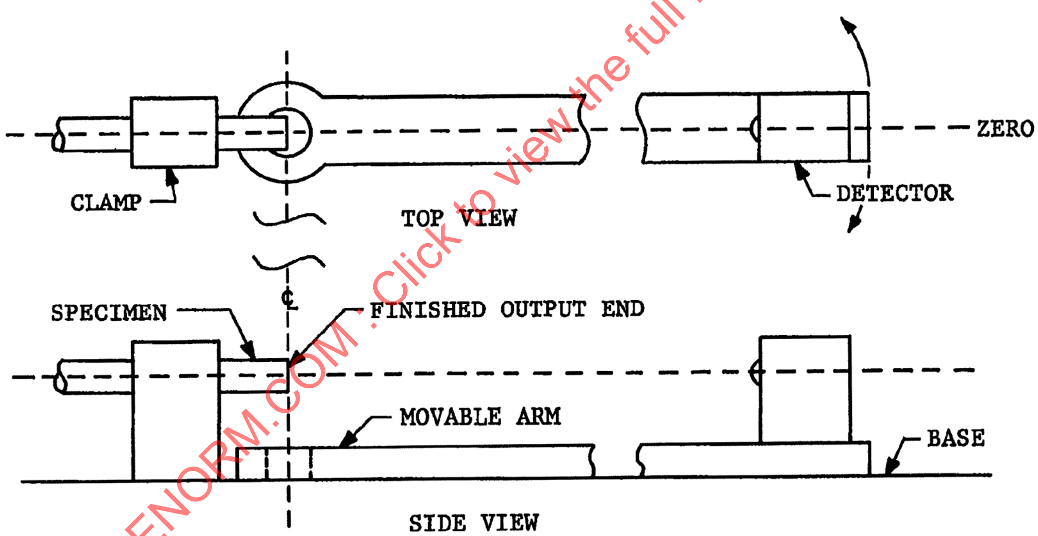


Figure 6030-1. Fixed Specimen, Movable Detector

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.

4.1 (Continued):

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 (± 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 ± 90°) 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).

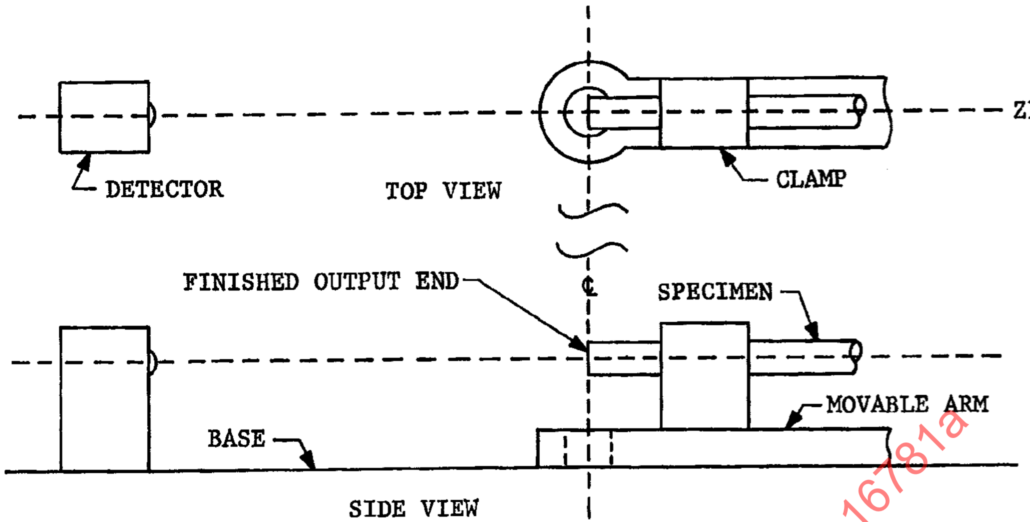


Figure 6030-2. Fixed Detector, Pivoting Specimen

4.2 (Continued):

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.

METHOD 6040
ACCEPTANCE PATTERN MEASUREMENT

1. SCOPE:

1.1 This method describes a procedure for measuring the acceptance patter 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° 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).

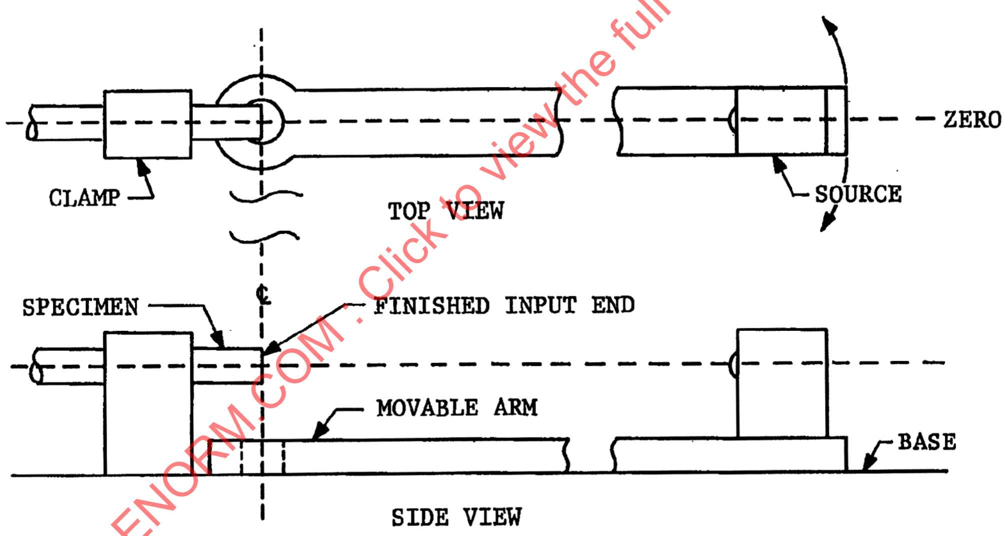


Figure 6040-1. Fixed Specimen, Movable Source

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.

4.1 (Continued):

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 (± 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 ± 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).

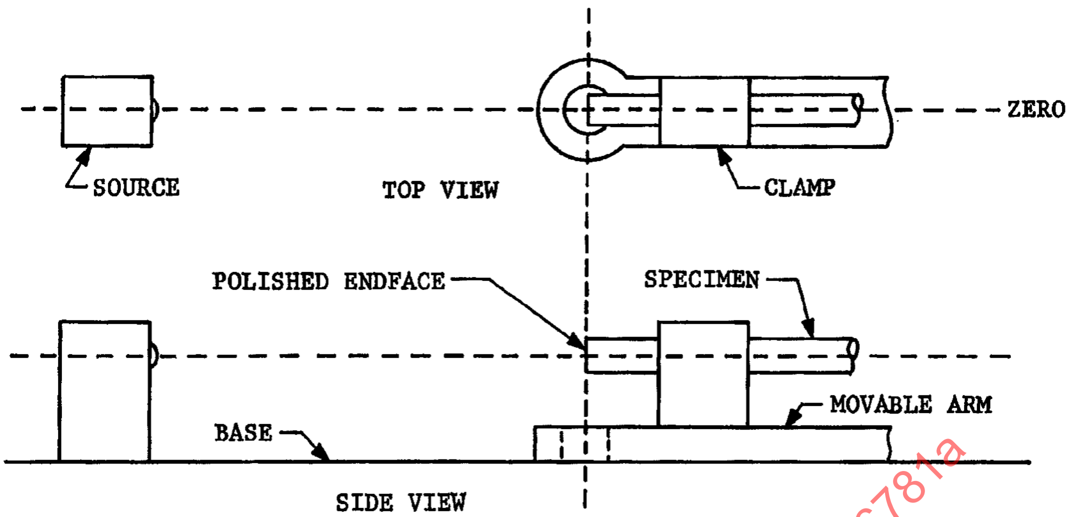


Figure 6040-2. Fixed Source, Pivoting Specimen

4.2 (Continued):

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.

METHOD 6050.1
OPTICAL FIBER BANDWIDTH BY TIME DOMAIN TECNIQUES

1. SCOPE:

1.1 This method describes a procedure for determining the bandwidth of a multimode optical fiber at a specified wavelength with specified launching conditions, using time domain techniques. The results are expressed as the “magnitude of the transfer function” and the “-3 dB bandwidth (optical).” Only those limitations to bandwidth due to intermodal effects are determined.

2. SPECIMEN:

2.1 Test specimen:

The test specimen shall be a known length of multimode optical fiber. The core diameter shall be determined by Method 1010 of DOD-STD-1678. The numerical aperture shall be determined by Method 6040 of DOD-STD-1678.

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 fiber which is representative of the fiber under test, as required by the applicable specification. The length of the reference specimen shall not be greater than 1 percent of the length of the test specimen.

2.3 End preparation:

A flat end face, perpendicular to the fiber axis shall be prepared at both ends of the test and reference speimens in accordance with Method 8040 of DOD-STD-1678.

2.4 Specimen handling:

The test specimen shall be suspended in a manner which relieves tension and minimizes microbending. Care should be taken to minimize external microbending.

3. APPARATUS:

(See Figure 6050-1).

3.1 Light source:

A suitable source (such as an injection laser diode), which produces short duration, narrow spectral width pulses shall be used.

3.1.1 Waveform: The source shall be modulated electrically or optically to produce short pulse waveforms. The pulse duration and shape shall be such that the magnitude of the Fourier transform of the waveform (as measured with the detector specified in 3.3 and following the procedure of 4.1) shall not vary by more than 15 dB over the range of frequencies of interest.

3.1.2 Wavelength: The center of the spectral linewidth shall be know to an accuracy of +5 nm and shall be within ± 10 nm of the specified wavelength. For injection laser diodes, the center of the stimulated emission shall be considered to be the center of the linewidth; the stimulated emission must exceed the spontaneous emission by no less than 15 dB.

3.1.3 Spectral linewidth: The spectral linewidth of the source will, in part, establish the upper frequency limit for valid measurements of the bandwidth limitations due to intermodal effects. The spectral linewidth shall be such that the measured -3 dB bandwidth (optical) will not differ from that which would be measured with a zero spectral width source by more than 10 percent. The required spectral linewidth will depend on wavelength, fiber length, and fiber composition. This condition,

$$\Delta\lambda \text{ (nm)} \leq \frac{\text{IDF (GHz km nm)}}{\text{L (km) IDL (GHz)}}$$

where $\Delta\lambda$ is the spectral width full width, half maximum (FWHM) of the source, L is the length of the test specimen, IDL (Intermodal Distortion Limit) is the highest frequency of interest for this measurement, and IDF (Intermodal Distortion Factor) is a parameter inversely proportional to the magnitude of the material dispersion (IDF = 0.2/|M| (ns/km nm)), may be used to estimate the maximum source linewidth for a valid measurement. For the germanium-phosphorus doped silica system, IDF can be estimated from the following table 6050-I.

TABLE 6050-I.

λ(nm)	IDF(GHz km nm)	λ(nm)	IDF(GHz km nm)
800	1.6	1200	18.
820	1.7	1250	42.
840	1.9	1300	220.
860	2.1	1340	40.
880	2.3	1510	11.
900	2.5		

Note: Gaussian impulse response shapes and Gaussian pulse shapes were assumed to generate these data. They will therefore apply most accurately to well compensated graded index fibers.

3.1.4 Spectrum stability: The spectral characteristics of the source shall be stable throughout the duration of a single pulse and over the time during which the measurement is made.

3.2 Launch system:

3.2.1 Mode scrambler: The light source shall be optically coupled to a mode scrambler, the output of which is independent of the spatial characteristics of the light source. The mode scrambler shall conform to one of the following types as specified in the applicable procurement specification. The prefered mode scrambler shall be a 3 meter length of fiber, constructed as follows: a one meter, step index fiber fusion spliced to a one meter graded index fiber which is fusion spliced to another one meter, step index fiber. See figure 6050-2. In lieu of the preferred type mode scrambler, the following shall be used: a single, 2 meter length of step index fiber. If necessary, large winding bends or a microbending device can be placed in the mode scrambler to alleviate its sensitivity to laser diode alignment. See figure 6050-3.

3.2.2 Coupling to specimen: The output of the mode scrambler shall be coupled to the input end of the specimen in such a way that both the size of the spot on the end of the specimen and the launch numerical aperture can be adjusted to specification. The fiber position shall be stable over the duration of the experiment. A viewing system may be used to aid fiber alignment.

3.3 Detection system:

3.3.1 Bandwidth: A detector with sufficient speed that the conditions of 3.1.1 can be met shall be used.

3.3.2 Uniformity: A detector that has been shown to have a uniform response (± 10%) over its active area shall be used.

3.3.3 Linearity: A detector that is linear in response over the range of power and energy required shall be used. A variable neutral density filter or other suitable device may be used to limit the range of power and energy over which the detector is used.

3.3.4 Stability: A detector that has been shown to be sufficiently stable, that is, a detector for which the ratio of output signal to applied optical power is sufficiently constant with time, shall be used.

3.3.5 Coupling: The output of the fiber shall be coupled to the detector in such a manner that all modes of the fiber are coupled equally.

3.4 Electronic instrumentation:

3.4.1 Display instrument: The detected optical pulse shall be displayed on a suitable instrument such as a high speed sampling oscilloscope. The instrument shall have a calibrated time base and shall be linear in amplitude response over the range of encountered signals.

3.4.2 Data recording: The display instrument shall be suitably connected to some external means of recording the detected pulse waveform for subsequent computer processing.

3.5 Computation:

3.5.1 Equipment: Suitable computational equipment capable of providing Fourier transforms of detected waveforms and computing ratios of linear arrays shall be provided.

3.5.2 Sampling: An appropriate transform technique along with suitable sampling parameters including the number of samples, the time between samples, the Nyquist frequency, and the frequency resolution, where applicable, shall be chosen. The same sampling parameters shall be used for Procedures I and II. The frequency resolution shall be at least a factor of ten smaller than the smallest -3 dB frequency measured.

4. PROCEDURE:

4.1 System calibration:

This section describes the procedure necessary to calibrate the system using the reference specimen.

Step 1 Alignment. The reference specimen shall be placed into the test system in such a manner that the specified launching conditions are obtained. The reference fiber core shall be centered in the output light signal from the mode scrambler. The intensity distribution across the input end of the refeerence fiber core shall vary by less than 25%. The launch numerical aperture, NA shall exeed the NA of the reference fiber. The output of the reference fiber shall be properly coupled to the detector.

Step 2 Signal level and time base adjustment. Display unit gain, neutral density filters and/or other devices shall be adjusted to obtain a single stable pulse waveform on the display instrument. The sweep rate used in this step must be the same as that used in Step 2 of paragraph 4.2 and must be such that an entire waveform is observed. Electrical phenomena (ringing, reflections, etc.) must be taken into account while performing measurements.

Step 3 Measurement. The system shall be caused to record a waveform and, using the known sampling parameters, to compute and properly scale the Fourier transform of that waveform. The magnitude of the transform shall be normalized to its value at the lowest frequency computed (not, in general, zero frequency). This normalized transform is called the system calibration function, $|G(f)|$ and shall be stored and/or otherwise recorded for use in Procedure III and for reporting in Section 5.

4.2 Measurement of test specimen:

This section describes the procedure for measurement of a test specimen using the system as previously calibrated.

Step 1 Alignment. The test specimen shall be placed into the test system in such a manner that the specified launching conditions are obtained. The test fiber core shall be centered in the output light signal from the mode scrambler. The intensity distribution across the input end of the test fiber core shall vary by less than 25%. The launch numerical aperture, NA, shall exceed the NA of the test fiber. The output of the test fiber shall be properly coupled to the detector.

Step 2 Signal level and time base adjustment. With the test specimen properly aligned, neutral density filters, as available, shall be adjusted to achieve a signal level on the detector that is approximately equal to the signal level obtained in Step 2 of the system calibration (4.1) (to within the demonstrated linearity range of the detector and electronics). Also, the same electronic gain (including detector gain, if any) and time base shall be used. The entire waveform must be displayed. Again, electrical phenomena (ringing, reflections, etc.) must be accounted for as in step 2 of the system calibration (4.1).

4.2.3 Measurement: The system can be caused to record a waveform and, using the known sampling parameters, to compute and properly scale the Fourier transform of that waveform. The magnitude of the transform shall be normalized to its value at the lowest frequency computed (not, in general, zero frequency). This normalized transform is called |F(f)| and shall be stored and/or otherwise recorded for use in Computations (4.3) and for reporting in Section 5.

4.3 Computations:

This section specifies the procedure by which the magnitude of the fiber transfer function and the fiber bandwidth are computed.

Step 1 Transfer function. The magnitude of the transfer function of the test specimen shall be determined by

$$|H(f)| = \left|\frac{F(f)}{G(f)}\right|$$

where |H(f)| is the magnitude of the transfer function, |F(f)| is the magnitude of the transform obtained in 4.2.3, |G(f)| is the system response function obtained in 4.1.3 and f is frequency. |H(f)| shall be expressed in decibels (optical) using $|H(f)|_{dB} = 10 \log_{10} |H(f)|$. $|H(f)|_{dB}$ shall be retained for reporting in Section 5.

Step 2 -3 dB Bandwidth (optical). The -3_{dB} bandwidth (optical) shall be determined as the lowest frequency at which $|H(f)|_{dB} = -3$ dB and shall be designated $f_{-3\ dB}$. The quantity $f_{-3\ dB}$ shall be retained for reporting in Section 5.

5. RESULTS:

5.1 Reporting:

The following information shall be reported with each test:

a. Operator and date.
b. Specimen identification.
c. Specimen length.
d. Reference length.
e. Source wavelength.
f. Launching conditions.
g. Magnitude of transfer function, ($|H(f)|_{dB}$ vs. f).
h. -3 dB Bandwidth (optical), ($f_{-3\ dB}$).

5.2 Documentation:

The following information shall be recorded and shall be made available upon request:

a. Source manufacturer, type, actual wavelength, and spectral characteristics.
b. Detector manufacturer, type, spatial response uniformity, gain at operating voltage, if applicable, and range of linearity.
c. Detection electronics/display system details.
d. Data recording method.
e. Lowest frequency at which |G(f)| = -15 dB.
f. Computation details, including sampling parameters.
g. dates of last equipment calibration and when calibration is next due.

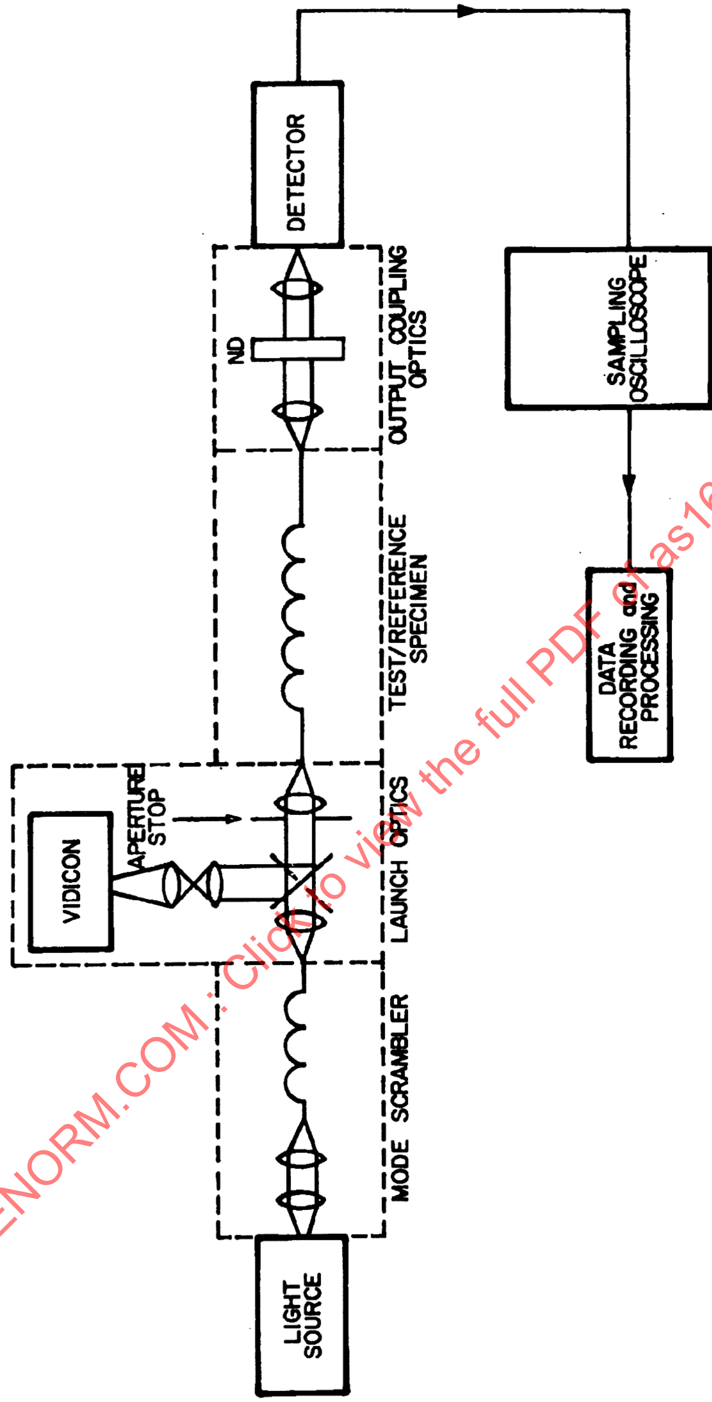


FIGURE 6050.1-1. Example system for fiber bandwidth measurement by time domain techniques.

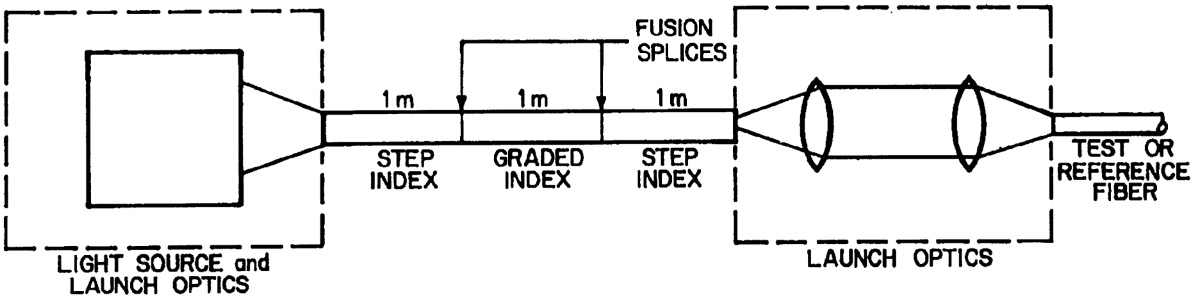


FIGURE 6050.1-2. Example of preferred type mode scrambler.

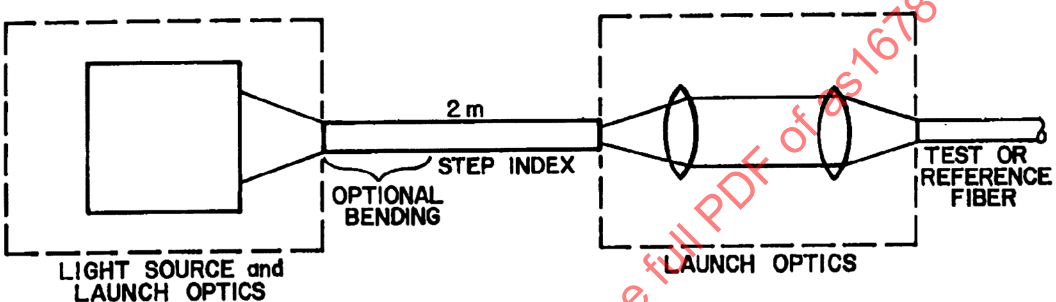


FIGURE 6050.1-3. Example of substitute type mode scrambler.

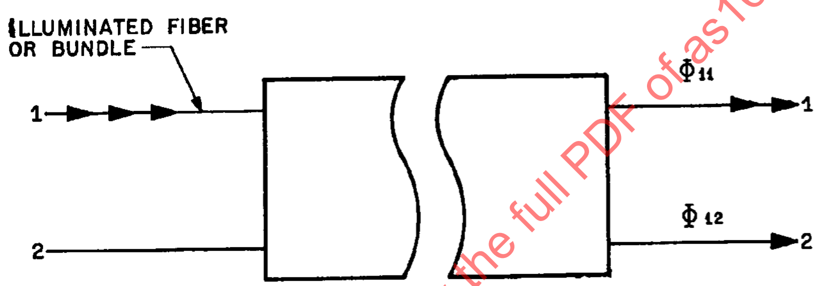
METHOD 6060.1
FAR-END CROSSTALK

1. SCOPE:

1.1 This method describes a procedure for measuring far-end corsstalk 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 F0 cable.

3. APPARATUS:

3.1 The apparatus shall be as specified herein and in Method 6010, Procedure II or III, of DOD-STD-1678.

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 radiation source and light modulator.

4. PROCEDURE:

Step 1 - The output of the source shall be adjusted, where necessary, to obtain the specified center wavelength, and its 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 its entire end is illuminated and that uniform illumination is present across the fiber launch cone specified in the specification sheet.

Step 4 - The input end of the non-illuminated fiber (Fiber 2) shall be optically blocked to prevent ambient light from entering the fiber and affecting the FEXT measurement.

Step 5 - Both ends of the illuminated and neighboring fiber (bundle) 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.

NOTE: One detector may be used and Φ_{11} and Φ_{12} measured serially (see Step 6).

Step 6 - 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) then either a shorter length of the specimen or a greater source intensity should be used. It may be necessary to use a calibrated attenuator in the illuminating fiber detector circuit (Φ_{11}).

5. RESULTS:

5.1 Reporting:

The following details shall be reported with each test:

a. Operator and date.
b. Specimen identification.
c. The measured power (in watts) Φ_{11} and Φ_{12}.
d. The radiation source, center wavelength(s), bandpass at the wavelength(s) and numerical aperture of the launched radiation cone.
e. The length (L_1) of the specimen.
f. The identity and refractive index at the wavelength(s) of interest of any index matching fluids, if used.
g. The far-end cross talk, FEXT (1, 2).

5.2 Documentation:

The following information shall be recorded and shall be made available upon request:

a. Source manufacturer, type, actual wavelength, and spectral characteristics.
b. Detector manufacturer, type, spatial response uniformity, gain at operating voltage, if applicable, and range of linearity.
c. Computation details, including sampling parameters.
d. Dates of last equipment calibration and when calibration is next due.

METHOD 6070.1
OPTICAL FIBER BANDWIDTH BY FREQUENCY DOMAIN TECHNIQUES

1. SCOPE:

1.1 This method describes a procedure for determining the bandwidth of a multimode optical fiber at a specified wavelength with specified launching conditions, using frequency domain techniques. The results are expressed as the "magnitude of the transfer function" and the "-3 dB bandwidth (optical)." Only those limitations to bandwidth due to intermodal effects are determined.

2. SPECIMEN:

2.1 Test specimen:

The test specimen shall be a known length of multimode optical fiber. The core diameter shall be determined by Method 1010 of DOD-STD-1678. The Numerical Aperture shall be determined by Method 6040 of DOD-STD-1678.

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 fiber which is representative of the fiber under test, as required by the applicable specification. The length of the reference specimen shall not be greater than 1 percent of the length of the test specimen.

2.3 End preparation:

A flat end face, perpendicular to the fiber axis, shall be prepared at both ends of the test and reference specimens in accordance with Method 8040 of DOD-STD-1678.

2.4 Specimen handling:

The test specimen shall be suspended in a manner which relieves tension and minimizes microbending. No external microbending shall be intentionally introduced.

3. APPARATUS:

(see Figure 6070-1)

3.1 Light source:

A suitable source (such as a continuous wave (cw) injection laser diode), capable of being stably amplitude modulated over a broad frequency range and having a narrow spectral width shall be used.

3.1.1 Modulation: The source shall be modulated electrically or optically to produce a sinusoidally time varying output power. The frequency of modulation shall be variable over a sufficiently wide range and the variation of modulation amplitude over the frequency range of interest shall be no greater than 15 dB (optical), (as measured with the detector specified in 3.3, the electronics specified in 3.4, and using the procedure of 4.1).

3.1.2 Wavelength: The center of the spectral linewidth shall be known to an accuracy of ± 5 nm and shall be within ± 10 nm of the specified wavelength. For injection laser diodes, the center of the stimulated emission shall be considered to be the center of the linewidth; the stimulated emission must exceed the spontaneous emission by no less than 15 dB.

3.1.3 Spectral linewidth: The spectral linewidth of the source will, in part, establish the upper frequency limit for valid measurements by this procedure of the bandwidth limitations due to intermodal effects. The spectral linewidth shall be such that the measured -3 dB bandwidth (optical) will not differ from that which would be measured with a zero spectral width source by more than 10 percent. The required spectral linewidth will depend on wavelength, fiber length, and fiber composition. This condition,

$$\Delta\lambda(\text{nm}) \le \frac{\text{IDF}(\text{GHz km nm})}{\text{L (km) IDL (GHz)}}$$

where $\Delta\lambda$ is the spectral width of the source full width, half maximum (FWHM), L is the length of the test specimen, IDL (Intermodal Distortion Limit) is the highest frequency of interest for this measurement, and IDF (Intermodal Distortion Factor) is a parameter inversely proportional to the magnitude of the material dispersion (IDF = 0.2/M (ns/km nm)), may be used to estimate the maximum source linewidth for a valid measurement. For the germanium-phosphorus doped silica system, IDF can be estimated from the following table 6070-I:

TABLE 6070-I

λ(nm)	IDF(GHz km nm)	λ(nm)	IDF(GHz km nm)
800	1.6	1200	18.
820	1.7	1250	42.
840	1.9	1300	220.
860	2.1	1340	40.
880	2.3	1510	11.
900	2.5		

Note: Gaussian impulse response shapes and Gaussian pulse shapes were assumed to generate these data. They will therefore apply most accurately to well compensated graded index fibers.

3.1.4 Spectrum stability: The spectral characteristics of the source shall be stable throughout the duration of the measurement.

3.2 Launch system:

3.2.1 Mode scrambler: The light source shall be optically coupled to a mode scrambler, the output of which is independent of the spatial characteristics of the light source. The mode scrambler shall conform to one of the following types as specified in the applicable procurement specification. The prefered mode scrambler shall be a 3 meter length of fiber, constructed as follows: a one meter, step index fiber fusion spliced to a one meter graded index fiber which is fusion spliced to another one meter, step index fiber. See figure 6070-2. In lieu of the preferred type mode scrambler, the following shall be used: a single, 2 meter length of step index fiber. If necessary, large winding bends or a microbending device can be placed in the mode scrambler to alleviate its sensitivity to laser diode alignment. See figure 6070-3.

3.2.2 Coupling to specimen: The output of the mode scrambler shall be coupled to the input end of the specimen in such a way that both the size of the spot on the end of the specimen and the launch numerical aperture can be adjusted to specification. The fiber position shall be stable over the duration of the experiment. A viewing system may be used to aid fiber alignment.

3.3 Detection system:

3.3.1 Bandwidth: A detector with sufficient speed that the conditions of 3.1.1 can be met shall be used.

3.3.2 Uniformity: A detector that has been shown to have a uniform response (± 10%) over its active area shall be used.

3.3.3 Linearity: A detector that is linear in response over the range of power required shall be used. A variable neutral density filter or other suitable device may be used to limit the range of power over which the detector is used.

3.3.4 Stability: A detector that has been shown to be sufficiently stable, that is, a detector for which the ratio of output signal to applied optical power is sufficiently constant with time, shall be used.

3.3.5 Coupling: The output of the fiber shall be coupled to the detector in such a manner that all modes of the fiber are coupled equally.

3.4 Electronic instrumentation:

3.4.1 Detection instrument: The output of the detector may be amplified with a suitable wideband low noise amplifier. It shall thereafter be detected with a suitable narrowband instrument, such as a spectrum analyzer, capable of providing a calibrated display of optical detector output versus frequency. The display shall provide output signals equivalent to the display information. The bandwidth of the instrument shall be sufficiently narrow that any harmonics of the modulation frequency are not detected.

3.4.2 Source electronics: The optical source shall be modulated with a variable radio frequency (rf) source, compatible with the detection electronics, such as a tracking generator.

3.4.3 Data recording: The detection electronics shall be connected to a suitable means of recording data for subsequent computation and reporting.

3.5 Computation:

3.5.1 Equipment: Suitable computational equipment capable of computing ratios of linear arrays shall be provided.

3.5.2 Software: Appropriate software, compatible with the procedures of 4. shall be used.

4. PROCEDURE:

4.1 System calibration:

This section describes the procedure necessary to calibrate the system using the reference specimen.

Step 1 Alignment. The reference specimen shall be placed into the test system in such a manner that the specified launching conditions are obtained. The reference fiber core shall be centered in the output light signal from the mode scrambler. The intensity distribution across the input end of the reference fiber core shall vary by les than 25%. The launch numerical aperture, NA, shall exceed the NA of the reference fiber. The output of the reference fiber shall be properly coupled to the detector.

Step 2 Signal level and frequency range adjustment. With the source electronics adjusted to sinusoidally modulate the source at frequencies covering the range of interest, the modulation level, neutral density filters (if used), and display electronics shall be adjusted to display the output of the detector as a function of frequency. The source modulation level and adjustments of the display electronics chosen for this step must be suitable for use in Step 2 of Procedure II.

Step 3 Measurement. The system shall be caused to record the magnitude of the detected modulation (detector output) as a function of frequency as the modulation frequency is varied either continuously or discretely over the range of interest. This function is called the system calibration function, $|G(f)|$. It shall be suitably normalized and shall be recorded and stored for use in Procedure III and for reporting as in Section 5.

4.2 Measurement of test specimen:

This section describes the procedure for measurement of a test specimen using the system as previously calibrated.

Step 1 Alignment. The test specimen shall be placed into the test system in such a way that the specified launching conditions are obtained. The test fibercore shall be centered in the output light signal from the mode scrambler. The intensity distribution across the input end of the test fiber core shall vary by less than 25%. The launch numerical aperture, NA, shall exceed the NA of the test fiber. The output of the test fibershall be properly coupled to the detector.

Step 2 Signal level and frequency range adjustment. With the test specimen properly aligned, neutral density filters, as available, shall be adjusted to achieve a signal level on the detector that is approximately equal to the signal level obtained in Step 2 of Procedure I (to within the demonstrated linearity range of the detector and electronics). The same electronic gain (including detector gain, if any) and display electronics adjustments shall be as used in Step 2 of Procedure I.

Step 3 Measurement. The system can be caused to record the magnitude of the detected modulation (detector output) as a function of frequency as the modulation frequency is varied either continuously or discretely over the range of interest. This curve is called |F(f)|. It shall be normalized in the same manner as |G(f)| and shall be recorded and stored for use in Procedure III and for reporting as Section 5.

4.3 Computations:

This section specifies the procedure by which the magnitude of the fiber transfer function and the fiber bandwidth are computed.

Step 1 Transfer function. The magnitude of the transfer function of the test specimen shall be determined by

$$|H(f)| = \left|\frac{F(f)}{G(f)}\right|$$

where |H(f)| is the magnitude of the transfer function, |F(f)| is the magnitude of the transform obtained in Step 3 of Procedure II, |G(f)| is the system response function obtained in Step 3 of Procedure I and f is frequency. |H(f)| shall be expressed in decibels (optical) using $H(f)_{dB} = 10 \log_{10} |H(f)|$. $|H(f)|_{dB}$ shall be retained for reporting in Section 5.

Step 2 -3 dB Bandwidth (optical). The -3 dB bandwidth (optical) shall be determined as the lowest frequency at which $|H(f)|_{dB}$ = -3 dB and shall be designated $f_{-3\ dB}$. Because the transforms have been normalized to their value at the lowest frequency computed the bandwidth computed as above shall be considered valid only if it exceeds the lowest frequency at which H(f) is computed by more than a factor of 10. The quantity $f_{-3\ dB}$ shall be retained for reporting in Section 5.