Optical Size 16 Expanded Beam Termini, Multimode Fiber for MIL-DTL-38999 Series III Style Circular Connector

1. INTRODUCTION

1.1. Purpose

Testing was performed on TE Connectivity optical size 16 expanded beam termini using a single channel multimode fiber to determine conformance to product specification 108-127013, rev A.

1.2. Scope

This report covers the optical, environmental, and mechanical performance of the optical size 16 expanded beam termini terminated to 1.8-mm flight grade cable with 50/125-µm multimode fiber. The termini are evaluated mounted in a MIL-DTL-38999 series III style circular connector with tight key/slot dimensions. Testing was performed between 10 May 13 and 26 Sep 13 at the Harrisburg Fiber Optic Component Test Laboratory (HFOCTL). The test file numbers are PRJ-3452-003 and PRJ-3452-006.

1.3. Conclusion

The optical size 16 expanded beam termini given in paragraph 1.5 meet the optical, mechanical, and environmental performance requirements of 108-127013, rev A.

1.4. Product Description

The optical size 16 expanded beam termini consist of a pin terminus and a spring-loaded socket terminus. Each termini has an anti-reflection coated ball lens at the fiber end, which on the launch side provides a collimated beam expansion. This beam crosses the free space termini interface and is collected on the receive side by the second ball lens, which focus the beam onto the fiber endface. This design provides a contact-less optical interface with only the mechanical interface making contact. The termini is rearward mounted into connectors having size 16 cavities. The design is suitable for use in rugged environments such as aviation and military applications.

1.5. Test Specimens

Test specimens were manufactured using normal manufacturing means.

Cable Type	Group	Qty	D38999 Series III Style Connector	Plug	Rcpt	Terminus to LC Connector		Total Channels
						Pin	Socket	
Cable Assembly	1	1	26WH21AN	X	—	2226428-1	—	15 Active, 6 Dummy Plugs
			24WH21BN	—	X	—	2226427-1	
	1	2	26WE8AN	X	—	2226426-1	—	16 Active
			24WE8BN	—	X	—	2226427-1	
	2	1	26WH21AN	X	—	2226428-1	—	15 Active, 6 Dummy Plugs
			24WH21BN	—	X	—	2226427-1	
	2	2	26WE8AN	X	—	2226428-1	—	16 Active
			24WE8BN	—	X	—	2226427-1	
	2	2	26WE8AN	X	—	2226426-1	—	16 Active
			24WE8BN	—	X	—	2226427-1	
Control Cable	2	1	2226425-1	—	—	2226425-1	—	1 Active

Figure 1. Sample Descriptions

Description	Part Number
Size 16 EB Pin (F) to LC, 50/125-µm OM4 Fiber, 3 Meters Long	2226426-1, Rev 1
Size 16 EB Socket to LC, 50/125-µm OM4 Fiber, 3 Meters Long	2226427-1, Rev 1
Size 16 EB Pin (C) to LC, 50/125-µm OM4 Fiber, 3 Meters Long	2226428-1, Rev 1
Size 17 Circular D38999 Plug with 8 Positions, Size 16 Pin Insert	26WE8AN
Circular D38999 Receptacle with 8 Positions, Size 16 Socket Insert	24WE8BN
Size 23 Circular D38999 Plug with 21 Positions, Pin Insert	26WH21AN
Size 23 Circular D38999 Receptacle with 21 Positions, Size 16 Socket Insert	24WH21BN
Fiber Optic Cable Assembly, LC-LC, Simplex, 50/125-µm OM4 Fiber, 6 Meters Long	2226425-1
Size 16 Empty Cavity Plug Seal (Dummy Terminus)	203839-2

Figure 2. Specimen Selection

1.6. Product Qualification Test Sequence

NOTE
For group 1, monitor six channels for discontinuities during vibration and mechanical shock. The channels shall be randomly selected as 4 channels from the size 23 D38999 assembly and one channel each from the size 17 D38999 assemblies. All testing where an optical discontinuity monitor is used shall be conducted at 1300 nm.

Test	Test Sequence	
	Test Group 1	Test Group 2
Examination of Product	1	1
Attenuation (Insertion Loss)	2,6	2,7
Vibration, Sinusoidal	3	
Vibration, Random	4	
Mechanical Shock	5	
Mating Durability	7	
Temperature Life, Hot		3
Temperature Life, Cold		4
Thermal Cycling		5
Thermal Shock		6

Figure 3. Test Groups

2. SUMMARY OF TESTING

2.1. Visual and Mechanical Inspection

All specimens submitted for testing were inspected and accepted by the Product Assurance Department.

2.2. Test Group 1 (Mechanical)

A. Initial Insertion Loss

The optical power source wavelengths are 850 and 1300 nanometers (nm) for the 50/125-µm multimode product. The multimode launch condition shall meet encircled flux requirement of IEC 62614.

The launch condition was calibrated and verified by the HFOCTL from June 5 through 7, 2013.

Wavelength	850 nm	1300 nm
Attenuation Measurements (dB)		
Group 1 Channel Count	31	31
Group 1 Average	0.89	0.79
Group 1 Maximum	1.36	1.22
Group 1 Minimum	0.55	0.44
Group 1 Standard Deviation	0.20	0.21
Attenuation Requirements (dB)		
Maximum, Any Channel	≤1.50	≤1.50

Figure 4

B. Vibration—Sinusoidal

NOTE
Due to fixture and setup issues, some connector samples were exposed to acceleration forces up to 146 G, which is much higher than the specification limit of 60 G. Even so, the samples survived, and the test sequence was continued.

Wavelength	850 nm	1300 nm
Attenuation Measurements (dB)		
Group 1 Maximum (After Test)	1.47	1.21
Group 1 Maximum Increase (After Test)	0.48	0.50
Discontinuities	NA	None
Attenuation Requirements (dB)		
Maximum, Any Channel	≤1.70	≤1.70
Maximum Attenuation Increase (After Test)	≤0.50	≤0.50
Discontinuities > 0.50 dB for More Than 10 µs	NA	None

Figure 5

C. Vibration—Random

Wavelength	850 nm	1300 nm
Attenuation Measurements (dB)		
Group 1 Maximum (After Test)	1.48	1.20
Group 1 Maximum Increase (After Test)	0.16	0.15
Discontinuities	NA	None
Attenuation Requirements (dB)		
Maximum, Any Channel	≤1.70	≤1.70
Maximum Attenuation Increase (After Test)	≤0.50	≤0.50
Discontinuities > 0.50 dB for More Than 10 µs	NA	None

Figure 6

D. Mechanical Shock

NOTE
One path was excluded (connector 17F1-chA) because the lens was scratched by the operator during handling/cleaning.

Wavelength	850 nm	1300 nm
Attenuation Measurements (dB)		
Group 1 Maximum (After Test)	1.23	1.11
Group 1 Maximum Increase (After Test)	0.19	0.19
Discontinuities	NA	None
Attenuation Requirements (dB)		
Maximum, Any Channel	≤1.70	≤1.70
Maximum Attenuation Increase (After Test)	≤0.50	≤0.50
Discontinuities > 0.50 dB for More Than 10 µs	NA	None

Figure 7

E. Durability

Wavelength	850 nm	1300 nm
Attenuation Measurements (dB)		
Group 1 Maximum (After Test)	1.31	1.11
Maximum Attenuation Increase (After Test)	0.21	0.21
Attenuation Requirements (dB)		
Maximum, Any Channel	≤1.70	≤1.70
Maximum Attenuation Increase (After Test)	≤0.50	≤0.50

Figure 8

F. End of Service Life

Wavelength	850 nm	1300 nm
Attenuation Measurements (dB)		
Group 1 Channel Count	30	30
Group 1 Average	0.86	0.72
Group 1 Maximum	1.31	1.11
Group 1 Minimum	0.57	0.46
Group 1 Standard Deviation	0.20	0.18
Attenuation Requirements (dB)		
Maximum, Any Channel	≤1.70	≤1.70

Figure 9

2.3. Test Group 2 (Environmental)

A. Initial Insertion Loss

The optical power source wavelengths are 850 and 1300 nm for the 50/125-µm multimode product. The multimode launch condition shall meet encircled flux requirement of IEC 62614.

The launch condition was calibrated and verified by the HFOCTL from June 5 through 7, 2013.

Wavelength	850 nm	1300 nm
Attenuation Measurements (dB)		
Group 2 Channel Count	47	47
Group 2 Average	0.72	0.66
Group 2 Maximum	1.14	1.07
Group 2 Minimum	0.45	0.43
Group 2 Standard Deviation	0.18	0.16
Attenuation Requirements (dB)		
Maximum, Any Channel	≤1.50	≤1.50

Figure 10

B. Temperature Life, Hot

Wavelength	850 nm	1300 nm
Attenuation Measurements (dB)		
Group 2 Maximum (After Test)	1.10	0.99
Group 2 Maximum Increase (After Test)	0.12	0.13
Attenuation Requirements (dB)		
Maximum, Any Channel	≤1.70	≤1.70
Maximum Attenuation Increase (After Test)	≤0.50	≤0.50

Figure 11

C. Temperature Life, Cold

Wavelength	850 nm	1300 nm
Attenuation Measurements (dB)		
Group 2 Maximum (After Test)	1.11	0.99
Group 2 Maximum Increase (After Test)	0.13	0.13
Attenuation Requirements (dB)		
Maximum, Any Channel	≤1.70	≤1.70
Maximum Attenuation Increase (After Test)	≤0.50	≤0.50

Figure 12

D. Temperature Cycling

NOTE
One channel (path F of connector 17F3) was excluded from the statistics due to a failure of the test equipment receive switch during test. The receive connector of the test sample was changed to another available switch position.

Wavelength	850 nm	1300 nm
Attenuation Measurements (dB)		
Group 2 Maximum (During Test)	1.27	1.14
Group 2 Attenuation Increase (During Test)	0.30	0.27
Group 2 Maximum Increase (After Test)	1.15	1.01
Group 2 Maximum Attenuation Increase (After Test)	0.13	0.12
Attenuation Requirements (dB)		
Maximum, Any Channel	≤1.70	≤1.70
Maximum Attenuation Increase (During Test)	≤0.50	≤0.50
Maximum Attenuation Increase (After Test)	≤0.50	≤0.50

Figure 13

E. Thermal Shock

NOTE
Two fibers broke during the transfer between chambers and one of the retainers in the D38999 connectors failed. A follow-up test where the samples were transferred between the two chambers, both set at room temperature, created yet another fiber breakage. This confirmed that the failures are not related to the product design, but can be solely attributed to the handling procedure.

Wavelength	850 nm	1300 nm
Attenuation Measurements (dB)		
Group 2 Maximum (After Test)	1.30	1.20
Group 2 Maximum Increase (After Test)	0.32	0.30
Attenuation Requirements (dB)		
Maximum, Any Channel	≤1.70	≤1.70
Maximum Attenuation Increase (After Test)	≤0.50	≤0.50

Figure 14

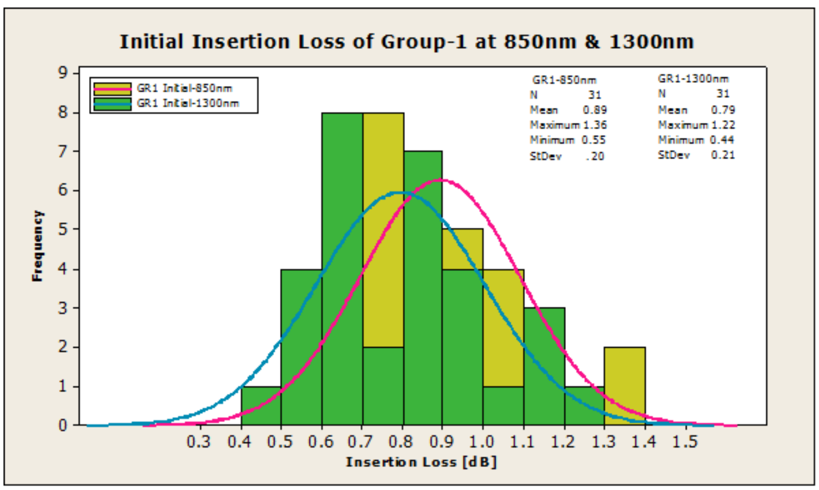
F. End of Service Life

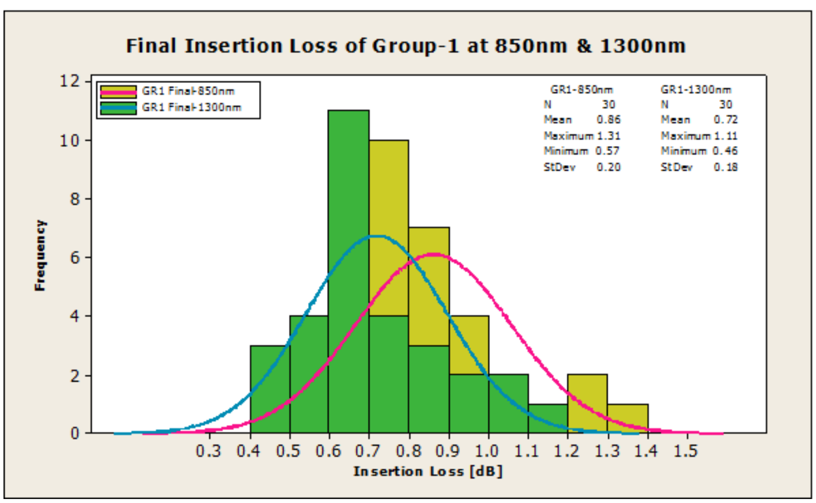
Wavelength	850 nm	1300 nm
Attenuation Measurements (dB)		
Group 2 Channel Count	44	44
Group 2 Average	0.78	0.69
Group 2 Maximum	1.28	1.18
Group 2 Minimum	0.48	0.44
Group 2 Standard Deviation	0.18	0.18
Attenuation Requirements (dB)		
Maximum, Any Channel	≤1.70	≤1.70

Figure 15

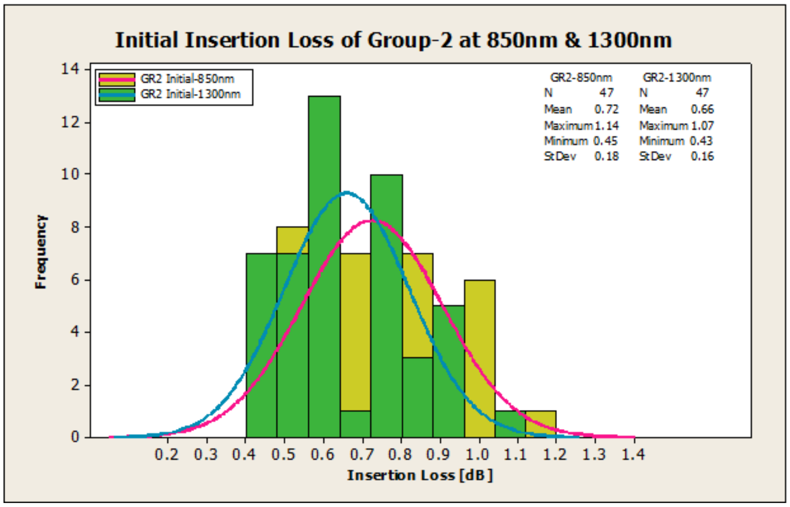
2.4. Graphical Presentations of the Initial and Final Insertion Losses of Test Groups 1 and 2

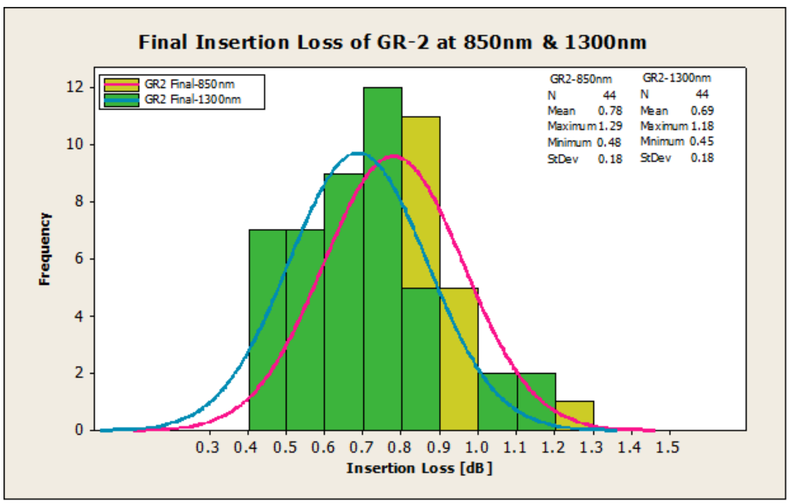
Test Group 1





Test Group 2





3. TEST METHODS AND PROCEDURES

3.1. Setup and Verification of Encircled Flux Launch Fill Condition

Specification: Fibre-Optic Communication Subsystem Test Procedures, Part 4-1: Installed Cable Plant—Multimode Attenuation Measurement, IEC 61280-4-1, December 2008

The modal power distribution of all 50/125-µm launch LC leads was measured at 850 nm and 1300 nm. Each lead was wrapped as necessary around an appropriate diameter mandrel using the appropriate number of loops in order to comply with the encircled flux requirements of IEC 61280-4-1.

All measured data are filed electronically at the HFOCTL.

3.2. Initial Examination

Specification: Visual/Mechanical Inspection of Fiber Optic Components Devices and Assemblies, TIA/EIA-455-13A, FOTP-13, August 1996

Product drawings and inspection plans were used in the visual and functional examination.

3.3. Initial Attenuation (Build-Up Insertion Loss)

Specification: Attenuation by Substitution Measurement for Short-Length Multimode Graded-Index and Single-Mode Optical Fiber Cable Assemblies, TIA/EIA-455-171A, FOTP-171, June 2001, Method D1

Initial attenuation data (build-up IL data) were calculated by subtracting P_1 from P_0 and compensating for any changes in the output power of the optical source. The same method was used for both groups submitted for testing. Refer to the sample measurement setup diagram shown in Figure 16.

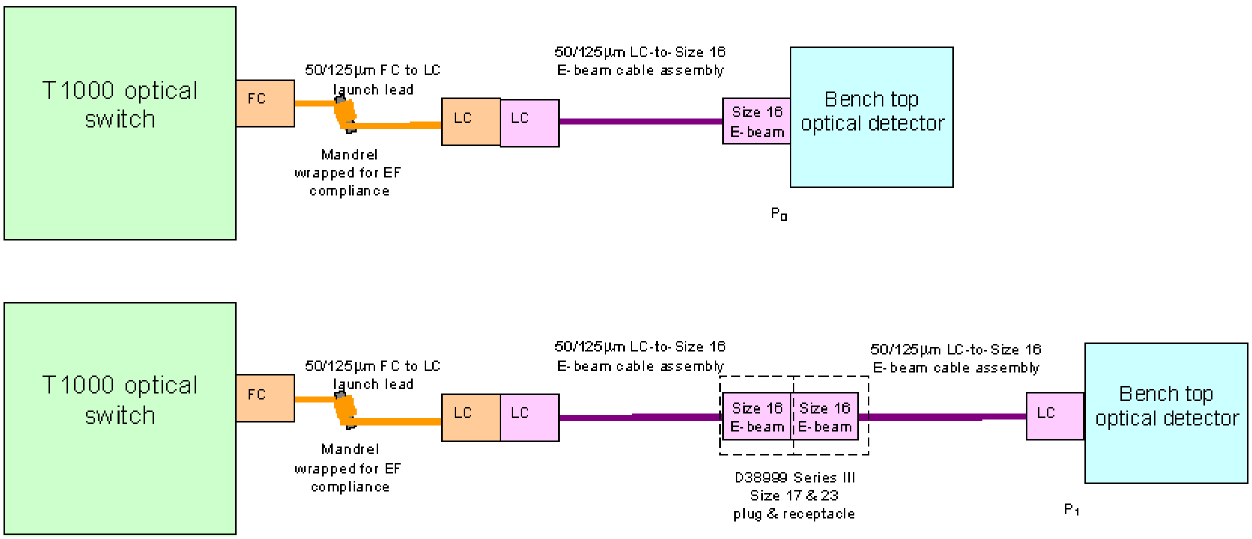


Figure 16. Measurement Setup Diagram for Initial Attenuation

3.4. Sinusoidal Vibration

Specification: Vibration Test Procedure for Fiber Optic Components and Cables, TIA/EIA-455-11D, FOTP-11, December 2010, Test Condition IV with Modifications

10- to 2000-Hz sine motion, except velocity of 10 in./sec from 10 to 50 Hz, 0.06-in. double amplitude from 50 to 140 Hz, and 60 G from 140 to 2000 Hz, conduct 36 sweeps of 20 minutes each applied in 3 mutually perpendicular axis for a total test time of approximately 12 hrs (4 hrs for each axis) at ambient temperature. Record optical transmittances before the test and after the specimens have been tested in each axis. Monitor 6 channels for discontinuities during the test.

Exposure Issue: When initially attempting to expose the 3 samples to the 60-G sinusoidal profile, the current limits of the shaker were exceeded. A sample and fixture block were removed from the cube to lessen the total mass. Running the profile with 2 samples also exceeded the current limit of the shaker. Another sample and fixture block were removed from the cube. Sample 23C1 was exposed in the Z-axis without any shaker problems.

With the control accelerometer still mounted to the top corner of the cube and the sample in the Y axis, a monitor accelerometer was wax-mounted as close to the sample as possible. The monitor revealed that the sample was being subjected to acceleration forces as high as 146 G.

Improved fixture means and positioning of the accelerometer closer to the sample under test to better monitor the true exposure allowed the test to proceed as intended. It was believed that the samples had not been damaged by the excessive exposure and the testing proceeded as planned.

3.5. Random Vibration

Specification: Vibration Test Procedure for Fiber Optic Components and Cables, TIA/EIA-455-11D, FOTP-11, December 2010, Test Condition VI-J

Test shall be applied for 8 hrs in the longitudinal direction and 8 hrs in a perpendicular direction for a total of 16 hrs at 37.8 GRMS. Test temperature shall be ambient, and record optical transmittance before following the test in each plane. Monitor 6 channels for discontinuities during the test.

3.6. Mechanical Shock

Specification: Fiber Optic Shock Tests (Specified Pulse), EIA/TIA-455-14A, FOTP-14, March 1992, Test Condition C

100-G, 6-ms half-sine pulse, 3 shocks in each direction shall be applied along the three mutually perpendicular axes of the test sample (18 shocks). Record optical transmittance before and after the test. Monitor 6 channels for discontinuities during the test.

3.7. Mating Durability

Specification: Mating Durability of Fiber Optic Interconnecting Devices, TIA-455-21-A, FOTP-21, January 2012

Perform initial cleaning of lenses and connector interfaces. Mate and unmate the connectors 300 times at a maximum rate of 300 cycles per hr. At the completion of the test, make final IL measurements after cleaning and inspecting (301st cycle).

3.8. Temperature Life, Hot

Specification: Fiber Optic Component Temperature Life Test, TIA/EIA-455-4C, FOTP-4, June 2002

Specimen shall be mated and optically functioning. Maintain specimens undisturbed in the chamber at room ambient (23±5°C and 20 to 70% RH) for 2 hrs prior to recording initial attenuation. Subject specimens to 85±2°C for 50 hrs. At the completion of testing, measure final attenuation 1 to 2 hrs after the chamber returns to ambient conditions with specimens undisturbed in the test chamber.

The chamber humidity shall be left uncontrolled throughout the entire exposure.

3.9. Temperature Life, Cold

Specification: Fiber Optic Component Temperature Life Test, TIA/EIA-455-4C, FOTP-4, June 2002

Specimen shall be mated and optically functioning. Maintain specimens undisturbed in the chamber at ambient room temperature (23±5°C and 20 to 70% RH) for 2 hrs prior to recording initial attenuation. Subject specimens to -50±2°C for 50 hrs. At the completion of testing, measure final attenuation 1 to 2 hrs after the chamber returns to ambient conditions with specimens undisturbed in the test chamber.

The chamber humidity shall be left uncontrolled throughout the entire exposure.

3.10. Thermal Cycling

Specification: Procedure to Measure Temperature Cycling Effects on Optical Fiber Units, Optical Cable, and Other Passive Fiber Components, TIA-455-3B, FOTP-4, July 2009

Subject mated specimens to 20 cycles from -40°C to +85°C. Dwell 1 hr at every 23°C crossing and at each temperature extreme. Measure insertion loss at least 30 minutes into each dwell. After completion of the final cycle, measure insertion loss within 1 to 2 hrs after the chamber returns to ambient conditions with specimens undisturbed in the test chamber.

The chamber temperature was ramped from +23°C down to -40°C in 1 hr and 45 minutes. This was followed by a 1-hr dwell at -40°C, followed by a 1-hr, 45-minute ramp to +23°C, followed by a 1-hr dwell at +23°C, followed by a 1-hr and 45-minute ramp to +85°C, followed by a 1-hr dwell at +85°C, followed by a 1-hr and 45-minute ramp to +23°C, and followed by a 1-hr dwell at +23°C. This constitutes one temperature cycle.

The chamber humidity was left uncontrolled throughout the entire exposure, but was recorded by a temperature-humidity sensor for information only.

3.11. Thermal Shock

Specification: Procedure to Measure Temperature Shock Effects on Fiber Optic Components, TIA/EIA-455-71, FOTP-71, April 1989

The high and low soak temperatures shall be 125°C+5°C/-0°C and -55°C+0°C/-5°C for 5 cycles. At the completion of testing, measure final attenuation and change in transmittance 1 to 2 hrs after the chamber returns to ambient conditions with specimens undisturbed in the test chamber.

Two independent environmental chambers were used for this exposure. Thermocouples were placed in each chamber. A third thermocouple was attached to one of the samples. The first chamber was set to +125+5/-0°C. The second chamber was set to -55°C.

Exposure Issue: With the 2 chambers stabilized at the temperature extremes, the samples and control cable were manually passed through the port hole of the cold chamber. The samples and control cable remained in the cold chamber for 1 hr. Even though care was taken during the manual transfer of the samples between chambers in order to lessen any damage to the fibers and sample terminations, efforts were made to bend the cables approximately 5 to 10 in. behind either the plug or receptacle connector instead of immediately behind the connectors. Bend distances were varied in order to stagger the connector shells so that they would better fit through the 3-in. port holes of the chambers. Still, as was reported in paragraph 2.3 E, two fibers broke during the handling.

After the test, the procedure was repeated with the samples optically active, now with both chambers at room temperature to eliminate the temperature factor as a potential failure mode. One more fiber broke in the process, thus proving that the damage was not caused by the product design or by the temperature influence, but was purely due to handling.

3.12. End of Service Life

After completion of the testing of the two groups, insertion loss measurements were taken on the samples to record the final optical performance condition after all the test exposures had been completed.