



Performance from Experience

Generic Requirements for Singlemode Optical Connectors and Jumper Assemblies

(A Module of FR-FIBER-1)

Telcordia Technologies Generic Requirements
GR-326-CORE
Issue 3
September 1999

Comments Requested (See Preface)

Generic Requirements for Singlemode Optical Connectors and Jumper Assemblies

Prepared for Telcordia Technologies by The Physical Network Integrity and Product Reliability Practice.

Target audience: Telecommunications service providers, local exchange carriers, Regional Bell Operating Companies, and telecommunications equipment manufacturers and suppliers.

This document replaces: GR-326-CORE, Issue 2, December 1996.

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Contents

Preface.....	Preface-1
1. Introduction.....	1-1
1.1 Purpose and Scope	1-1
1.2 Target Audience	1-2
1.3 Structure and Use of This Document.....	1-2
1.4 Changes from Issue 2 of GR-326-CORE.....	1-3
1.5 Requirements Terminology	1-9
1.6 Requirement Labeling Conventions	1-9
1.6.1 Numbering of Requirement and Related Objects.....	1-9
1.6.2 Requirement, Conditional Requirement, and Objective Object Identification	1-10
2. General Information.....	2-1
2.1 Description	2-1
2.2 Connector Applications	2-2
3. General Requirements.....	3-1
3.1 Documentation.....	3-1
3.2 Packaging and Shipping.....	3-2
3.3 Design Features	3-2
3.3.1 Materials	3-2
3.3.2 Cleanability.....	3-3
3.4 Intermateability.....	3-4
3.4.1 Latching Intermateability Requirements for Push-Pull Type Connectors	3-8
3.5 Product Marking and Packaging.....	3-8
3.5.1 Keying.....	3-9
3.5.2 Specialty Fiber	3-10
3.6 Safety.....	3-11
4. Connector Tests and Criteria.....	4-1
4.1 Test Samples.....	4-2
4.1.1 Definitions	4-2
4.1.2 Population.....	4-4
4.2 Criteria	4-4
4.2.1 Overview of Optical Performance Criteria.....	4-4
4.2.2 Modifications and Conditions	4-6
4.2.2.1 Measurement Error	4-6
4.2.2.2 Jumper Cable Assembly Measurements.....	4-7
4.2.2.3 Reflectance Increase Criteria Applicability	4-7
4.2.2.4 Reflectance Criteria Applicability	4-8
4.2.2.5 Handling of Nonconformance.....	4-8

4.2.3	Damage Criteria	4-9
4.3	Cleaning Procedures	4-9
4.3.1	Cleaning Procedure A	4-10
4.3.2	Cleaning Procedure B	4-10
4.4	Statement of Criteria	4-11
4.4.1	Performance of New Product	4-11
4.4.2	Temperature, Humidity, Condensation Tests	4-13
4.4.2.1	Thermal Age Test	4-13
4.4.2.2	Thermal Cycle Test	4-14
4.4.2.3	Humidity Aging Test.....	4-16
4.4.2.4	Humidity / Condensation Cycling Test	4-17
4.4.2.5	Dry-Out Step.....	4-18
4.4.2.6	Post-Condensation Thermal Cycle Test	4-19
4.4.3	Mechanical Tests	4-19
4.4.3.1	Vibration Test.....	4-19
4.4.3.2	Flex Test.....	4-20
4.4.3.3	Twist Test.....	4-21
4.4.3.4	Proof Test.....	4-22
4.4.3.5	Transmission With Applied Tensile Load.....	4-24
4.4.3.6	Equilibrium Tensile Loading.....	4-28
4.4.3.7	Impact Test.....	4-28
4.4.3.8	Durability.....	4-30
4.4.3.9	End of Test Criteria.....	4-33
4.4.4	Materials and Environmental Tests.....	4-33
4.4.4.1	Dust Test.....	4-33
4.4.4.2	Adhesive Testing	4-38
4.4.4.3	Airborne Contaminants	4-38
4.4.4.4	Salt Spray.....	4-41
4.4.4.5	Immersion/Corrosion Test	4-43
4.4.4.6	Groundwater Immersion	4-44
4.4.5	Geometry Requirements	4-45
4.4.5.1	Ferrule Endface Geometry for Non-Angled Physical Contact Connectors	4-45
4.4.5.2	Endface Geometry Requirements for Angled Physical Contact (APC) Connectors	4-47
4.4.5.3	Endface Geometry Measurement Areas.....	4-49
4.4.6	Connector Installation	4-50
5.	Facilities for Product Testing.....	5-1
5.1	Ambient Laboratory Conditions	5-1
5.2	Optical Measurements.....	5-1
5.2.1	Transmission Measurement Facility	5-2
5.2.1.1	Measurement of Optical Loss with a Transmission Measurement Facility	5-3

5.2.1.2	Measurement of Reflectance with a Transmission Measurement Facility	5-4
5.2.2	OTDR Measurement Facility	5-6
5.2.2.1	Measurement of Optical Loss with an OTDR	5-7
5.2.2.2	Measurement of Reflectance with an OTDR	5-9
5.3	Product Test Facilities	5-10
5.3.1	Environmental Tests	5-10
5.3.2	Vibration Test.....	5-10
5.3.3	Jumper Tension Test Fixture	5-11
5.3.4	Durability Test.....	5-12
5.3.5	Impact Test.....	5-12
5.3.6	Adhesive Test	5-14
5.3.7	Dust Test.....	5-14
5.3.8	Groundwater Immersion Test.....	5-17
6.	Service Life Tests.....	6-1
6.1	Service Life Tests.....	6-1
6.2	New Product Measurements	6-2
6.3	Tensile Tests.....	6-2
7.	Reliability Tests.....	7-1
7.1	Description of Reliability Tests.....	7-1
7.2	Reliability Test Samples.....	7-2
7.2.1	Type of Sample.....	7-2
7.2.2	Sample Size.....	7-2
7.3	Criteria to be Applied to Reliability Tests	7-3
8.	Reliability Assurance Program.....	8-1
8.1	Reliability Testing	8-1
8.2	Manufacturing and Process Control.....	8-1
8.2.1	Materials and Components.....	8-1
8.2.1.1	Quality Levels.....	8-2
8.2.1.2	Materials and Components Requirements	8-2
8.2.1.2.1	Vendor Qualification.....	8-2
8.2.1.2.2	Part Qualification	8-3
8.2.1.2.3	Qualification of Epoxies.....	8-4
8.2.1.2.4	Raw Material Specifications	8-4
8.2.1.2.5	Determination of Acceptability of Raw Materials	8-5
8.2.1.2.6	Reliability Controls	8-6
8.2.1.2.7	Feedback and Corrective Action.....	8-6
8.2.2	Physical Design	8-7
8.2.2.1	Contact of Dissimilar Metals.....	8-7
8.2.2.2	Flammability	8-8
8.2.3	Manufacturing and Assembly	8-8
8.2.3.1	Training.....	8-9

8.2.3.2	Product Documentation	8-9
8.2.3.3	Product Inspection	8-10
	8.2.3.3.1 Segregation of Nonconforming Material	8-11
	8.2.3.3.2 Storage and Handling of the Product.....	8-11
8.2.3.4	Product Assembly	8-11
8.2.3.5	Product Traceability	8-12
8.2.3.6	Customer Complaints	8-12
8.2.3.7	Field Trials	8-13
8.2.3.8	Statistical Process Control and Quality Data.....	8-13
8.2.4	Manufacturer Testing	8-13
8.2.4.1	Test Documentation.....	8-14
8.2.4.2	In-Process Testing	8-14
8.2.4.3	Finished Goods Testing	8-15
	8.2.4.3.1 Test Data.....	8-15
	8.2.4.3.2 Connector Adapters	8-16
	8.2.4.3.3 Replacement of Testing Parts.....	8-16
8.2.4.4	Calibration.....	8-17
8.2.4.5	Product Qualification Testing.....	8-18
	8.2.4.5.1 Repeat of Initial Qualification Testing.....	8-19
	8.2.4.5.2 Periodic Requalification Test Schedule.....	8-19
	Requirement-Object List.....	ROL-1
	References.....	References-1
	Glossary.....	Glossary-1
	Requirement-Object Index	ROI-1

List of Figures

Figure 2-1.	Sample Connector Assembly with One Plug Removed.....	2-1
Figure 3-1.	SC Connector Plug	3-5
Figure 3-2.	FC Connector Plug.....	3-6
Figure 3-3.	SC Connector Reference Plane	3-6
Figure 3-4.	FC Connector Reference Plane	3-7
Figure 3-5.	The Latch Spacing in SC Adapters	3-7
Figure 4-1.	Pigtail Assembly	4-3
Figure 4-2.	Jumper Cable Assembly	4-3
Figure 4-3.	Thermal Cycle Profile	4-15
Figure 4-4.	Temperature/Humidity Profile for Humidity/Condensation Test ..	4-17
Figure 4-5.	Dust Test Flow Chart.....	4-36
Figure 4-6.	Ferrule Endface Geometry.....	4-46
Figure 4-7.	The Maximum Allowed Fiber Undercut for a Ferrule Radius of Curvature Between 7 mm and 25 mm.....	4-46
Figure 4-8.	Dome Offset for APC Connectors	4-48
Figure 4-9.	The Connector Endface Geometry Measurement Areas.....	4-49
Figure 4-10.	Connector Installation Test	4-51
Figure 5-1.	Transmission Measurement Facility.....	5-2
Figure 5-2.	Cutback Measurement Location (Transmission).....	5-4
Figure 5-3.	OTDR Measurement Facility	5-6
Figure 5-4.	OTDR Response to a Connector	5-8
Figure 5-5.	Cutback Measurement Location (OTDR)	5-8
Figure 5-6.	Jumper Test Facility	5-12
Figure 5-7.	Impact Test Facility	5-13
Figure 5-8.	Adhesive Test Facility.....	5-14
Figure 5-9.	Dust Exposure Sample Groups	5-15
Figure 5-10.	Dust Test Facility	5-16

List of Tables

Table 1-1.	Changes from GR-326-CORE, Issue 2 to Issue 3	1-4
Table 3-1.	Reflectance Color Code.....	3-9
Table 4-1.	List of Connector Tests	4-1
Table 4-2.	Summary of Optical Performance Criteria: Loss	4-5
Table 4-3.	Summary of Optical Performance Criteria: Reflectance.....	4-5
Table 4-4.	Test Conditions for the Thermal Age Test.....	4-14
Table 4-5.	Test Conditions for the Thermal Cycle Test.....	4-15
Table 4-6.	Test Conditions for the Humidity Aging Test.....	4-16
Table 4-7.	Test Conditions for the Humidity / Condensation Cycling Test.....	4-17
Table 4-8.	Number of Turns for Twist Test.....	4-22
Table 4-9.	Tensile Loads for Transmission with Applied Load	4-24
Table 4-10.	Small Form Factor Connector Tensile Loads for Transmission with Applied Load.....	4-26
Table 4-11.	Airborne Contaminants Test Gases	4-39
Table 4-12.	Operating Parameters for the Salt Spray Test.....	4-41
Table 5-1.	Particle Size Distribution	5-16
Table 5-2.	Chemical Composition	5-16
Table 5-3.	Organism Exposure for Completed Splices.....	5-18
Table 6-1.	Service Life Tests	6-1
Table 7-1.	Reliability Tests	7-1
Table 7-2.	Lot Tolerance Percent Defective Table	7-3
Table 8-1.	Definition of Quality Levels	8-3

Preface

This Preface contains important information about the Telcordia Technologies GR process in general, as well as important information about this document.

Telcordia's GR Process

Generic Requirements documents (GRs) provide the Telcordia Technologies, Inc. (Telcordia) view of proposed generic criteria for telecommunications equipment, systems, or services, and involve a wide variety of factors, including interoperability, network integrity, funding participant expressed needs, and other input.

The Telcordia GR process implements Telecommunications Act of 1996 directives relative to the development of industry-wide generic requirements relating to telecommunications equipment, including integral software and customer premises equipment. Pursuant to that Act, Telcordia invites members of the industry to fund and participate in the development process for such GRs. Invitations to fund and participate are issued monthly in the *Telcordia Digest of Technical Information*, and posted on the Telcordia web site at <http://www.telcordia.com/DIGEST>.

At the conclusion of the GR development process, Telcordia publishes the GR, which is available by subscription. The subscription price entitles the purchaser to receive that issue of the GR (GR-CORE) along with any Issues List Report (GR-ILR) and revisions, if any are released under that GR project. ILRs contain any technical issues that arise during GR development that Telcordia and the funding participants would like further industry interaction on. The ILR may present issues for discussion, with or without proposed resolutions, and may describe proposed resolutions that lead to changes to the GR. Significant changes or additional material may be released as a revision to the GR-CORE.

Telcordia may also solicit general industry nonproprietary input regarding such GR material at the time of its publication, or through a special Industry Interaction Notice appearing in the *Telcordia Digest of Technical Information*. While unsolicited comments are welcome, any subsequent work by Telcordia regarding such comments will depend on funding support for such GR work. Telcordia will acknowledge receipt of comments and will provide a status to the submitting company.

About GR-326-CORE

A. Funders of GR-326-CORE, Issue 3, are

ADC Telecommunications
AMP Incorporated
Ameritech Services, Inc.
Bell Atlantic
BellSouth Telecommunications, Inc.
Lucent Technologies, Inc.
Siecor
Southwestern Bell Telephone Company
3M Corporation.

B. Relative Maturity Level

The technology for singlemode optical connectors is maturing. However, advances are occurring in optical performance including angle connector technologies, miniaturization, and technologies related to the measurement and testing singlemode fiber optic connectors. Issue 3 updates GR-326-CORE to include advances in these technology areas for singlemode fiber optic connectors. The updates in GR-326-CORE are based upon issues identified in GR-326-ILR *Single-Mode Optical Connectors and Jumper Assemblies Issue List Report*, Issue 2A, November 1997 and issues submitted by the funders that are listed above. From the more than fifty issues that were considered by the members of the GR-326 Telcordia Technical Forum (TTF), approximately thirty were adopted for inclusion into Issue 3 of GR-326-CORE.

C. GR-326-CORE Plans

GR-326-CORE will be updated to include new singlemode fiber optic connector technology as the industry deems necessary. Telcordia may propose GR documents for multimode connectors, small form or miniature connectors, and connectors for Local Area Networks in the future.

To Submit Comments

When submitting comments, please include the GR document number, and cite any pertinent section and requirement number. In responding to an ILR, please identify the pertinent Issue ID number. Please provide the name and address of the contact person in your company for further discussion.

Comments should be submitted by **January 2000**.

Send comments to:

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1. Introduction

1.1 Purpose and Scope

This Generic Requirements (GR) document sets forth the Telcordia view of the generic technical requirements and characteristics required of connectors used for joining singlemode optical fibers and for jumper assemblies made using such connectors. The Telcordia view represents the expressed needs of the Telcordia Technical Forum (TTF) companies funding these generic requirements (see Preface) and may meet the needs of other telecommunications service providers. It should be noted that a TTF or other telecommunications service provider may have actual requirements which differ from the generic criteria contained in this document.

Included in this GR is the Telcordia view of the various requirements, desired features, and characteristics of connectors and jumper assemblies, and the performance tests for comparing such products against the stated criteria.

The performance tests for analyzing optical connectors and jumper assemblies are intended to reflect a composite picture of various operating conditions. The generic requirements, objectives, conditional requirements, and test methods are subject to change.

The criteria in this document are presented in five categories:

- **General Requirements** - The requirements in this section cover documentation, packaging, and certain design features.
- **Performance Requirements** - This section presents tests to which connectors may be subjected, and the performance criteria to be applied during these tests. Tests in this category are called out in the Service Life Tests and in the Long Term Reliability Tests. Any of the tests in this category may also be conducted individually as required.
- **Service Life Tests** - A concise sequence of tests that simulate the stresses that connector assemblies may be subjected to while in service in the telecommunications plant. The tests in this category are selected from the Performance Requirement Tests.
- **Reliability Tests** - Those tests that are deemed appropriate to establish long term reliability of the fiber optic connectors. The tests in this category are selected from the Performance Requirement Tests.
- **Reliability Assurance Program** - A comprehensive program to ensure satisfactory long term operation of fiber optic connectors in a telecommunications environment. This category includes tests selected

from the Reliability Tests, and requirements on the manufacturing process that relate to the reliability and performance of the finished product.

1.2 Target Audience

This document is intended for users or purchasers and manufacturers, suppliers, or vendors of singlemode fiber optic connectors and jumper assemblies. User and purchasers of these products may include telecommunications service providers, local exchange carriers, Regional Holding Companies, and telecommunications equipment manufacturers. It gives guidance as to features which are necessary or desirable for such products, and gives performance criteria which these products should meet. Products that meet these criteria may be used to build optical networks with integrity and reliability.

1.3 Structure and Use of This Document

The information contained in this document is divided into 10 sections.

- | | |
|-----------|---|
| Section 1 | includes the scope, organization of the document, the definition of key terms and major changes from Issue 2 of GR-326-CORE, (December 1996). |
| Section 2 | provides general information that describes the products, intended application, and operating environment. |
| Section 3 | describes general product criteria such as documentation, marking, packaging and shipping requirements. |
| Section 4 | establishes the tests and performance criteria against which the tests will be conducted. |
| Section 5 | describes testing procedures and facilities required to determine the degree to which the product meets the criteria presented in Section 4. |
| Section 6 | provides listings of Service Life Tests and Reliability Tests for the convenience of the user of this document and also to maintain continuity with Issue 2 of GR-326-CORE. |
| Section 7 | states the Reliability Tests. |
| Section 8 | contains the requirements for the Reliability Assurance Program. |
| ROL List | listing of all Requirement Objects (Requirement and Objective criteria). |

References	provides references to Telcordia and external documentation sources.
Glossary	contains a glossary of fiber optic terms.
ROI Index	index giving page numbers of all Requirement and Objective criteria.

1.4 Changes from Issue 2 of GR-326-CORE

In developing this document, we have relied on several inputs for technical information. Primarily, the GR-326 TTF resolved the issues in GR-326-ILR, Issue 2A, December 1997 and issues raised by the TTF members. Second, Telcordia maintains numerous ongoing informal contacts with the industry (fiber optic connector and component manufacturers, equipment suppliers, RBOCs, and other service providers) and technical community. Finally, Telcordia conducts research, performs post-mortem investigations, and conducts field audits of product deployment processes.

As a result of this broad scope of inputs, we have been able to assemble an industry consensus document that serves the interests of participants, users and suppliers. This has resulted in some significant changes in the strategy of this document and in some specific criteria. Some of the most important are highlighted here, but all changes are indicated by change bars in the margins of the document, starting with Section 3. Some of the changes are additions of new material, and others are deletions and adjustments of criteria.

Some of the criteria represent useful features, which naturally come at additional cost. It must be emphasized that a criterion labeled as an Objective [**O**] rather than a Requirement [**R**] should be seen as useful, but not necessary. Conformance to such criteria may improve the productivity of the craftsperson, or give an extra margin of performance, or merely provide convenience features. The Objective [**O**] criteria should be seen as goals, or suggestions, or simply clever ideas which may be worth the additional cost to some users, but are not required in order to build a high performance, high reliability fiber optic physical plant.

The most significant changes in this document from Issue 2 of GR-326-CORE are given in Table 1-1. The organizational and general changes are given first, followed by changes which impact criteria. Most changes which impact criteria follow the order in which they appear in Issue 3 of GR-326-CORE.

Table 1-1. Changes from GR-326-CORE, Issue 2 to Issue 3 (Sheet 1 of 5)

Category	Description of Change
Document Organization, General Changes	
Company Name Change	Bellcore has changed its name to Telcordia Technologies, Inc.
Fiber Optic Type	Single-mode was changed to singlemode to be consistent with contemporary technical usage.
Nonconformance	The spelling of non-conformance has been changed to nonconformance to be consistent with contemporary technical usage.
Design Features	The cable media type definitions have been expanded and clarified. Cable Media Type: Type I media has been changed to include simplex, duplex or quad cable products. See Section 3.3.
Changes Impacting Criteria	
Intermateability	The Fiber Optic Connector Intermateability Standard (FOCIS) has been generalized in this document as requirements for intermateability, key intermateability requirements that are particularly important to verify for ferrule extension contact force, length distance between the mechanical reference planes for connector adapters, adapter sleeve/ferrule frictional forces, adapter sleeve latch spacing, glass transition temperature of connector adapter latches, and latchability requirements for push-pull type connectors have been added to Section 3.4.
Test Samples	Test sample definitions have been changed from Type I and Type II to Pigtail Assemblies and Jumper Cable Assemblies so as to eliminate confusion with media types. The pre-screening of test samples is permitted and a definition of pre-screening is included. See Section 4.1.1.
Optical Performance Criteria	The new product insertion loss criteria has been changed from 0.5 to 0.4 dB. In this issue a decrease in optical reflectance is not of concern. The change in reflectance criteria has been changed to an increase in reflectance criteria applying only to reflectances greater than -64 dB. See Sections 4.2.1 and 4.2.2.3.

Table 1-1. Changes from GR-326-CORE, Issue 2 to Issue 3 (Sheet 2 of 5)

Category	Description of Change
Modifications and Conditions	Modifications applicable to jumper cable assemblies has been clarified. A clarification has been added that the modifications for loss increase and reflectance increase that are applied to jumper cable assemblies do not apply during the mechanical testing of a single fiber optic connection (two plugs joined by an adapter) at the end of a jumper assembly. See Section 4.2.2.2.
Nonconformance	It is now permissible to substitute for nonconforming product with product that has been subjected to the same previous conditions as the nonconforming product. No more than ten initial test samples may be replaced. How to handle non-conformance is discussed in Section 4.2.2.5.
New Product Performance	Pre-screened new product is to be reported. All measurement results and reason for substitution will be reported. The cause(s) of nonconformance or conditions that resulted in the substitution must be determined by the supplier and/or Telcordia and included in reports based upon this GR Document. See Section 4.4.1.
Small Form Factor Connectors	The applied load level for Small Form Factor Connectors was reduced to 2/3 of the current value for the following Mechanical Tests in Section 4.4.3: Flex Test (Section 4.4.3.2), Proof Test - Side Pull (Section 4.4.3.4), 90° and 135° Transmission Under Load Tests (Section 4.4.3.5). It is an Objective that Small Form Factor Connectors meet the loss and reflectance requirements at the higher current load levels. See definition Section 4.1.1.
Humidity / Condensation Cycling Test	Clarifications were added to Section 4.4.2.4. Figure 4-4 was moved to be included in Section 4.4.2.4 for clarity. The ramp-up and ramp-down intervals shown in Figure 4-4 were also clarified.
Proof Test	The proof test requirements of 10 lbf, 0° straight pull and 5 lbf, 90° side pull loads shall be tested prior to the objective loads of 15 lbf, 0° straight pull and 7.5 lbf, 90° side pull. The kgf loads were corrected to be consistent with the lbf. Small Form Factor Connector requirements were added at 2/3 the load level and a conditional objective was added at the current full load level requirement for the 90° side pull. See Section 4.4.3.4.
Transmission With Applied Tensile Load	The text in Section 4.4.3.5 was corrected to be consistent with Table 4-9. Small Form Factor Connector requirements were added at 2/3 the load level and a conditional objective was added at the current full load level requirement for the 90° and 135° angles.

Table 1-1. Changes from GR-326-CORE, Issue 2 to Issue 3 (Sheet 3 of 5)

Category	Description of Change
Impact Test	Ferrule caps may now be placed over the ferrules during testing to protect the connector endface. The number of impacts has been decreased from ten to eight. See Section 4.4.3.7.
Dust Test	With the consolidation of the tests in Issue 3 of GR-326-CORE, this test has been moved from the Service Life Tests to Section 7, “Reliability Tests”. The Reliability Section requires a larger sample size than defined in Section 4.4.4.1 for a 10% Lot Tolerance Percent Defective (LTDP). However, either sample size may be chosen, depending on the reliability level required by the user.
Adhesive Testing	The following clarification has been added: Prior to adhesive testing initial plug endface geometry criteria for fiber undercut/protrusion, ferrule endface radius, and apex offset must be met. See Section 4.4.4.2.
Airborne Contaminants	With the consolidation of the tests in Issue 3 of GR-326-CORE, this test has been moved from the Service Life Tests to Section 7, “Reliability Tests”. The Reliability Section requires a larger sample size than defined in Section 4.4.4.3 for a 10% Lot Tolerance Percent Defective (LTDP). However, either sample size may be chosen, depending on the reliability level required by the user.
Salt Spray	With the consolidation of the tests in Issue 3 of GR-326-CORE, this test has been moved from the Service Life Tests to Section 7, “Reliability Tests”. The Reliability Section requires a larger sample size than defined in Table 4-12, Section 4.4.4.4 for a 10% Lot Tolerance Percent Defective (LTDP). However, either sample size may be chosen, depending on the reliability level required by the user.
Immersion/Corrosion Test	The requirements have been changed to include a degradation factor for ferrule deformation and the objective has been changed to and clarified to include that the fiber dissolution should not be greater than 10 nm. With the consolidation of the tests in Issue 3 of GR-326-CORE, this test has been moved from the Service Life Tests to Section 7, “Reliability Tests”. The Reliability Section requires a larger sample size than defined in Section 4.4.4.5 for a 10% Lot Tolerance Percent Defective (LTDP). However, either sample size may be chosen, depending on the reliability level required by the user.

Table 1-1. Changes from GR-326-CORE, Issue 2 to Issue 3 (Sheet 4 of 5)

Category	Description of Change
Groundwater Immersion	Samples requirements for products intended for use in the underground plant were clarified in Section 4.4.4.6. A separate set of five mated connector assemblies is required for each of the five immersion media, for a total of twenty-five (25) mated connector assemblies. With the consolidation of the tests in Issue 3 of GR-326-CORE, this test has been moved from the Service Life Tests to Section 7, “Reliability Tests”. The Reliability Section requires a larger sample size than defined in Section 4.4.4.6 for a 10% Lot Tolerance Percent Defective (LTDP). However, either sample size may be chosen, depending on the reliability level required by the user.
Endface Geometry	The fiber undercut criteria for endface geometry for non-angled physical contact connectors has been changed to agree with IEC-60874-14-n for radius of curvatures from 10 mm to 25 mm. An undercut requirement of 125 nm maximum has been added for radius of curvatures of 7 mm to 10 mm. The ferrule endface radius has been changed to a range of 7mm to 25 mm. Endface geometry requirements for Angled Physical Contact (APC) connectors has been added. Endface geometry measurement areas are defined to be consistent with IEC 61300-3-23. See Section 4.4.5.3.
Connector Installation	The “x” dimension has changed from 57 mm to 75 mm. A insertion loss increase requirement of 0.2 dB has been included along with an objective for a maximum boot length of 75 mm. The boot contact requirement has been removed. However, a boot contact requirement for right angle boots has been added. See Section 4.4.6.
Optical Measurement Accuracy	The accuracy for reflectance measurements has been changed from ± 2 dB down to -60 dB to ± 2 dB down to -64 dB and ± 5 dB down to -80 dB. See Section 5.2.
Service Life Tests	To eliminate redundancy, the Salt Spray, Airborne Contaminant, Dust, Groundwater Immersion, and Immersion Corrosion tests have been removed from the Service Life Testing and moved to Reliability Tests in Section 7. Accordingly, Service Life Tests - Part B and Part C have been eliminated from Section 6 and Service Life Test - Part A has been renamed Service Life Tests. The number of “Hot Spares” that can be substituted for original test samples during service life testing has been limited to ten. See Section 6.1.

Table 1-1. Changes from GR-326-CORE, Issue 2 to Issue 3 (Sheet 5 of 5)

Category	Description of Change
Reliability Tests	The Temperature Humidity Cycle test has been eliminated from the Reliability Tests in Section 7 in order to remove redundancy with a similar test that is part of the Service Life Testing, the Humidity / Condensation Cycling Test in Section 4.4.2.4. Also, to eliminate redundancy and consolidate testing; the Salt Spray, Airborne Contaminant, Dust, Groundwater Immersion, and Immersion Corrosion tests have been moved from the Service Life Testing to the Reliability Tests in Section 7. See Table 7-1, Reliability Tests.

1.5 Requirements Terminology

The following requirements terminology is used throughout this document:

- **Requirement** — Feature or function that, in the view of Telcordia, is *necessary* to satisfy the needs of a typical telecommunications service provider. Failure to meet a requirement may cause application restrictions, result in improper functioning of the product, or hinder operations. A Requirement contains the words *shall* or *must* and is flagged by the letter “**R**.”
- **Conditional Requirement** — Feature or function that, in the view of Telcordia, is *necessary in specific customer applications*. If a customer identifies a Conditional Requirement as necessary, it shall be treated as a requirement for the application(s). Conditions that may cause the Conditional Requirement to apply include, but are not limited to, certain customer application environments, elements, or other requirements, etc. A Conditional Requirement is flagged by the letters “**CR**.”
- **Objective** — Feature or function that, in the view of Telcordia, is *desirable* and may be required by a typical telecommunications service provider. An Objective represents a goal to be achieved. An Objective may be reclassified as a Requirement at a specified date. An objective is flagged by the letter “**O**” and includes the words *it is desirable* or *it is an objective*.
- **Conditional Objective** — Feature or function that, in the view of Telcordia, is *desirable in specific telecommunications service provider applications* and may be required by a customer. It represents a goal to be achieved in the specified Condition(s). If a customer identifies a Conditional Objective as necessary, it shall be treated as a requirement for the application(s). A Conditional Objective is flagged by the letters “**CO**.”
- **Condition** — The circumstances that, in the view of Telcordia, will cause a Conditional Requirement or Conditional Objective to apply. A Condition is flagged by the letters “**Cn**.”

1.6 Requirement Labeling Conventions

As part of the Telcordia new GR Process, proposed requirements and objectives are labeled using conventions that are explained in the following two sections.

1.6.1 Numbering of Requirement and Related Objects

Each Requirement, Objective, Condition, Conditional Requirement, and Conditional Objective object is identified by both a local and an absolute number.

The local number consists of the object's document section number and its sequence number in the section (e.g., **R3-1** is the first Requirement in Section 3). The local number appears in the margin to the left of the Requirement. A Requirement object's local number may change in subsequent issues of a document if other Requirements are added to the section or deleted.

The absolute number is a permanently assigned number that will remain for the life of the Requirement; it will not change with new issues of the document. The absolute number is presented in brackets (e.g., **[2]**) at the beginning of the requirement text.

Neither the local nor the absolute number of a Conditional Requirement or Conditional Objective depends on the number of the related Condition(s). If there is any ambiguity about which Conditions apply, the specific Condition(s) will be referred to by number in the text of the Conditional Requirement or Conditional Objective.

References to Requirements, Objectives, or Conditions published in other Generic Requirements documents will include both the document number and the Requirement object's absolute number. For example, **R2345-12** refers to Requirement **[12]** in GR-2345.

1.6.2 Requirement, Conditional Requirement, and Objective Object Identification

A Requirement object may have numerous elements (paragraphs, lists, tables, equations, etc.). To aid the reader in identifying each part of the requirement, an ellipsis character (...) appears in the margin to the left of all elements of the Requirement.

2. General Information

2.1 Description

Optical fiber connectors are used to join optical fibers where a connect/disconnect capability is required. The connectors covered under this document are for joining optical fiber jumper cables that contain one singlemode fiber. Single fiber connectors may be linked together so as to form multiple fiber connectors. Criteria for linked single fiber connectors may be found in GR-1435-CORE, *Generic Requirements for Multi-Fiber Optical Connectors*.

The basic connector unit is a connector assembly. A connector assembly consists of an adaptor and two connector plugs; a representative example is illustrated in Figure 2-1.

Specific connector designs may vary somewhat from the illustration in Figure 2-1.

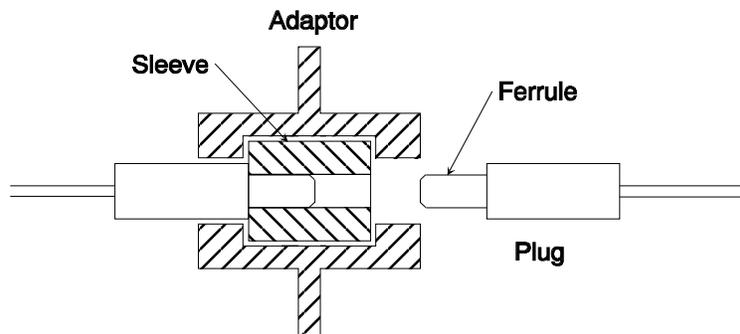


Figure 2-1. Sample Connector Assembly with One Plug Removed

For example, in the illustration, the alignment surfaces are straight cylindrical ferrules; another connector design uses a plug with a conical alignment surface.

Due to the sophisticated polishing and tuning procedures which may be incorporated into optical connector manufacturing, connectors are generally assembled onto optical fiber in a supplier's manufacturing facility. However the assembly and polishing operations involved can be performed in the field, for example to make cross-connect jumpers to size. Criteria for connectors which may be assembled in the field are given in GR-1081-CORE, *Generic Requirements for Field-Mountable Optical Fiber Connectors*. In a different approach, some connector products incorporate a pre-polished fiber stub, so that field-mounting involves splicing the target fiber to the pre-polished internal stub fiber. Criteria for such products are given in GR-2919-CORE *Generic Requirements for Hybrid Optical Splice / Connectors for Single-Mode Optical Fibers*.

2.2 Connector Applications

Optical fiber connectors are used in telephone company central offices, at installations on customer premises, and in outside plant applications. Their uses include making the connection between equipment and the telephone plant in the central office; connecting fibers to remote and outside plant electronics such as ONUs and DLC systems; optical cross connects in the central office; patch panels in the outside plant to provide architectural flexibility and to interconnect fibers belonging to different service providers; connecting couplers, splitters, and Wavelength Division Multiplexers (WDMs) to optical fibers; and connecting optical test equipment to fibers for testing and maintenance.

Outside plant applications may involve locating connectors underground in subsurface enclosures which may be subject to flooding, on outdoor walls, or on utility poles. The closures which enclose them may be hermetic, or may be “free-breathing.” Hermetic closures will subject the connectors within to temperature swings unless they are breached. Free-breathing closures will subject them to temperature and humidity swings, possibly condensation, and possibly biological action from airborne bacteria, insects, etc. Connectors in the underground plant may be subjected to groundwater immersion if the closures containing them are breached or improperly assembled.

3. General Requirements

3.1 Documentation

R3-1 [1]Test Reports

... Test Reports issued under the terms of this document shall include the following information:

- ... 1. The ordering information for the items being tested. This is to include as appropriate: the part number and model number for the adapter, connector plug, jumper cable assembly, etc.
- ... 2. The specification for the media type, See the glossary for the definitions.
- ... 3. The manufacturer and type of fiber being used.
- ... 4. The base materials used in the connector plug and adapter.
- ... 5. A list of the metallic materials which come into contact with each other, used in the adapter and the plug.
- ... 6. The operating instructions included with the product, for example the cleaning instructions.
- ... 7. A description of the training material the supplier recommends for training operators in the use of the product.

R3-2 [2]Product Documentation

... A complete set of documentation in accordance with GR-454-CORE, *Generic Requirements for Supplier-Provided Documentation*, shall be available from the manufacturer upon request and shall provide all related information, as applicable to the particular connector, alignment sleeve, or jumper assembly product, to describe

- ... a. Use and application
- ... b. Cleaning procedures
- ... c. Bend radius limits at 1310 nm and 1550 nm
- ... d. Operational limits (temperature, humidity, etc.)
- ... e. Testing operations
- ... f. Materials used for ferrule, sleeve, plug body, housing, etc.

- ... g. Traceability information for critical components obtained from third party sources, e.g., ferrules and alignment elements
- ... h. Safety instructions
- ... i. Auxiliary equipment required and usage
- ... j. Storage and transportation instructions
- ... k. Packaging list of all items included in the shipping container.
- ... The documentation may require preparation in accordance with instructions from the individual customers.

NOTE This criterion is intended to be generic and applicable to a range of products. Conformance determination will be based on engineering practices and conformance to the criteria of GR-454-CORE.

3.2 Packaging and Shipping

R3-3 [3]Packaging

- ... The packaging shall be adequate to ensure that the product will not be damaged under normal handling, shipping, and storage. Jumper cables shall be packaged individually.

3.3 Design Features

3.3.1 Materials

R3-4 [4]Metallic elements

- ... Metallic elements shall be corrosion resistant. Dissimilar metals shall not be used in contact with each other unless they are suitably finished to prevent electrolytic corrosion.

R3-5 [5]Index Matching Fluid or Gel

- ... The connector product shall not incorporate an index matching fluid or gel which is designed to prevent glass-to-air contact or glass-to-glass contact nor require application of such material for use.

R3-6 [6] Fungus Resistance

... Polymeric materials that are used shall not support fungus growth per ASTM-G21-70. A rating of 0 (zero) is required.

R3-7 [7] Flammability

... Polymeric materials that are used shall have a rating of V-1 or better as determined by Underwriters Laboratories (UL) Standard 94, and an oxygen index of 28 percent or greater as determined by ASTM D-2863-87.

R3-8 [8] Cable Media Types

... The media on which connector plugs are mounted shall meet the criteria in either GR-409-CORE, *Generic Requirements for Premises Fiber Optical Cable*, or GR-20-CORE, *Generic Requirements for Optical Fiber and Optical Fiber Cable*.

... Cable Media Types shall be defined as follows:

- Type I Media: Reinforced jacketed cable of any diameter used as jumper cordage.¹
- Type II Media: Cable with 900 μm buffer coating that may or may not be reinforced.
- Type III Media: Connectors mounted on fiber with a 250 μm coating.

RATIONALE — The media types defined represent the different applications of optical jumpers used in typical telecommunications service provider environments. The different applications generate the need for different media types. However, even though the applications may be different, the media types must be compatible with the optical fiber cable requirements in the telecommunications applications. Therefore, it is necessary that optical jumpers use fiber cable, which meet criteria in GR-409-CORE, or GR-20-CORE.

3.3.2 Cleanability

O3-9 [9] Cleanability

1. Type I media may include simplex, duplex or quad cable products.

... The connector structure should allow the area of the ferrule that engages the alignment sleeve to be cleaned by means of the cleaning procedures in Section 4.3.

3.4 Intermateability

Companies must be able to purchase plugs and adapters from a variety of manufacturers with assurance that the product purchased from one vendor will function satisfactorily when intermated with a product manufactured by another supplier.

Connector Intermateability is the ability to form connector assemblies that meet specific performance criteria with connectors and plugs of a given design, even though they may come from different suppliers.

The criteria in this document apply to both intramated connector assemblies, connector assemblies of plugs and adapters from the same manufacturer, and to intermated connector assemblies, assemblies of plugs and adapters from other manufacturers.

An Intermateability standard is needed for each connector design that will ensure Intermateability. The Intermateability standard is to ensure that connector assemblies from more than one supplier will meet the performance requirements of this document, provided:

- the respective suppliers' products individually meet the performance requirements of this document
- the respective products meet the requirements of the Intermateability standard.

The development of Intermateability standards is the joint responsibility of industry standards bodies and the connector manufacturers. As of September 1999, the Fiber Optic Connector Intermateability Standard (FOCIS) documents are in various stages of development/balloting/publication within the Telecommunications Industry Association (TIA).

CR3-10 [10]Intermateability

... The product (connectors, adapters) shall meet the requirements of the applicable FOCIS-n (ANSI/TIA/EIA-604-n), where "n" is a number designation assigned to a specific connector type. The requirements should be met both on new product and after the completion of Service Life Tests.

In addition to the above criteria, the connectors shall also conform to the following specific intermateability requirements, which are included in the referenced TIA FOCIS documents:

RATIONALE — Although connectors should meet all of the TIA FOCIS requirements, there are certain key intermateability requirements that are particularly important to verify; these are described below.

CR3-11 [11] Ferrule extension contact force

... The ferrule extension distance and the spring loading force shall meet the conditional limits specified by TIA/EIA FOCIS documents.

Figures 3-1 and 3-2 show examples of how the FOCIS specifications apply to SC (TIA/EIA-604-3 (FOCIS 3)) and FC connectors (TIA/EIA-604 (FOCIS 4)), respectively.

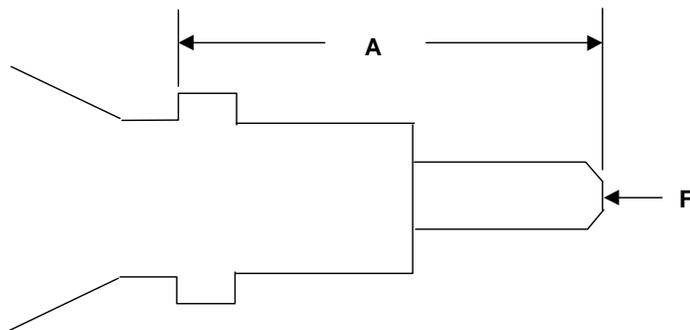


Figure 3-1. SC Connector Plug

A is the distance from the mechanical reference plane to the tip of the connector ferrule. When **F** = 0 (no load is applied to the ferrule), **A** \geq 7.15 mm. When **A** is in the range of 6.9 to 7.1 mm, **F** should be in the range of 7.8 to 11.8 N.

CR3-12 [212] Length requirements for the distance between the mechanical and optical reference planes in connector adapters.

... The distance between the mechanical reference planes for connector adapters shall be within the limits specified by the TIA/EIA FOCIS documents.

Figures 3-3 and 3-4 show examples of how the FOCIS specifications apply to SC (TIA/EIA-604-3 (FOCIS 3)) and FC (TIA/EIA-604-4 (FOCIS 4)) adapters.

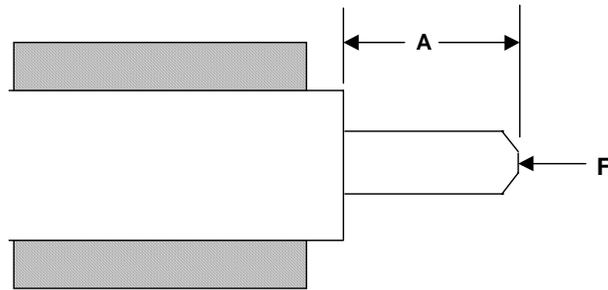


Figure 3-2. FC Connector Plug

A is the distance from the mechanical reference plane to the tip of the connector ferrule. When $F = 0$ (no load is applied to the ferrule), $A \geq 3.8$ mm. When A is in the range of 3.6 to 3.7 mm, F should be in the range of 7.8 to 11.8 N.

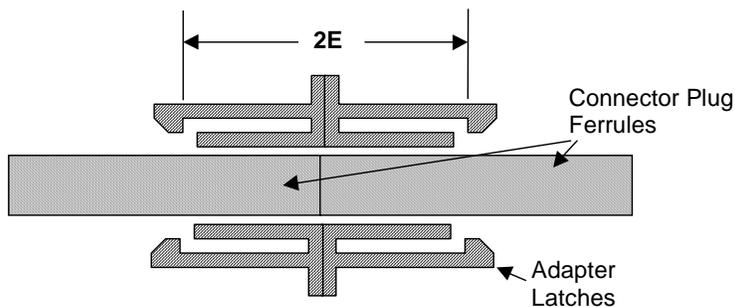


Figure 3-3. SC Connector Reference Plane

The distance between the two mechanical reference planes for SC connectors is $2E$. For SC connectors, E is in the range of 6.9 to 7.1 mm.

CR3-13 [213]Adapter Sleeve/Ferrule Frictional Forces

... The force required to remove a gauge pin from the adapter sleeve shall meet the requirements specified by TIA/EIA (FOCIS) documents.

CR3-14 [214]Adapter Sleeve Latch Spacing

... The latch spacing for connector adapters shall meet the requirements specified by TIA/EIA (FOCIS) documents.

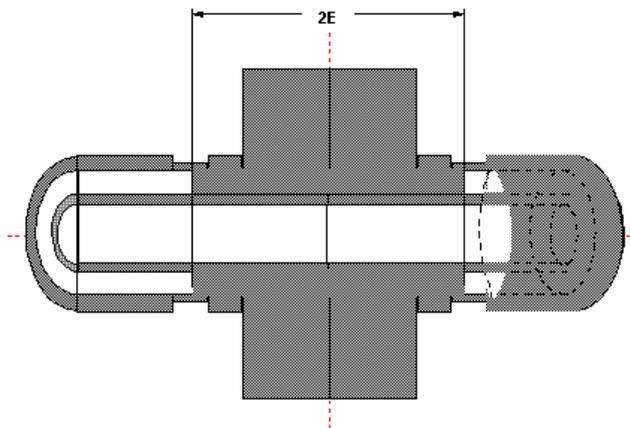


Figure 3-4. FC Connector Reference Plane

The distance between the two mechanical reference planes for FC connectors is $2E$. For FC connectors, E is in the range of 3.6 to 3.7 mm.

Figure 3-5 shows an example of how the FOCIS latch spacing requirement applies to SC connector adapters (TIA/EIA-604-3 (FOCIS 3)).

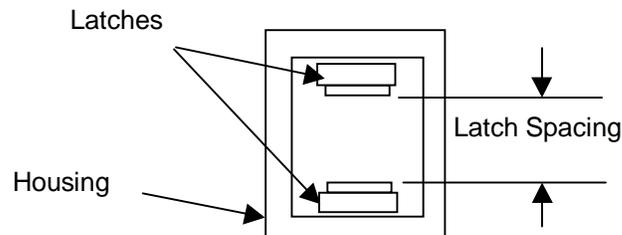


Figure 3-5. The Latch Spacing in SC Adapters

The latch spacing specified is in the range of 4.90 to 5.50 mm.

CR3-15 [215] Glass Transition Temperature of Connector Adapter Latches

... The glass transition temperature of the latches in connector adapters shall be $> 100^{\circ}\text{C}$.

RATIONALE — If the glass transition temperature of the connector adapter latches is too low (within 20°C of the maximum operating range of the connector), and the connector plugs are not fully latched, the latches will spread apart during environmental aging, and will no longer be able to latch properly. If the glass transition temperature is sufficiently high, the adapters will still latch properly even after aging.

3.4.1 Latching Intermateability Requirements for Push-Pull Type Connectors

For push-pull type connectors, a sample set of 144 connectors shall be tested to determine the ability of the plugs to latch properly into the adapters. The adapters should be mounted in a typical termination shelf configuration (12 rows and 12 columns, with a vertical center spacing of approximately 12.7 mm (0.5 in) and horizontal center spacing of approximately 29.4 mm (1.156 in)), using either a termination shelf or mounting fixtures with the same configuration. Connector plugs should be inserted into the backs of the adapters initially. The mating connector plugs shall then be randomly inserted into the adapters with an insertion force of between 2.2 kgf and 2.7 kgf (5 and 6 lbf) until the termination shelf or mounting fixture is completely populated, using **only the boots** of the connector plugs to perform the insertions. After all of the connector plugs have been inserted, they are tested by pulling them out of the adapters **using the jumper cable behind the boot. The operator's fingers are not to come into contact with the connector housing at any time during the test.** If a connector plug pulls out at a force of less than 2.2 kgf (5 lbf), the connector fails the test. A complete configuration of 144 terminations should be tested in this manner using four different operators (each operator testing 36 connector plugs).

CO3-16 [216]Latchability of Push-Pull Type Connectors

... No more than 30% of the connectors (a total of 43 connectors) shall fail the latchability test.

RATIONALE — Reflectance field failures have occurred due to the failure of the latching mechanism in SC connectors. Laboratory testing has determined that the failures occur when the connectors are not completely latched initially, and that certain products are more susceptible to this problem than others. This test allows users to identify products that are more robust against craft error, and to minimize field failures. Four operators are used to minimize the spread in the test results, and the percent of acceptable failures has been increased to take into account the spread in the test results.

3.5 Product Marking and Packaging

R3-17 [12]Product Marking

... Connector plugs and adapters shall be marked to identify the supplier, the model or series of the parts, and a code that identifies the vintage of the parts. Vintage markings shall allow for the identification by date of the adapters to within 6 months and the plugs to within 3 months.

NOTE Markings to identify plugs may be on the plug, the boot, or the cable. If the marking is on the cable, the markings shall be located within 20 cm (8 inches) of the boot. The medium on which markings are made shall not be loose or dangling from the cable and shall not interfere with the use of the connector.

O3-18 [13]Color Code

... Connector plugs, of non-angled polished connectors, should be color-coded on the basis of their typical maximum reflectance when mated to themselves, using the color code indicated in Table 3-1.

... The color code shall be applied to the connector boot.

Table 3-1. Reflectance Color Code

Color	Typical Maximum Reflectance
Red	< -30 dB
White	< -40 dB
Dark-Blue	< -55 dB
Green	Angled (APC)

CR3-19 [14]Color Code APC

... Angled polished (APC) connectors shall have green plug body or green boots.

3.5.1 Keying

O3-20 [15]Presence

... The connector plug should be keyed such that a particular angular orientation is required for insertion of the plug in the adapter.

RATIONALE — An unkeyed plug can assume any angular orientation with respect to its mate, therefore insertion loss repeatability will depend on the concentricity of the components used (fiber, ferrule, ferrule bore, etc.)

O3-21 [16] Visibility of Key Orientation

... The key orientation should be clearly visible either through the design of the connector plug and adapter or by means of marking on the plug and adapter.

RATIONALE — If the orientation is not visible then the plug will be rotated with respect to the alignment sleeve until the proper orientation is found, leading to generation of wear particles and erratic behavior.

3.5.2 Specialty Fiber

Where very densely populated patch bays are involved, it may be possible to experience a temporary interruption in service due to temporary bend induced losses in optical fiber patch cords. This would happen only when the patch cords are bent well beyond their recommended limits. The 1550 nm operating window would be more susceptible to these losses. Theoretically, a fiber that gives the best of both worlds could be manufactured. There are trade-offs that must be considered.

Some singlemode fibers are manufactured with a larger index of refraction difference between the core and cladding. This larger difference makes them less susceptible to losses induced by extreme bends. However, these fiber types typically have a smaller mode field diameter, MFD, resulting in higher connector insertion loss. Theoretically, the cutoff wavelength could be adjusted (shifted up) to achieve a bend resistant fiber. It is uncertain at this time what effect this may have on operations in the 1310 nm window. The fiber may support multiple modes but the probable presence of bends would act as mode strippers.

Another problem presented by this fiber type would be that it masks the issue of exceeding the fiber's minimum bend radius. With this fiber, optical patch cords could be left in a position that exceeds the recommended minimum bend radius of the fiber to ensure long term reliability.

The cost of developing a specialty fiber for jumper applications may have to be borne by a relatively small quantity of product. It is uncertain whether the cost premium for this product would be acceptable to users.

Thus despite the interest in the concept expressed by respondents to the Industry Interaction process, it is premature at this time to apply performance criteria to such a product. Further comments and inputs are encouraged on this issue.

3.6 Safety

R3-22 [17] Radiation Hazard

... The instructions that describe the procedures for cleaning the adapters and plugs shall indicate the possible hazard due to the presence of invisible (infrared) radiation when examining connectors with the naked eye or using a microscope. The instructions shall also contain ordering information for an IR indicator card (Edmund Scientific part #53-031 or equivalent) to allow visualization of invisible IR light.

R3-23 [18] Cleaning Materials

... The instructions that describe the procedures for cleaning the adapters and plugs shall contain the following information regarding any materials that are used for cleaning that may be considered hazardous to health or to the environment:

- ... 1. Warning as to the toxicity hazard
- ... 2. Instructions for handling and use
- ... 3. Instructions for disposal.

4. Connector Tests and Criteria

The tests to which connectors are subjected and the criteria to be applied to the results of these tests are in this section. Three types of criteria may be applied to the results of these tests. The tests, the type of criteria to be applied, and the sections in which these tests may be found are listed in Table 4-1.

Table 4-1. List of Connector Tests

TESTS	CRITERIA	SECTION
New Product	R4-2 [19] - CO4-8 [25]	4.4.1
Environmental Tests		
1. Thermal Age Test	R4-9 [26] - O4-10 [27]	4.4.2.1
2. Thermal Cycle	R4-11 [27] - O4-12 [28]	4.4.2.2
3. Humidity Age	R4-13 [30] - O4-14 [31]	4.4.2.3
4. Humidity / Condensation Cycle	R4-15 [32] - O4-16 [33]	4.4.2.4
5. Dry-out Step	none	4.4.2.5
6. Post-Condensation Thermal Cycle	R4-17 [34] - O4-18 [35]	4.4.2.6
7. Dust	R4-49 [62] - O4-53 [66]	4.4.4.1
Mechanical Tests		
1. Flex Test Test	R4-21 [38] - CO4-23 [218]	4.4.3.2
2. Twist Test Test	R4-24 [40] - O4-25 [41]	4.4.3.3
3. Proof Test Test	R4-26 [42] - CO4-28 [219]	4.4.3.4
4. Transmission With Applied Tensile Load	R4-29 [44] - CO4-36 [221]	4.4.3.5
5. Impact Test Test	R4-37 [50] - O4-38 [51]	4.4.3.7
6. Durability Test	R4-39 [52] - O4-44 [57]	4.4.3.8
7. Vibration Test Test	R4-19 [36] - O4-20 [37]	4.4.3.1
Materials Tests		
1. Adhesive Testing	R4-54 [67]	4.4.4.2
2. Airborne Contaminants Test	R4-55 [68] - R4-58 [71]	4.4.4.3
3. Salt Spray Test	R4-59 [72] - R4-62 [75]	4.4.4.4
4. Immersion/Corrosion	R4-63 [76] - O4-64 [77]	4.4.4.5

Table 4-1. List of Connector Tests (Continued)

TESTS	CRITERIA	SECTION
5. Groundwater Immersion Test	CR4-65 [78] - CR4-66 [79]	4.4.4.6
Geometry Requirements		
1. Ferrule Endface Geometry for Non-Angled Physical Contact Connectors	R4-67 [80] - R4-69 [82]	4.4.5.1
2. Endface Geometry Requirements for Angled Physical Contact (APC) Connectors	R4-70 [222]	4.4.5.2
3. Endface Geometry Measurement Areas	R4-71 [223]	4.4.5.3
Application Requirements		
1. Connector Installation Test	R4-72 [224] - O4-75 [226]	4.4.6

Measurements of optical performance, i.e., loss and reflectance, are made with a facility meeting the requirements in Section 5.2. Facilities capable of performing these measurements are described in Sections 5.2.1 and 5.2.2.

All measurements of optical performance are made at both 1310 nm and at 1550 nm, unless otherwise specified.

4.1 Test Samples

4.1.1 Definitions

There are two types of Test Samples:

- **Pigtail assembly**, consists of two connector plugs mated with an adapter with unterminated leads as shown in Figure 4-1. Each of the unterminated leads should be 3 ± 0.5 meters long so that the splices may be located outside of the environmental test chamber.
- **Jumper cable assembly**, consists of a jumper cable terminated with plugs on each end connected with adapters to two additional connector plugs

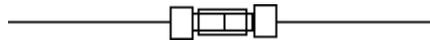


Figure 4-1. Pigtail Assembly

with unterminated leads on either end as shown in [Figure 4-2](#). The jumper cable shall be 3 ± 0.5 meters. Each of the unterminated leads should also be 3 ± 0.5 meters long so that the splices may be located outside of the environmental test chamber.



Figure 4-2. Jumper Cable Assembly

- **Pre-Screening** is the initial measurement of pigtail and jumper cable assemblies to the new product criteria in [Tables 4-2](#) and [4-3](#) to ensure that the product meets the insertion loss and reflectance requirements prior to the start of testing. Nonconforming products are replaced with conforming product before the start of any testing. Any nonconformance needs to be documented, see [Section 4.4.1](#) for more information. Once testing has started, product which subsequently becomes nonconforming is to be handled as described in [Section 4.2.2.5](#), [Handling of Nonconformance](#).
- **Small Form Factor Connectors** are connectors with a ferrule with an outside diameter of less than 2.0 mm. Small form factor connectors (e.g., MU, LC™, LX.5) have a smaller cross-sectional area, about one-half that of traditional connectors (e.g., SC, FC, D4 and ST®).
- **High Density** environment (e.g., high density fiber distributing frame) is an application that provides limited access (e.g., small spacing between connectors) for the installation and removal of connectors. A relatively large number of connectors concentrated in a given area. A useful guideline is given in [Section 2.3.1.3](#) of [GR-449-CORE](#), *Generic Requirements for Fiber Distributing Frames*, which considers that a “low-density” distributing frame shelf would terminate up to 648 fibers (54 12-fiber ribbons) in a 7-ft. high bay and a “high-density” frame would terminate up to 1440 fibers (120 12-fiber ribbons) in the same space.

4.1.2 Population

A population of twenty test samples, (15) pigtail assemblies and five (5) jumper cable assemblies, is required in Issue 3 of GR-326-CORE for performance verification testing. The pigtail assembly samples are to be tested sequentially to all the environmental and mechanical tests described in Section 6.1, “Service Life Tests”. Jumper cable assemblies need only be tested sequentially through Thermal Aging followed by Thermal Cycling, Tests 1 and 2 in Table 4-1. The jumper cable assemblies must not be coiled to a diameter of less than 0.4 meter, this is so that they be placed in a standard environmental chamber which is approximately 0.5 meter square. The coils should not touch so that the jackets cannot thermally fuse together during environmental testing. The jumper cable assemblies need only be monitored at 1550 nm. With jumper cable assemblies, it is recognized that although it may be difficult to separate the contributions of the two ends to the overall loss and reflectance of the jumper cable assembly, possibly at the end of testing, nevertheless there are two connectors under test for each jumper cable assembly sample.

RATIONALE — The Telcordia Technical Forum judged that a single fiber connection was necessary to accurately represent the performance of a connector assembly. The sample size of fifteen was historic and was therefore applied to the pigtail assemblies that represents a single fiber connection. Jumper cable assemblies are being tested to observe the effects of Temperature Induced Cable Loss (TICL) during environmental testing. TICL is caused by cable shrinkage after heat aging usually when exposed to low temperatures. Coiling the jumper can reduce and possibly eliminate the effects of TICL. Since TICL is more pronounced at the longer wavelengths, jumpers need only be monitored at 1550 nm.

4.2 Criteria

The general optical performance criteria are summarized in this section. The criteria for the specific tests are included with the respective tests.

4.2.1 Overview of Optical Performance Criteria

Optical measurements are to be made at both 1310 nm and 1550 nm for connectors with a single fiber joint. Criteria for the loss of hybrid splice/connectors with two or three sequential joints may be found in GR-2919-CORE. The loss of connectors with a single joint is only slightly dependent on wavelength, whereas the loss of

connectors with multiple sequential joints is an oscillating function of wavelength and can vary by several tenths dB.

Tables 4-2 and 4-3 summarize the optical criteria. These criteria apply at both 1310 nm and 1550 nm wavelengths. The specific numbered criteria are stated in Section 4.4.3, and refer back to these tables.

Table 4-2. Summary of Optical Performance Criteria: Loss

Test	Maximum Loss		Mean Loss		Loss Increase	
	(R)	(O)	(R)	(O)	(R)	(O)
New Product	0.40	0.20	0.20	0.15	---	---
During Test, Not Under Load	0.50	0.30	0.30	0.20	0.30	0.20
During Test, Under Load	---	---	---	---	0.50	0.30
End of Test	0.50	0.30	0.30	0.20	---	---

Table 4-3. Summary of Optical Performance Criteria: Reflectance

Test	Reflectance			Increase in Reflectance	
	(R)	(CR)	(CO)	(R)	(O)
New Product	-40	-55	-60	---	---
During Test, Not Under Load	-40	-55	-60	5	2
During Test, Under Load	-40	-55	-60	5	2
End of Test	-40	-55	-60	5	2

IMPORTANT In the criteria which follow throughout this document, whenever reference is made to criteria found in Table 4-3, Conditional Requirement and Conditional Objective reflectance criteria should be used where appropriate to the product being tested.

The specific application of the criteria in Tables 4-2 and 4-3 is defined for each of the tests in the description of the respective test. The following, however, are general guidelines for the application of the optical performance criteria:

- The New Product criteria are applied to brand new product, as delivered by the supplier, product that has not been in service or subjected to any tests.
- The “During Test, Not Under Load” criteria are applied to measurements made during tests in which mechanical load is not applied.
- The “During Test, Under Load” criteria are applied to measurements made during tests in which mechanical load is applied.
- The End of Test criteria apply to measurements made at the end of a test with all stress removed and the product at normal ambient conditions.
- The Loss Increase Criteria apply to the difference between New Product and End of Test loss measurements.
- A decrease in reflectance is not of concern. Note that the definition of “reflectance” is that of a negative number, as opposed to Optical Return Loss, which is a positive number. The terms “greater than” and “less than” are applied to the numerical values of the reflectance, and not the absolute values of these numbers. Thus, a -50 dB reflectance is greater than a -60 dB reflectance.

4.2.2 Modifications and Conditions

The following sections describe modifications and conditions which apply to the criteria stated in Section 4.4 and summarized in Tables 4-2 and 4-3.

4.2.2.1 Measurement Error

The criteria described below and summarized in Tables 4-2 and 4-3 do not consider potential measurement errors. The testing agency must indicate in the analysis report an allowance for measurement error, which will be applied to individual measurements. For example, if the criterion is 0.2 dB and a measurement of 0.23 dB is obtained using an instrument with an estimated accuracy of 0.05 dB, then that particular connector will be considered to be conforming. The experimental error allowance is not applied to mean values, since it is equally likely that individual measurements overstate or understate the true value. Thus, if the mean loss value of 15 connections is determined to be 0.23 dB and the criterion is 0.20 dB, then the product is nonconforming for that criterion.

In the past Telcordia has applied an allowance of 2 dB for reflectance measurements and 0.05 dB for loss measurements. This was based on the observed repeatability of measurements on internal standards during testing.

4.2.2.2 Jumper Cable Assembly Measurements

The measurement of jumper cable assemblies presents a small difficulty, as the two events are difficult to separate either with an OTDR or an OCWR during testing. Individual measurements for the connections may be obtained at the start of testing, during new product acceptance (i.e., incorporation into the testbed), and at the end of testing when product is cut out. However such measurements are impractical during testing, so that the criteria defined in Tables 4-2 and 4-3 are modified when applied to Jumper Cable Assembly test samples for Service Life Tests as follows:

- Loss, Loss Increase - Divide the measured values by 2 and apply the appropriate criteria Table 4-2.
- Reflectance - Subtract 3.0 dB from each measurement and apply the respective criteria from Table 4-3.

These modifications do not apply during the mechanical testing of a single fiber optic connection (two plugs joined by an adapter) at the end of a jumper assembly. When stressing a single fiber optic connection the loss increase and reflectance increase are attributed to only the connection under test.

NOTE When two closely spaced connections are seen as a single event by the measurement system, then it is reasonable to suppose that they contribute equally to any change observed in the composite measurement. Some judgement needs to be used when applying this modification. For example, if the New Product values of the two connections of a jumper are 0.7 and 0.1 dB, the high loss connection does not meet the Loss criterion. If then, during testing, the same two connections are measured as a composite 0.8 dB (i.e., no change), it is not reasonable to apply the modification such that $0.8 \text{ dB}/2 = 0.4 \text{ dB}$, thereby meeting the Loss criterion.

4.2.2.3 Reflectance Increase Criteria Applicability

The Reflectance Increase Criteria defined in Table 4-3 do not apply to connections with reflectances less than -64 dB due to measurement uncertainty at the low reflected power levels involved.

RATIONALE — Applying a Reflectance Increase criterion to product which exhibits a level of reflectance so low that normal measurement uncertainty results in large fluctuations in the value would be punishing the product for good performance. An

accuracy of 2 dB can be achieved in reflectance measurement of -64 dB or greater.

4.2.2.4 Reflectance Criteria Applicability

Reflectance criteria in Table 4-3 are applied as follows:

- Connectors intended for use in digital systems shall meet the **Requirement** criterion of reflectance not exceeding -40 dB.
- Connectors intended for use in AM-VSB (analog video) systems shall meet the **Conditional Requirement** criterion of reflectance not exceeding -55 dB.
- Connectors intended for use in AM-VSB (analog video) systems should meet the **Conditional Objective** criterion of reflectance not exceeding -60 dB.

Recall that an allowance for measurement error may be applied to individual measurements as discussed in Section 4.2.2.1.

4.2.2.5 Handling of Nonconformance

R4-1 [217] If a connector assembly becomes nonconforming in the course of a test then the criteria for that test are a priori not met. However, rather than consider this specimen nonconforming for all subsequent tests (as was the case in Issue 1 of GR-326-CORE), it is permissible to substitute for the failed product to replenish the test group with product from the same production lot to its original size, with the condition that substitute product has also been subjected to the conditions of the previous tests. It is therefore desirable to maintain a supply of unmonitored “hot spares” in the environmental chamber. Any product substitutions shall be noted clearly within any report issued under this document. “Hot spares” do not need to be monitored until they are substituted for failed product. No more than ten (10) initial test samples may be replaced by “hot spares”. This criteria does not apply to samples that are pre-screened to New Product criteria, see Section 4.4.1.

RATIONALE — All nonconformance to requirements shall be recorded, whether at the initial measurements or at any point in the testing. It also does not make sense to continue to test a product that has already failed and apply the failure to all subsequent tests. By allowing substitutions, the failure is only counted against the test in which it failed to meet requirements. It is necessary to limit the number of sample replacements because an unlimited number of replacements is not practical.

4.2.3 Damage Criteria

At the completion of the respective test the connector plugs and adapters shall be inspected for damage that might impair the performance of the connector. This inspection shall include inspections for

- Distortion of housing parts, as indicated by difficulty in insertion, improper snap-fits, etc.
- Distortion of ferrules and sleeves, as indicated by change in mating force, changes in endface geometry, etc.
- Cracks
- Presence of debris, shavings, etc.
- Corrosion or residue
- Other potentially service-affecting damage
- Permanent Loss Increase of more than 0.5 dB from the New Product Measurement
- Permanent Reflectance Increase of more than 5 dB from the New product Measurement.

Permanent is defined as having the specified level of increase in loss or reflectance at the end of all tests performed on connector assemblies. The connector assemblies may be cleaned up to 2 times, using Cleaning Procedure A of Section 4.3.1 or Cleaning Procedure B of Section 4.3.2, at the supplier's option, in an attempt to bring their increases below the criteria level.

Examination shall also include inspection of the polished end of the ferrule under a magnification of 100 power for cracks, chips, or scratches.

4.3 Cleaning Procedures

The performance of an optical fiber connector assembly is, to a large degree, dependent on the state of cleanliness of the connector and adapter at the time of connection. Therefore, the cleaning procedures to be used during the tests conducted under the terms of this document must be clearly defined and followed very specifically.

During all tests Cleaning Procedure A shall be observed for all cleanings, unless otherwise noted in the test procedure.

4.3.1 Cleaning Procedure A

1. If both plugs have been removed from the adapter, blow compressed gas through the adapter. If both plugs are not to be removed, blow compressed gas into the open end of the adapter.
2. Wipe completely around the ferrule of the plug twice with a lint-free wiping material that has been moistened with alcohol. Then wipe across the end of the ferrule.
3. Repeat Step 2 with a dry wipe.
4. Blow compressed gas across the end of the ferrule. This is the final step before inserting the plug. Do not wipe the ferrule or allow it to touch anything after completion of this step and before the ferrule is inserted into the sleeve.
5. Insert the plug in the adapter.
6. If both plugs have been removed, repeat Steps 2 through 5 with the second plug.

The following materials are needed for Cleaning Procedure A:

- Laboratory wipes that are free of lint and abrasive particles
- Ethyl alcohol, nominal USP $\geq 99\%$
- Compressed air or canned compressed gas that is clean, dry, and oil-free.

NOTE Cleaning Procedure A is presented for use only in the testing of optical fiber connectors conducted under the terms of this document. Procedure A is a minimum level of cleaning against which the manufacturer's cleaning procedure is to be compared. Local plant procedures may require more rigorous cleaning methods.

4.3.2 Cleaning Procedure B

Cleaning Procedure B is the procedure recommended by the supplier for use by craft personnel while installing and using the connector. Cleaning procedures are to meet all applicable safety requirements.

4.4 Statement of Criteria

4.4.1 Performance of New Product

The connector assemblies are selected randomly from the sample that has been submitted for testing. The supplier of the product shall ensure that the product submitted is representative of the product being sold, and not selected for improved performance or reliability. The connectors are cleaned prior to being assembled for the measurements using Cleaning Procedure B, or Cleaning Procedure A if the supplier has no recommendation. A description of the cleaning procedures used shall be included in the report of the tests.

Before any testing all connectors used for testing shall be tested to the New Product Criteria listed below. Pigtail and jumper cable assemblies tested to the new product criteria may be pre-screened. See Section 4.1.1 for definitions. Nonconforming products may be replaced with conforming product before the start of any testing. Product that is replaced as a result of pre-screening is not to be reported as nonconforming. However, the data on the samples that were replaced and reason for replacement must be reported in any test report generated based upon this document. The supplier must analyze the cause of the nonconformance, or other problem, and provide Telcordia with a written explanation of the cause(s) and the corrective actions taken by the supplier. The supplier may alternately choose to have Telcordia perform the required analysis. The supplier's explanation shall appear in the final version of any test report generated based upon this document.

Once testing has started, product which subsequently becomes nonconforming is to be handled as described in Section 4.2.2.5, Handling of Nonconformance.

RATIONALE — Pre-screening of samples does not represent the actual random performance of the product. However, it is not practical to begin testing with nonconforming product. All test results need to be recorded, whether at the initial measurements or at any point during testing in order to provide a complete view of the capabilities of the product to potential customers. It is likewise necessary to report the reason for product replacements and determine what caused the product nonconformance and what corrective measures were taken by the supplier.

R4-2 [19]New Product Maximum Loss Requirement

... All connections in the population shall meet the New Product Loss Requirement of 0.40 dB stated in Table 4-2.

O4-3 [20]New Product Maximum Loss Objective

... All connections in the population should meet the New Product Loss Objective of 0.20 dB stated in Table 4-2.

- R4-4** [21]New Product Mean Loss Requirement
... The mean of the losses for the population of connections shall meet the New Product Mean Loss Requirement of 0.20 dB stated in Table 4-2.
- O4-5** [22]New Product Mean Loss Objective
... The mean of the losses for the population of connections should meet the New Product Mean Loss Objective of 0.15 dB stated in Table 4-2.
- R4-6** [23]New Product Reflectance (Digital)
... All connections in the population shall meet the New Product Reflectance Requirement of -40 dB stated in Table 4-3.
- CR4-7** [24]New Product Reflectance (Analog)
... Connectors intended for use in AM-VSB (analog video) systems shall meet the Conditional Requirement of -55 dB stated in Table 4-3.
- CO4-8** [25]New Product Reflectance (Analog)
... Connectors intended for use in AM-VSB (analog video) systems should meet the Conditional Objective of -60 dB stated in Table 4-3.

RATIONALE — For digital systems, the requirement is deemed sufficient. AM-VSB video systems are more susceptible to reflective impairments. The effects depend upon system configuration, including laser and fiber properties, and the number and spacings of splices along the fiber link. The maximum reflectance criteria are intended to reduce these impairments to a tolerable level. More stringent reflectance criteria might reduce the impairment further but this is deemed unnecessary at this point.

Some system specifications (e.g., SONET specifications in GR-253-CORE, *Synchronous Optical Network (SONET) Transport Systems: Common Generic Criteria*) allow relaxed point reflectances compared to the specifications in GR-1095-CORE, *Generic Requirements for Multi-Fiber Single-Mode Optical Splices and Splicing Systems*. The relaxed reflectance criteria, requiring increased system tolerance to reflections, enables use of some current embedded plant. The reflectance values given in GR-326-CORE are intended to enable graceful upgrades to future systems that may have reduced tolerance to reflections.

4.4.2 Temperature, Humidity, Condensation Tests

The Temperature, Humidity, Condensation Tests consist of multiple steps of increasing severity which stress the connector product by virtue of the differences in thermal expansion coefficient of the materials used, which will typically be greater than that of glass. Additional stress is provided by the presence of humidity and condensation, which will potentially penetrate the product causing chemical changes or damage during subsequent freezing.

Tolerances for the operating conditions during temperature and humidity tests (where specified) are

- Temperature $\pm 2^{\circ}$ C ($\pm 4^{\circ}$ F)
- Humidity $\pm 2\%$ RH (Except for Temperature/Humidity Cycling Test).

The test samples are allowed to reach equilibrium for at least 2 hours at 23° C (73° F) before measurements are made of loss and reflectance at the start and at the finish of each test.

A population of (15) pigtail and (5) jumper cable assembly samples is required for this test. This will initially be the same samples as for the New Product Test. Substitution or replacement of product which does not conform to the criteria of one test is permitted in order to obtain the required population of conforming pigtails and/or jumper assemblies for subsequent tests. The rating for the previous test would remain “not met”. However, the replacement product must have experienced the same environmental history.

For example, continuing the discussion in the Rationale of Section 4.2.2.2, the presence of a loss of 0.70 dB on one end of a jumper assembly causes the New Product criteria not to be met. This jumper would then be replaced and the measurement results recorded and included in the final report. Similarly, degradation of a connection from 0.20 dB to 0.70 dB during the Thermal Cycling Test would cause the criteria of this test not to be met. After noting the nonconformance, this test sample may be replaced by another which had experienced the same environmental history, in order to reconstitute the population of original samples for the next test, in this case Humidity Aging. For more information on the handling of nonconformance see Section 4.2.2.5, Handling of Nonconformance.

4.4.2.1 Thermal Age Test

The Thermal Age Test (see Table 4-4) is the least severe of the environmental tests and is intended to simulate and accelerate the processes that may occur during shipping of product. This test is similar to the Adhesives Test (Section 4.4.4.2) in the

conditions imposed on the product, thus if the Adhesives Test is performed, this stage may be omitted to save time and testing expense.

Table 4-4. Test Conditions for the Thermal Age Test

Temperature:	85° C (185° F)
Humidity:	Uncontrolled
Duration:	168 hr. (7 days)
Measurement of Loss, and Reflectance:	To be done before and after application of 85° C.
Measurements to which the criteria are to be applied	Loss and Reflectance - The measurements made after the application of 85°C. Change in Loss and Reflectance - The difference between the measurements made before and after the application of 85°C.
Reference:	EIA/TIA-455-4A

R4-9 [26] Thermal Age Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load”

O4-10 [27] Thermal Age Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load”

4.4.2.2 Thermal Cycle Test

The test condition for the Thermal Cycle Test are shown on Table 4-5. Figure 4-3 shows the temperature profile for this test.

Table 4-5. Test Conditions for the Thermal Cycle Test

Temperature: Cycle in Figure 4-3 (-40° C to +75° C)

NOTE This cycle may be modified by decreasing the transition times and increasing the hold times, if necessary to complete the measurements.

Humidity: Uncontrolled

Duration: 21 Cycles, 168 hr. (7 days)

Measurement of Loss, and Reflectance: At every temperature plateau, and at 23° C at the end of the test. The measurements at the temperature plateau are to be made at least thirty minutes after the start of the plateau interval.

Measurements to which the criteria are to be applied. **Loss and Reflectance** - All measurements.
Change in Loss and Reflectance - The difference between any measurement at which the criteria are applied and the measurement made at the beginning (at 23° C) of the Thermal Cycle Test.

Reference: EIA/TIA-455-3A

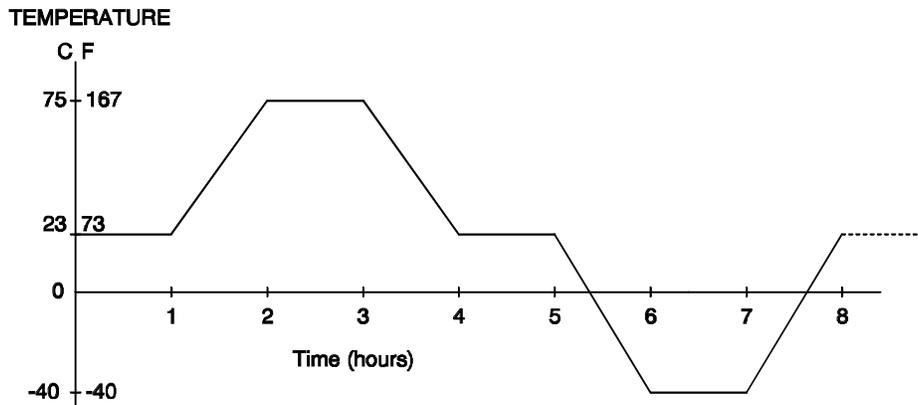


Figure 4-3. Thermal Cycle Profile

R4-11 [28] Thermal Cycle Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

O4-12 [29] Thermal Cycle Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

4.4.2.3 Humidity Aging Test

Table 4-6 shows the test conditions for the Humidity Aging Test.

Table 4-6. Test Conditions for the Humidity Aging Test

Temperature:	75°C (167°F)
Humidity:	95%
Duration:	168 hr. (7 days)
Measurement of Loss, and Reflectance:	At least every 6 hours during the test and at the beginning and end of the test (at 23° C).
Measurements to which the criteria are to be applied.	Loss and Reflectance - All measurements, except those made at the beginning (at 23° C) of the test. Change in Loss and Reflectance - The difference between any measurement during the Humidity Test and the measurement made at the beginning of the Humidity Test.
Reference:	EIA/TIA-455-5A

R4-13 [30] Humidity Age Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

O4-14 [31] Humidity Age Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

4.4.2.4 Humidity / Condensation Cycling Test

The test condition for the Humidity / Condensation Cycle Test are shown on Table 4-7. Figure 4-4 shows the temperature profile for this test. See NOTE following Figure 4-4 for test details and rationale.

Table 4-7. Test Conditions for the Humidity / Condensation Cycling Test

Temperature:	Cycle in Figure 4-4 (-10° C to + 65° C)
Humidity:	90% - 100% RH at points indicated
Duration:	14 Cycles, 168 hr. (7 days)
Measurement of Loss and Reflectance:	At every temperature plateau, and at 23° C at the end of the test. The measurements at the temperature plateau are to be made at least thirty minutes after the start of the plateau interval.
Measurements to which the criteria are to be applied.	Loss and Reflectance - All measurements. Change in Loss and Reflectance - The difference between any measurement at which the criteria are applied and the measurement made at the beginning (at 23° C) of the Thermal Cycle Test.
Reference:	EIA/TIA-455-3A

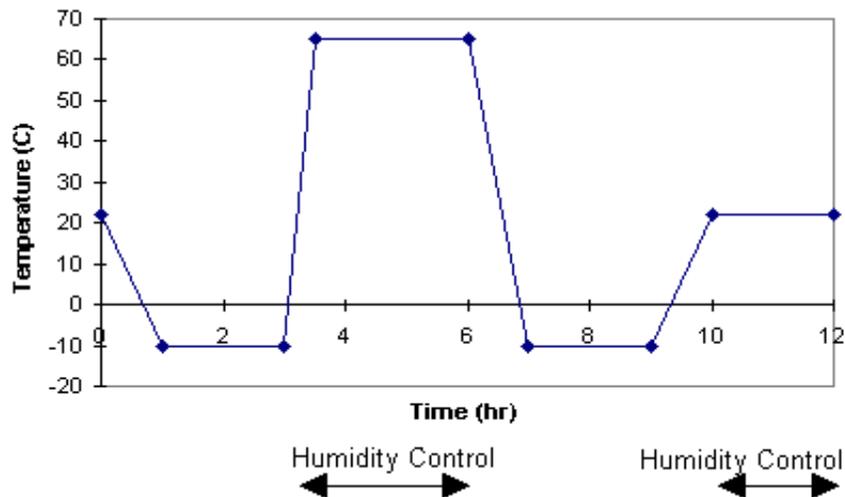


Figure 4-4. Temperature/Humidity Profile for Humidity/Condensation Test

NOTE The ramp-up and ramp-down intervals shown in Figure 4-4 are one hour with the exception of the first ramp-up in the cycle starting at 3 hours into the cycle. The ramp up at three (3) hours in the cycle needs to be done as fast as possible to achieve heavy condensation on the test samples. The purpose of this is to simulate a worst case condensation condition that may occur in outside plant applications such as closures. In order to maximize the condensation, it is necessary to warm-up the chamber faster than the samples so that the samples remain below the dew point of the atmosphere within the chamber. To achieve this condition, it has been found that it is necessary to ramp up the chamber temperature from -10 °C to + 65 °C in only 15 to 20 minutes maximum. This has been shown to consistently produce heavy condensation. A fast temperature rise may require the use of modern environmental chambers.

R4-15 [32]Humidity / Condensation Cycling Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

O4-16 [33]Humidity / Condensation Cycling Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

NOTE The Humidity/Condensation Test takes the place of the Temperature Humidity Cycle test in Issue 1 of GR-326-CORE.

4.4.2.5 Dry-Out Step

The product shall be exposed to a drying step consisting of 24 hours (1 day) at 75°C prior to commencement of the last phase of the Environmental Tests.

RATIONALE — An outcome of the Industry Interaction process used to develop this document was the consensus desire to introduce this step.

4.4.2.6 Post-Condensation Thermal Cycle Test

Following the dry-out step, a second round of thermal cycling is performed, identical to the Thermal Cycle Test of Section 4.4.2.2.

RATIONALE — The effect of some of the changes which occur during Humidity/Condensation cycling will often become more apparent when condensation is removed. For example, moisture may fill an air gap that was created during condensation cycling, providing an optical path between the connectors during the hot, humid condensation interval. When the condensation is removed, the gap may still exist and a large reflectance and/or loss may result.

R4-17 [34] Post-Condensation Thermal Cycle Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

O4-18 [35] Post-Condensation Thermal Cycle Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

4.4.3 Mechanical Tests

The test samples emerging from the Temperature, Humidity, Condensation Tests are exposed to a variety of mechanical stress conditions of increasing severity. Substitution of nonconforming product may be performed in order to obtain the population of 15 samples. See Section 4.2.2.5 for information on the handling of nonconformance. Loss and reflectance criteria are stated for each of the tests.

A facility suitable for conducting the Flex, Twist, Proof, and Transmission Under Load Tests is described in Section 5.3.3.

4.4.3.1 Vibration Test

The test is conducted as follows:

- a. Mount the connector assemblies in the shaker so that the axis of vibration will be along one of the principal axes of the connectors. They may be mounted singly or in batches.

- b. Measure loss and reflectance.
- c. Vibrate the connectors for 2 hours at an amplitude of 1.5 mm (peak-to-peak) with the frequency sweeping continuously between 10 and 55 Hz at a rate of 45 Hz per minute.
- d. Measure loss and reflectance.
- e. Remount the fixture with the direction of vibration along a second principal axis of the connector assemblies and repeat Steps "c" and "d."
- f. Repeat Steps "c" and "d" for the third principal axis.

R4-19 [36]Vibration Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

O4-20 [37]Vibration Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

4.4.3.2 Flex Test

This test is applied to samples of Media Type I only. Refer to Section 3.3.1, Materials, Requirement [8] for definition.

- a. Measure loss and reflectance.
- b. Apply 0.9 kgf. (2.0 lbf.) load, the load level may be reduced to 0.6 kgf. (1.3 lbf) load for Small Form Factor Connectors, as defined in Section 4.1.1.
- c. Rotate the angle of the test fixture arm through the following cycle (see Figure 5-6): 0°, 90°, 0°, -90°, 0°, and repeat for 100 cycles.
- d. Remove load.
- e. Measure loss and reflectance.

Conformance to loss and reflectance criteria is determined from the measurement taken at Step 'e' of the procedure above minus the measurement at Step 'a'.

R4-21 [38]Flex Test Requirements

... The product shall not become uncoupled under this load and shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

O4-22 [39]Flex Test Objectives

... The product shall not become uncoupled under this load and should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

CO4-23 [218]Flex Test Objective for Small Form Factor Connectors

... When applying a 0.9 kgf. (2.0 lbf.) load to Small Form Factor Connectors, the product shall not become uncoupled under this load and should meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

RATIONALE — It was the consensus of the Telcordia Technical Forum that the Small Form Factor Connectors must be able to meet the loss and reflectance requirements with side loads at a level two-thirds that of the larger tradition connectors because of their smaller size. However, the Forum also felt it should be an objective that the Small Form Factor Connectors meet the same requirements for side loads as traditional connectors.

4.4.3.3 Twist Test

The test is conducted as follows:

- a. Mount the test sample in the test facility; see Figure 5-6.
- b. Measure loss and reflectance.
- c. Apply load:
 - Media Type I, 1.35 kgf (3.0 lbf.)
 - Media Type II, 0.75 kgf (1.65 lbf.)
 - Media Type III, 0.5 kgf (1.1 lbf.)
- d. Rotate the capstan (see Figure 5-6) X revolutions about the axis of the fiber. (See Table 4-8).
- e. Reverse direction and rotate Y revolutions. Reverse direction again, and rotate Y revolutions. (See Table 4-8).
- f. Repeat Step "c" nine times.

- g. Remove load, and measure loss and reflectance.

Conformance to loss and reflectance criteria is determined from the measurement taken at Step ‘g’ of the procedure above minus the measurement at Step ‘b’.

Table 4-8. Number of Turns for Twist Test

Media Types	X	Y
Type I	2.5	5
Types II & III	1.5	3

R4-24 [40] Twist Test Requirements

... The product shall not become uncoupled and shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

O4-25 [41] Twist Test Objectives

... The product shall not become uncoupled and should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

4.4.3.4 Proof Test

This test is applied to samples of Media Type I. Refer to Section 3.3.1, Materials, Requirement [8] for definition.

The procedure is as follows:

- a. Mount the test sample in the test facility, see Figure 5-6.
- b. Measure loss and reflectance.

Straight pull:

- c. Apply 4.5 kgf (10 lbf) 0° for at least 5 seconds.
- d. Remove the load, and after at least 10 seconds, measure loss and reflectance. Go to Step e, see note below.
- e. Apply 6.8 kgf (15 lbf) at 0° for at least 5 seconds.
- f. Remove the load, and after at least 10 seconds, measure loss and reflectance.

90° Side pull:

- g. Apply 2.3 kgf (5.0 lbf) at 90° for at least 5 seconds. The load level may be reduced to 1.5 kgf (3.3 lbf) load for Small Form Factor Connectors, as defined in Section 4.1.1.
- h. Remove the load, and after at least 20 seconds, measure loss and reflectance. Go to Step i, see note below.
- i. Apply 3.4 kgf (7.5 lbf) at 90° for 5 seconds. The load level may be reduced to 2.3 kgf (5.0 lbf) load for Small Form Factor Connectors, as defined in Section 4.1.1.
- j. Remove the load, and after at least 20 seconds measure loss and reflectance.

NOTE If the supplier feels that a connector product cannot support a load at a higher (Objective) level without disconnecting or being damaged by the attempt, the product may be tested only at the lower (Requirement) levels, and a rating of “not met” will be applied to the Objectives.

R4-26 [42]Proof Test Requirements

... The product shall not become uncoupled under this load and it shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” when subjected to the lower loading level in Steps ‘c’ and ‘g’.

O4-27 [43]Proof Test Objectives

... The product shall not become uncoupled under this load and it should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” when subjected to the higher loading level in Steps ‘e’ and ‘i’.

CO4-28 [219]90° Side Pull Proof Test Objects for Small Form Factor Connectors

... The Small Form Factor Connector shall not become uncoupled under this load and it should meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” when subjected to the higher loading level in Step ‘g’.

NOTE The measurements in this test are taken after removal of the load, not while load is applied, hence the “During Test, Not Under Load” criteria apply. The Objectives criteria are more difficult than the

Requirements criteria in two ways. First, the load levels are higher. Second, the performance criteria are more stringent. This approach is consistent with Issue 2 of GR-326-CORE.

4.4.3.5 Transmission With Applied Tensile Load

Mount the test sample in the tensile test facility (see Figure 5-6) and apply loads at a series of angles as defined in Table 4-9. The first load to be applied to a connector with Type I Media is 0.25 kgf at an angle of 0°. The angle is increased to 90°. For jumpers intended for use on “high density” distributing frames (see Section 4.1.1 for definition), a final measurement is made with the angle increased to 135°. The second load is 0.7 kgf, and is applied first at 0° then at 90°. This is continued for each of the conditions in Table 4-9.

Table 4-9. Tensile Loads for Transmission with Applied Load

Media Type I			
Load	0°	90°	135°
0.25 kgf (0.55 lbf)	X	X	X
0.7 kgf (1.54 lbf)	X	X	
1.5 kgf (3.3 lbf)	X	X	
2.0 kgf (4.4 lbf)	X	X	
Media Type II			
Load	0°	90°	135°
0.25 kgf (0.55 lbf)	X	X	X
0.7 kgf (1.54 lbf)	X	X	
Media Type III			
Load	0°	90°	135°
0.25 kgf (0.55 lbf)	X	X	
0.5 kgf (1.1 lbf)	X	X	

Loads are applied similarly to Type II and Type III media. See Section 3.3.1 Materials, Requirement [8] for definitions of the Media Types.

Loss and reflectance is measured at both 1310 nm and 1550 nm wavelengths before application of load and again with each combination of load and angle. Loads are applied until stability or equilibrium is reached before measurement are made. The measurement at the end of the test is not made until at least 20 seconds after the load has been removed to allow relaxation of stresses within the materials.

For Small Form Factor Connectors (see Section 4.1.1 for definition) the load levels shown in Table 4-9 for angles of 90° and 135° may be reduced to 2/3 of the value shown. The modified loads for Small Form Factor Connectors is shown in Table 4-10.

Table 4-10. Small Form Factor Connector Tensile Loads for Transmission with Applied Load

Media Type I			
Load	0°	90°	135°
0.25 kgf (0.55 lbf)	R ^a	O ^b	O
0.17 kgf (0.37 lbf)		R	R
0.7 kgf (1.54 lbf)	R	O	
0.47 kgf (1.00 lbf)		R	
1.5 kgf (3.3 lbf)	R	O	
1.0 kgf (2.2 lbf)		R	
2.0 kgf (4.4 lbf)	R	O	
1.3 kgf (2.9 lbf)		R	
Media Type II			
Load	0°	90°	135°
0.25 kgf (0.55 lbf)	R	O	O
0.17 kgf (0.37 lbf)		R	R
0.7 kgf (1.54 lbf)	R	O	
0.47 kgf (1.00 lbf)		R	
Media Type III			
Load	0°	90°	135°
0.25 kgf (0.55 lbf)	R	O	
0.17 kgf (0.37 lbf)		R	
0.5 kgf (1.1 lbf)	R	O	
0.33 kgf (0.73 lbf)		R	

a. "R" stands for Requirement.

b. "O" stands for Objective.

R4-29 [44]Transmission with Applied Load at 0° Requirements

... The product shall not become uncoupled under this load and shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Under Load", when subjected to all of the loading levels at an angle of 0° in Table 4-9, for

Small Form Factor Connectors in Table 4-10. If the product fails to do so, then the highest load which was supported shall be reported.

R4-30 [45]Transmission with Applied Load at 90° Requirements

... The product shall not become uncoupled under this load and shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Under Load”, when subjected to all of the loading levels at an angle of 90° in Table 4-9 or for Small Form Factor Connectors in Table 4-10. If the product fails to do so, then the highest load which was supported shall be reported.

O4-31 [46]Transmission with Applied Load at 0° Objectives

... The product shall not become uncoupled under this load and should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Under Load”, when subjected to all of the loading levels at an angle of 0° in Table 4-9 or for Small Form Factor Connectors in Table 4-10. If the product fails to do so, then the highest load which was supported shall be reported.

O4-32 [47]Transmission with Applied Load at 90° Objectives

... The product shall not become uncoupled under this load and should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Under Load”, when subjected to all of the loading levels at an angle of 90° in Table 4-9 or for Small Form Factor Connectors in Table 4-10. If the product fails to do so, then the highest load which was supported shall be reported.

CO4-33 [220]Transmission with Applied Load at 90° Objectives for Small Form Factor Connectors

... Small Form Factor Connectors shall not become uncoupled under this load and should meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Under Load”, when subjected to all of the loading levels at an angle of 90° in Table 4-9. If the product fails to do so, then the highest load which was supported shall be reported.

R4-34 [48]Use in High Density Environment

... The supplier of a connector or jumper assembly product shall state if that product is intended for use in a “high density” environment. See Section 4.1.1 for definition.

CR4-35 [49]Transmission with Applied Load at 135°

... If the product is intended for use in “high density” environments, then it should meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Under Load”, when subjected to all of the loading levels at an angle of 135° in Table 4-9 or for Small Form Factor Connectors in Table 4-10. If the product fails to do so, then the highest load which was supported shall be reported.

CO4-36 [221]Transmission with Applied Load at 135° for Small Form Factor Connectors

... If the Small Form Factor Connector is intended for use in “high density” environments, then it should meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Under Load”, when subjected to all of the loading levels at an angle of 135° in Table 4-9. If the product fails to do so, then the highest load which was supported shall be reported.

RATIONALE — In Issue 1, GR-326-CORE imposed the 135° loading on all products. This led to over-design and extra cost for products not intended for use in high density environments. The user must decide whether his application warrants the extra cost and possibly reduced flexibility of a design which will meet the 135° loading Conditional Requirement.

4.4.3.6 Equilibrium Tensile Loading

This section was present in Issue 1 of GR-326-CORE and was removed in Issue 2 because of overlap with Section 4.4.3.5. It is left in the document as a place holder so as to maintain consistency of section numbering between the issues of this document.

4.4.3.7 Impact Test

The Impact Test is conducted as follows:

- a. Measure loss and reflectance.

- b. Remove one plug from the connector assembly and mount that plug by its jumper cable in the Impact Test Fixture (see Figure 5-7). A ferrule cap is to be placed over the ferrule only to protect the fiber endface. The ferrule cap shall not impede impact stress, nor protect the connector from impact. The ferrule cap cannot cover any portion of the outer housing or shell. The ferrule cap is to be made of material that does not contaminate the ferrule.

RATIONALE — The intent of this test is to determine the effect of accidentally dropping the connector while working with it. It is most likely that this will happen while inserting or removing the plug. The environmental conditioning of the samples before the impact test can cause minor bends and curves in the patch cord so that it doesn't hang straight down. Because of this, it is not uncommon for a connector to strike the block endface first which can result in unintentional scratching of the fiber core. The impact test is not intended to test the connector for scratch resistance, therefore, a ferrule cap is to be used to prevent this.

- c. Raise the plug to the horizontal position and release it so that it will strike the block. Repeat for a total of 8 impacts.

RATIONALE — Changing the number of impacts from 10 to 8 brings GR-326-CORE into conformance with FOTP-2 Impact Test Measurements for Fiber Optic Devices.

- d. Clean the connector assembly per Cleaning Procedure A (Section 4.3.1) or Cleaning Procedure B (Section 4.3.2), at the supplier's option.
- e. Measure loss and reflectance.

Loss and reflectance criteria are evaluated to the measurement taken at Step 'e' of the procedure given above. Increase in loss is the loss at Step 'e' minus the loss at Step 'a'.

R4-37 [50]Impact Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

O4-38 [51]Impact Test Objectives

- ... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

4.4.3.8 Durability

The connector assemblies are mounted in the Durability Test Facility. The Durability Test is conducted with an equal number of connectors mounted at each of the following distances above the floor: 1.8 m (6 ft.), 1.4 m (4.5 ft.), and 0.9 m (3 ft.).

An initial cleaning is performed and baseline optical measurements taken. Re-cleaning is permitted if necessary to bring a connector into conformance. Each of the connector assemblies is reconnected a total of 200 insertions during the course of this test. The operator must stand on the floor for all cleanings and reconnections. The following sequence is used in making successive insertions:

- A. Disconnect and reconnect 1 connector assembly at the 6 ft. height.
- B. Disconnect and reconnect 1 connector assembly at the 4.5 ft. height.
- C. Disconnect and reconnect 1 connector assembly at the 3 ft. height.
- D. Disconnect and reconnect 1 connector assembly at the 3 ft. height.
- E. Disconnect and reconnect 1 connector assembly at the 4.5 ft. height.
- F. Disconnect and reconnect 1 connector assembly at the 6 ft. height.
- G. repeat Steps ‘a’ - ‘f’ until all 15 connector assemblies have been disconnected and reconnected.
- H. This sequence counts as a single insertion.

The following scheme is used during the course of the 200 insertions.

- A. Measurements are taken at insertions 24, 49, 74, 99, 124, 149, 174, and 199, without cleaning.
- B. Readings are taken at insertions 25, 75, 125 and 175 after one-sided cleaning. No re-cleaning is performed at this point.

NOTE The cleaning method used is Cleaning Method A (Section 4.3.1) or Cleaning Method B (Section 4.3.2), at the supplier’s option. Also, cleaning may be omitted at the request of the supplier, if the product purports to be one which does not require cleaning.

C. Readings are taken at insertions 50, 100, 150 and 200 after two-sided cleaning. No re-cleaning is performed at this point (except for insertion 200, if required). The Note above applies to this Step also.

D. If at the end of 200 insertions some connectors do not meet the optical criteria, and after cleaning they still do not meet optical criteria, then up to two re-cleanings are performed.

The Durability Test measures the change in performance between the beginning and the end of the test, the repeatability of the connector during the test, and the degree to which the connector is cleanable. Connectors tend to generate debris (wear particles) when being connected. While such wear has little effect on the mechanical performance, the retention of these particles in the connector assembly tends to degrade the optical performance.

Single-sided cleanings are included in this test since it is frequently impractical to clean both sides of a connector every time a plug is removed.

The objective of the Durability Test is to observe both the overall change in performance of the connector with many insertions and the repeatability during successive insertions. The test also measures the effectiveness of two different cleaning procedures.

Connectors are mounted at various heights during the Durability Test to simulate the effect of craft personnel working in an equipment office.

R4-39 [52] Remateability Requirement

... Of the entire body of measurements taken after either one-sided or two-sided cleaning (at insertions 25, 50....), 90% shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

O4-40 [53] Remateability with Cleaning Objective

... Of the entire body of measurements taken after either one-sided or two-sided cleaning (at insertions 25, 50....), 95% shall meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

O4-41 [54] Remateability without Cleaning Objective

... Of the entire body of measurements taken without cleaning (at insertions 24, 49....), 90% shall meet the loss and reflectance **Requirements** (not Objectives) criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

RATIONALE — The Objective above recognizes that despite recommendations to clean connectors with each insertion, the reality is that many reconnections will be made without cleaning.

R4-42 [55]Durability Requirement

... After having been subjected to the complete set of 200 insertions, the product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.” Up to two re-cleanings may be performed for each connection.

O4-43 [56]Durability Objective

... After having been subjected to the complete set of 200 insertions, the product shall meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.” Up to two re-cleanings may be performed for each connection.

RATIONALE — The Durability criteria addresses wear of the product. If performance is satisfactory after 200 insertions, the product is durable, even if several cleaning attempts are required to obtain the satisfactory performance.

O4-44 [57]Cleanability Objective

... The criterion is not met if connectors which are nonconforming after 200 insertions and the subsequent automatic two-sided cleaning are brought back into conformance by one or two re-cleanings.

RATIONALE — If a product is easily cleanable, then the automatic cleaning after the 200th insertion should bring performance back into conformance, even if debris has been generated. If several cleanings are required, then the first (automatic) cleaning was not completely effective, hence the Cleanability criterion is not met.

4.4.3.9 End of Test Criteria

At the completion of all tests contained in Service Life Tests (refer to Table 6-1), the following criteria shall be applied.

- R4-45** [58]Optical Requirements
... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “End of Test.”
- O4-46** [59]Optical Objectives
... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “End of Test.”
- R4-47** [60]Ferrule Endface Geometry
... The product shall meet the Ferrule Endface Geometry Requirement criteria stated in Section 4.4.5.1.
- R4-48** [61]Damage
... At the completion of the tests there shall be no damage that would impair the performance of either the connector plug or the adapter, as described in Section 4.2.3.

RATIONALE — Changes in performance of connectors during exposure to extreme environments often occur due changes in ferrule endface geometry, pitting or etching of the glass, or other damage.

4.4.4 Materials and Environmental Tests

4.4.4.1 Dust Test

The Dust Test in Issue 1 of GR-326-CORE used a coarse dust which is not representative of the dust expected to be most troublesome for connectors. This revised Dust Test utilizes a fine dust known as “Arizona Road Dust.” The results of this test indicate the performance of connector assemblies after exposure to severe dust conditions. The test can be performed in the facility described in Section 5.3.7.

With the consolidation of the tests in Issue 3 of GR-326-CORE, this test has been moved from the Service Life Tests to Section 7, “Reliability Tests”. The Reliability Section requires a larger sample size than defined below for a 10% Lot Tolerance

Percent Defective (LTDP). However, either sample size may be chosen, depending on the reliability level required by the user.

A minimum of ten new pigtail assemblies are subjected to the Dust Test. On half the samples or a minimum of five of the pigtail assemblies, samples #1 to 5, are to have both connector plugs mated during dust exposure (Set "A", Figure 5-9A), and the other half also a minimum of five, samples #6 to 10, are to have one plug in each of the pigtails disconnected (Set "B", Figure 5-9B). If dust caps and covers are supplied with the adapters or plugs, the disconnected plugs and the open adapters are covered or capped during the Dust Test. Test details are given in Section 5.3.7. Samples may be pre-screened with respect to loss and reflectance, to ensure that the initial population consists of conforming product as described in Section 4.4.1. The cleaning procedure to be used throughout is cleaning Procedure "A" in Section 4.3.1 or cleaning Procedure "B" in Section 4.3.2, at the supplier's option.

The Dust Test procedure is as follows:

- a. Clean the plugs and adapters and assemble the connector assemblies.
- b. Measure loss and reflectance.
- c. Disconnect one plug (plug a) from each of the assemblies in samples #6 to 10 and cap the respective plugs and adapters (see Figure 5-9B).
- d. Subject all the samples to the Dust Test as described in Section 5.3.7.
- e. Remove the samples from the dust chamber and, without disconnecting any of the plugs or removing any of the dust caps, clean the exposed surfaces of the connector assemblies and the sections of cable exposed to the dust. Cleaning may be done by brushing, wiping (with a dry and/or wet wipe), and blowing with canned compressed gas.
- f. Measure loss and reflectance of only the samples that were mated during dust exposure, samples #1 to 5.
- g. Disconnect one plug (plug a) from samples #1 to 5. Leave the remaining plug (plug b) as a bulkhead configuration, i.e., still connected to the adapter. Clean all disconnected plugs and all bulkhead configurations (see Figure 5-9B).
- h. Re-connect and measure loss and reflectance for all ten connector assemblies.
- i. Repeat Steps "g" and "h" two additional times. The plugs still inside an adaptor may be cleaned with canned air, alcohol and a cotton swab. Always remove the same plug from each connector assembly.
- j. Disconnect all plugs from the adaptors, clean thoroughly with procedures appropriate to plugs and adaptors respectively.

k. Re-connect all plugs and adaptors as before, measure loss and reflectance for all ten connector assemblies.

l. Repeat Steps “j” and “k” two additional times.

These steps are summarized in a flow chart in Figure 4-5.

Criteria are applied to the changes in loss and reflectance measurements made after exposure to dust compared to the Pre-Dust measurement.

R4-49 [62]Dust Test Requirements: Set “A”

... The product of Set “A” (Group I) shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” during the first measurement (before cleaning).

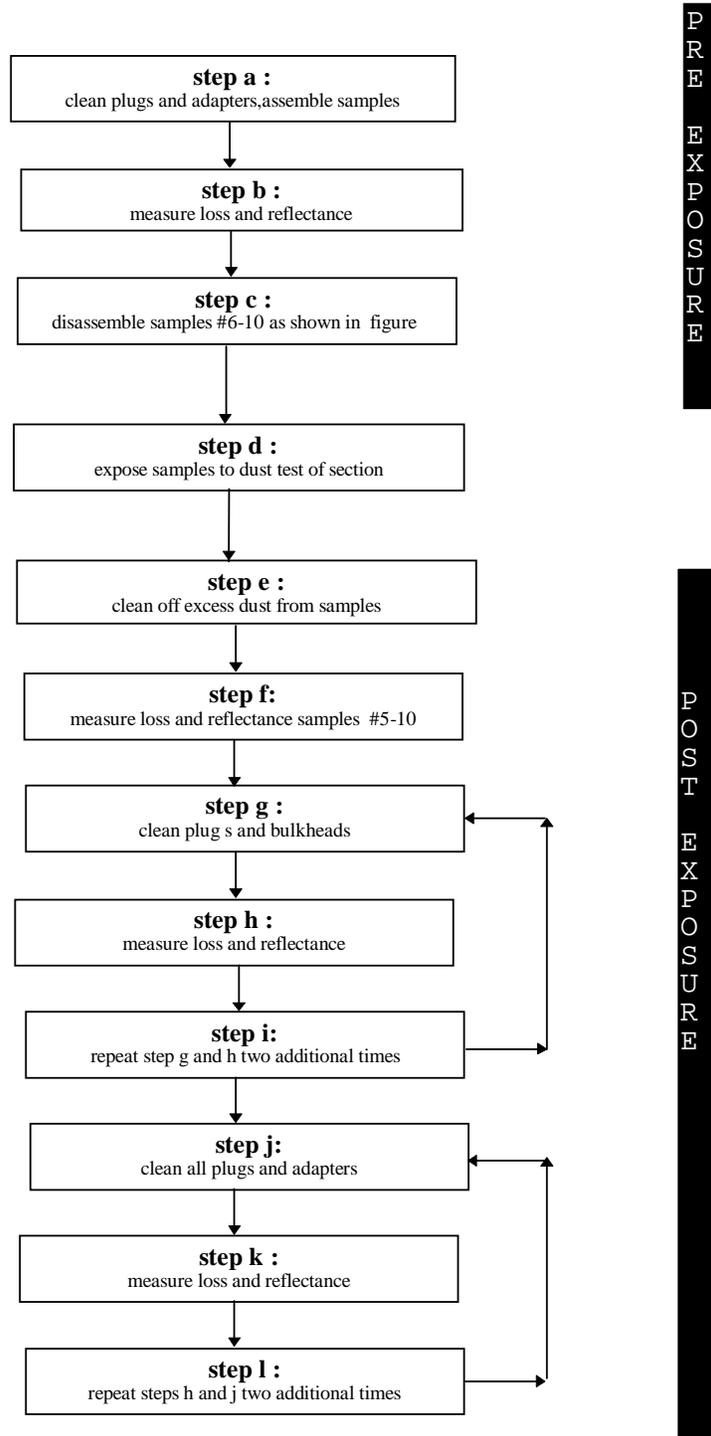


Figure 4-5. Dust Test Flow Chart

RATIONALE — At this point the product will not have been demated, so its performance should not be affected by dust exposure.

R4-50 [63]Dust Test Requirements: Sets “A” and “B”

... The product of both Sets “A” and “B” (Groups II and III) shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after the last cleaning in Step “l.”

RATIONALE — At this point the product will have been thoroughly cleaned three times, so performance should be returned to conforming levels.

O4-51 [64]Dust Test Objectives

... The product of both Sets “A” and “B” (Groups II and III) should meet the loss and reflectance **Requirements** (not Objectives) criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after the last cleaning in Step “i.”

RATIONALE — At this point the product will have been cleaned three times but with one plug still in the adaptor; i.e., not as thoroughly as possible.

O4-52 [65]Dust Test Cleanability Objective

... The criterion is **not met** if connectors which are nonconforming to the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 after the first cleaning in Step “G” or Step “J” are brought back into conformance during the subsequent two cleanings.

RATIONALE — It is most desirable that the first cleaning be effective, and that subsequent cleanings are not required to bring the product into conformance.

O4-53 [66]Dust Resistance Objective

... The criterion is **not met** if product which is conforming after the first cleaning becomes nonconforming after a subsequent cleaning.

RATIONALE — It is most desirable that a product be resistant to degradation in performance from the very act of cleaning, since the recommended procedure is to

clean after every demating.

4.4.4.2 Adhesive Testing

This test is designed to measure the strength of the adhesive bond between the fiber and the ferrule.

This test requires the use of a ceramic blank. This blank is to have an end face in the shape of a ferrule, but without a center hole. The exact dimensions and tolerances may be found in Section 5.3.6. The blank is then placed against the test plug so that the blank touches the ferrule as two plugs would in a connector assembly. A load equal to two pounds total is then applied to the plug under test via the blank.

The sample population required is five fresh connector plugs. It is not desirable to use plugs which had previously been exposed to Salt Spray or Airborne Contaminants, since any residue on the plug may damage the sensitive profilometer or interfere with interferometric measurements. Plug endface geometry is measured before and after loading. Initial plug endface geometry must meet the criteria for fiber undercut/protrusion, ferrule endface radius, and apex offset as stated in Section 4.4.5.1 or Section 4.4.5.2.

R4-54 [67] Adhesive Test

... After subjecting the specimens to loading with a ceramic blank for 7 days at 65°C with uncontrolled humidity, the endface geometry shall still be within the tolerances allowed by the Fiber Undercut and Protrusion Requirement [80] (Section 4.4.5.1 or Section 4.4.5.2).

NOTE As mentioned in Section 4.4.2.1 (Thermal Age Test) there is an overlap between the Adhesive Test and the Thermal Age test. If the Thermal Age Test is performed, then the duration of exposure for the Adhesive Test may be reduced to 24 hours.

4.4.4.3 Airborne Contaminants

This test is conducted with Pigtail Assembly samples. The samples for this test may be pre-screened on the basis of loss and reflectance to be conforming to the New Product criteria in Tables 4-2 and 4-3 as described in Section 4.4.1, unless otherwise specified by the test program under which the tests are being conducted.

With the consolidation of the tests in Issue 3 of GR-326-CORE, this test has been moved from the Service Life Tests to Section 7, “Reliability Tests”. The Reliability

Section requires a larger sample size than defined below for a 10% Lot Tolerance Percent Defective (LTDP). However, either sample size may be chosen, depending on the reliability level required by the user.

The samples used may be the same pigtail assemblies as used for the Salt Spray Test, or new product, at the option of the supplier.

The Airborne Contaminants Test is performed according ASTM B827-92 using the gas mixture indicated in Table 4-11. The test sample shall consist of a minimum of 10 connector assemblies.

Table 4-11. Airborne Contaminants Test Gases

Duration (Days)	Gas Concentrations (ppb)			
	Cl ₂	H ₂ S	NO ₂	SO ₂
20	20	100	200	200

Half of the connector assemblies, Set A, are to have both connector plugs mated during exposure, and the other half, Set B, are to have one plug in each of the assemblies disconnected. If caps and covers are supplied with the adapters or plugs, the disconnected plugs and the open adapters are covered or capped during the Airborne Contaminants Test.

The following is the test procedure:

Steps “a” through “l” are the same as the Dust Test procedure in Section 4.4.4.1 (see also Figure 4-5) with the substitution in Step “d” of an exposure to Airborne Contaminants Test per ASTM B827-92.

- m. The metal parts of the pugs and adaptors shall be visually examined, with no magnification, for evidence of corrosion.
- n. The metal parts of the plugs and adapters shall be examined under a magnification of 18x for evidence of corrosion.

RATIONALE — This sequence makes measurements at three stages. In the first stage samples which were assembled during exposure are not cleaned prior to measurement. In the second stage, all samples are cleaned such that one plug is not removed from its adapter. In the third stage, all samples are thoroughly cleaned such that both plugs are removed from the adapter.

Criteria are applied to the increase in loss and reflectance measurements made before and after exposure to airborne contaminants.

- R4-55** **[68]** Airborne Contaminants Requirements: Set “A”
... The product of Set “A” (Group I) shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” during the first measurement (before cleaning).

RATIONALE — At this point the product will not have been demated, so its performance should not be affected by dust exposure.

- R4-56** **[69]** Airborne Contaminants Requirements: Sets “A” and “B”
... The product of both Sets “A” and “B” (Groups II and III) shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after the last cleaning in Step “l.”

RATIONALE — At this point the product will have been thoroughly cleaned three times, so performance should be returned to conforming levels.

- O4-57** **[70]** Airborne Contaminants Objectives
... The product of both Sets “A” and “B” (Groups II and III) should meet the loss and reflectance **Requirements** (not Objectives) criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after the last cleaning in Step “i.”

RATIONALE — At this point the product will have been cleaned three times but with one plug still in the adaptor; i.e., not as thoroughly as possible.

- R4-58** **[71]** Airborne Contaminants Corrosion Requirement
... There shall be no visible evidence of the formation of corrosion under visual inspection.

4.4.4.4 Salt Spray

Table 4-12 shows the operating parameters for the Salt Spray Test.

Table 4-12. Operating Parameters for the Salt Spray Test

Temperature:	35° C (95° F)
Salt Content:	5% (±1%) NaCl by weight dissolved in distilled water
Duration:	168 hr. (7 days)
Measurement of Loss and Reflectance:	Before and after testing.
Test Sample:	10 connector assemblies minimum (10 adaptors and 20 plugs)
Reference:	EIA/TIA-455-16A

With the consolidation of the tests in Issue 3 of GR-326-CORE, this test has been moved from the Service Life Tests to Section 7, “Reliability Tests”. The Reliability Section requires a larger sample size than defined in Table 4-12 for a 10% Lot Tolerance Percent Defective (LTDP). However, either sample size may be chosen, depending on the reliability level required by the user.

This test is conducted with pigtail assembly samples. The samples for this test may be pre-screened on the basis of loss and reflectance to be conforming to the New Product criteria in Tables 4-2 and 4-3 as described in Section 4.4.1, unless otherwise specified by the test program under which the tests are being conducted.

During the Salt Test, the pigtail assemblies are exposed both as mated assemblies and with one plug removed from the assembly. After exposure to the salt solution, loss and reflectance are measured. The connector assemblies are disconnected, cleaned, and reconnected; and more measurements are made.

Half of the connector assemblies, Set A, are to have both connector plugs mated during salt exposure, and the other half, Set B, are to have one plug in each of the assemblies disconnected. If caps and covers are supplied with the adapters or plugs, the disconnected plugs and the open adapters are covered or capped during the Salt Spray Test.

The following is the test procedure:

Steps “a” through “l” are the same as the Dust Test procedure in Section 4.4.4.1 (see also Figure 4-5) with the substitution in Step “d” of an exposure to Salt Spray per EIA/TIA-455-16A.

- m. The metal parts of the pugs and adaptors shall be visually examined, with no magnification, for evidence of corrosion.

- n. The metal parts of the plugs and adapters shall be examined under a magnification of 18x for evidence of corrosion.

RATIONALE — This sequence makes measurements at three stages. In the first stage samples which were assembled during exposure are not cleaned prior to measurement. In the second stage, all samples are cleaned such that one plug is not removed from its adapter. In the third stage, all samples are thoroughly cleaned such that both plugs are removed from the adapter.

R4-59 [72]Salt Spray Requirements: Set “A”

- ... The product of Set “A” (Group I) shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” during the first measurement (before cleaning).

RATIONALE — At this point the product will not have been demated, so its performance should not be affected by dust exposure.

R4-60 [73]Salt Spray Requirements: Sets “A” and “B”

- ... The product of both Sets “A” and “B” (Groups II and III) shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after the last cleaning in Step “l.”

RATIONALE — At this point the product will have been thoroughly cleaned three times, so performance should be returned to conforming levels.

O4-61 [74]Salt Spray Objectives

- ... The product of both Sets “A” and “B” (Groups II and III) should meet the loss and reflectance **Requirements** (not Objectives) criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after the last cleaning in Step “i.”

RATIONALE — At this point the product will have been cleaned three times but with one plug still in the adaptor; i.e., not as thoroughly as possible.

R4-62 [75]Salt Spray Corrosion Requirement

- ... There shall be no visible evidence of the formation of corrosion under visual inspection.

4.4.4.5 Immersion/Corrosion Test

With the consolidation of the tests in Issue 3 of GR-326-CORE, this test has been moved from the Service Life Tests to Section 7, “Reliability Tests”. The Reliability Section requires a larger sample size than defined below for a 10% Lot Tolerance Percent Defective (LTDP). However, either sample size may be chosen, depending on the reliability level required by the user.

The endface geometry of fifteen (15) plugs shall be determined, and photos taken using optical microscopy and/or interferometry. Five (5) mated connector assemblies (10 plugs) and five (5) unmated plugs shall then be immersed in 250 mL of deionized or distilled water at 85 °C for two weeks. The connector housings and adapters shall be completely immersed. Changes in surface features, such as distortions of the ferrule material or surface roughening will be noted, but will not result in nonconformance.

The five mated connector assemblies (10 plugs) are used to determine ferrule deformation. If the five unmated plugs are assembled with fiber that has a Germanium-doped core and pure silica cladding, these samples may be used to determine fiber dissolution. If the connector plugs use different fiber type, a separate set of five fiber/ferrule samples shall be assembled with polished endfaces, to be used to monitor the rate of fiber dissolution. These samples should be immersed in the test beaker along with the other connector samples.

R4-63 [76]Immersion/Corrosion Requirement for Ferrule Deformation
... The degradation factor shall be less than 0.015 after two weeks of aging in 85°C de-ionized water.
The Degradation Factor = $(R_{\text{final}} - R_{\text{initial}}) / (R_{\text{initial}} * R_{\text{final}})$, where R_{initial} and R_{final} are the initial and final radii of curvature, respectively.

O4-64 [77]Immersion/Corrosion Objective for Fiber Dissolution
... The fiber core recess shall not increase by more than 10 nm with respect to the cladding during the two-week aging test.

RATIONALE — Any geometric instability in the connector endface is potentially performance-affecting and may be an indication of improperly stabilized zirconia used for the ferrule. A visible ring of easily cleaned residue (“moisture ring”) is often seen on ferrules after immersion at the point where the ferrules mate. This has not been seen to be performance-affecting, and does not constitute nonconformance to the Objective criteria.

4.4.4.6 Groundwater Immersion

Optical connectors used in the underground plant may be exposed to immersion in a variety of fluids if the closures containing them are breached. An immersion test based on distilled water would not capture the effects of the various contaminants which might be found in realistically contaminated groundwater. One of the immersion media which must be considered is that of biologically active organisms. While it is obvious that product exposed to groundwater will be exposed to such organisms, it is less obvious, but nevertheless likely, that products deployed in free-breathing above-ground and aerial closures will be exposed to air-borne organisms. Additional discussion of this topic can be found in Section 4.9.4 of GR-1095-CORE.

With the consolidation of the tests in Issue 3 of GR-326-CORE, this test has been moved from the Service Life Tests to Section 7, “Reliability Tests”. The Reliability Section requires a larger sample size than defined below for a 10% Lot Tolerance Percent Defective (LTDP). However, either sample size may be chosen, depending on the reliability level required by the user.

For products intended for use in the underground plant, a separate set of five mated connector assemblies is required for each of the five immersion media, for a total of twenty-five (25) mated connector assemblies. Products intended for use in free-breathing closures in the above-ground or aerial plant will be exposed to organisms only. A detailed description of the Groundwater Immersion Test is found in Section 5.3.8.

CR4-65 [78]Groundwater Immersion Test (Underground)

... Product intended for deployment underground shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after groundwater exposure.

See Section 5.3.8 for test procedure.

CR4-66 [79]Organism Exposure Test (Free-breathing)

... Product intended for deployment in free-breathing closures in the above-ground or aerial plant shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after Organism Exposure.

See Item 1) of Section 5.3.8 for test procedure.

4.4.5 Geometry Requirements

4.4.5.1 Ferrule Endface Geometry for Non-Angled Physical Contact Connectors

Three parameters define the connector endface geometry as shown in Figure 4-6. The Radius of Curvature of the ferrule endface is the local value in close proximity to the fiber. The Fiber Undercut or Protrusion is the location of the fiber with respect to the spherical dome surface defined by the radius of curvature. The Apex Offset is the distance from the center of the optical axis (fiber core) to the apex of the spherical dome surface of the ferrule.

To maintain physical contact between mated connectors fiber undercut (x) and protrusion (y) must be maintained within the requirements given below. A larger undercut may prevent physical contact, especially at higher temperatures. A larger protrusion will lead to pushback problems in the plug to which it is mated.

The endface geometry requirements are based upon the assumption that the ferrules are ceramic zirconia (Young's modulus of approximately 15,000 kgf/mm²) or a material with comparable physical properties. If materials are used that exhibit other material properties they would likely call for different requirements.

R4-67 [80] Fiber Undercut and Protrusion

... The Fiber Undercut (x) as shown in Figure 4-6 shall meet the requirements stated in IEC 60874-14-n, where "n" is any of the applicable (singlemode, single fiber, physical contact) released connector detailed specifications in the IEC 60874-14-n series. In those detail specifications, the radius of curvature of the ferrule is between 10 mm and 25 mm. That is, the value of fiber undercut (in units of nanometers) shall be no larger than $-0.02R^3 + 1.3R^2 - 31R + 325$, where R is the radius of curvature, expressed in millimeters. When the radius of curvature is between 7 mm and 10 mm, the value of the fiber undercut shall be no larger 125 nm. See Figure 4-7.

... The Fiber Protrusion (y) as shown in Figure 4-6 shall be ≤ 50 nm for all radii of curvature.

NOTE The test equipment used to measure the fiber position may define the value of the protrusion/undercut to be either positive or negative. In order to avoid confusion, the sign convention of the equipment being used to make the measurements should be verified, and the fiber position should be reported in terms of protrusion or undercut.

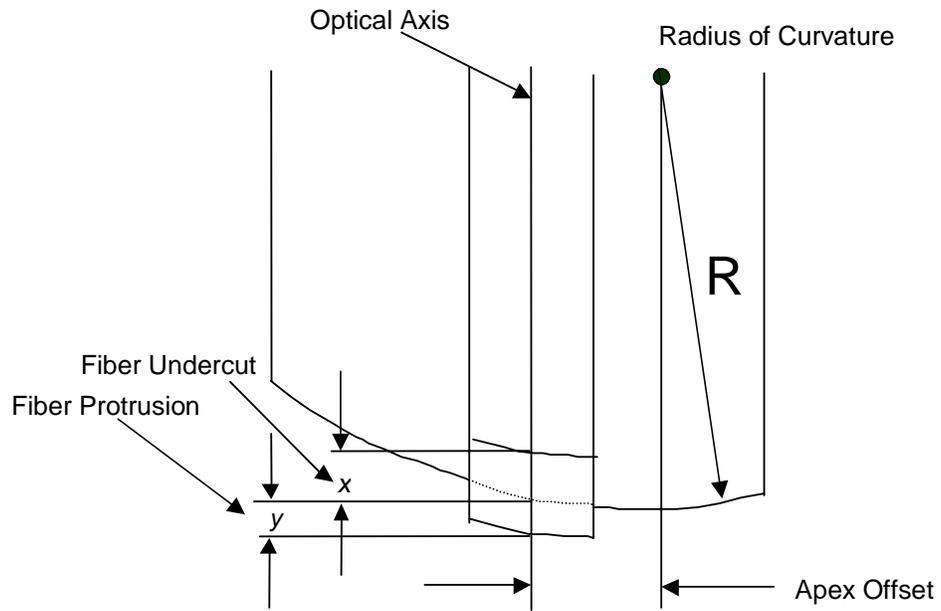


Figure 4-6. Ferrule Endface Geometry

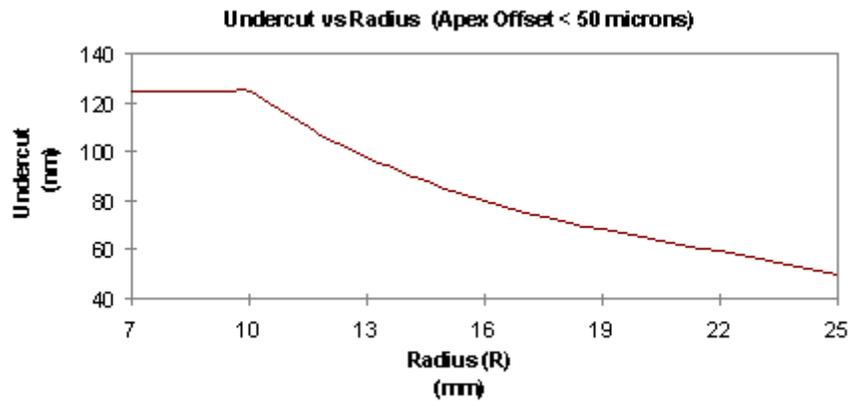


Figure 4-7. The Maximum Allowed Fiber Undercut for a Ferrule Radius of Curvature Between 7 mm and 25 mm

R4-68 [81] Ferrule Endface Radius

... The Radius of Curvature of the ferrule shall be between 7 mm and 25 mm.

R4-69 [82] Apex Offset

... The Apex Offset of the spherical endface to the axis of the ferrule shall be less than 50 μm .

4.4.5.2 Endface Geometry Requirements for Angled Physical Contact (APC) Connectors

R4-70 [222] The endface geometry parameters for angled physical contact connectors must meet the requirements of IEC 60874-14-6 for an angle of 9° for untuned connectors, IEC 60874-14-7 for an angle of 9° for tuned connectors.

The IEC parameter for optical intermateability of the SC/APC connectors found in IEC 60874-14-6 (9° untuned), and IEC 60874-14-7 (9° tuned) connectors give values for endface geometry parameters that are as follows:

- **Radius Of Curvature** between 5 mm and 12 mm.
- **Dome Offset** less than 50 μm
- **Maximum Fiber Undercut** (x) or **Protrusion** (y) ≤ 100 nm. For definitions, see Figure 4-6.

The “Dome Offset” is defined as the distance between the ferrule center and the vertex of the spherically polished endface relative to the angle of the reference plane. This dimension is measured in both extreme positions when the ferrule is rotated with an alignment sleeve clockwise and counter clockwise.

The relationship between Dome Offset and angle error is defined by the following formula by the following formula:

$$\text{Dome Offset} = R \sin \alpha \quad (4-1)$$

Where R is the radius of curvature and α is the angle error in degrees as illustrated in Figure 4-8.

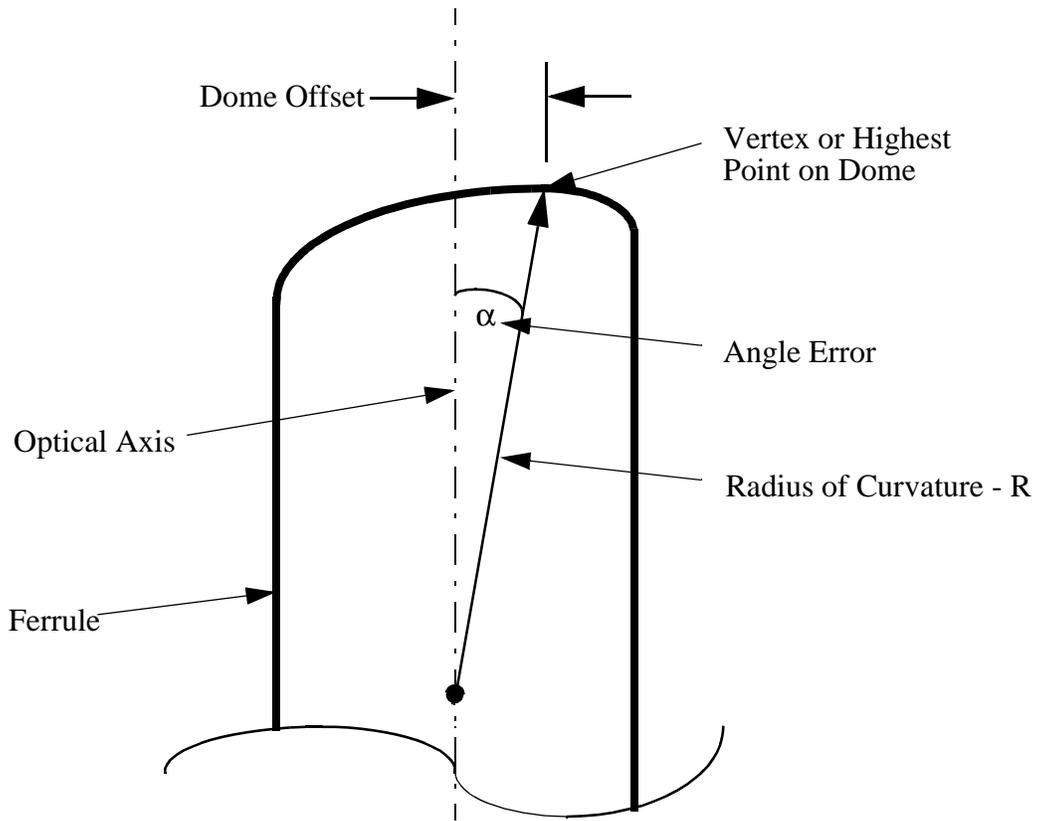


Figure 4-8. Dome Offset for APC Connectors

4.4.5.3 Endface Geometry Measurement Areas

R4-71 [223] Endface Geometry Measurement Areas

... The endface geometry measurement areas shall meet the requirements of IEC 61300-3-23 for measuring the radius of curvature and fiber undercut/protrusion.

The current version of the IEC measurement standard defines the measurement areas shown in Figure 4-9, where “D” is equal to 250 μm , “E” is equal to 140 μm , and “F” is equal to 50 μm . The annular region bounded by “D” and “E” is the fitting region

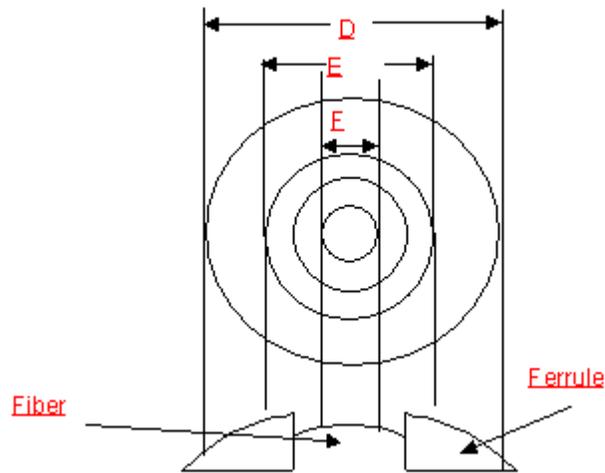


Figure 4-9. The Connector Endface Geometry Measurement Areas

on the connector ferrule over which the radius of curvature is measured. The annular region bounded “E” and “F” is the extraction region, at the interface between the fiber and the ferrule, which is excluded from any measurement. Finally, the “F” averaging region is over the center of the fiber, and used to estimate the fiber position.

RATIONALE — The measurement areas are defined in order to ensure that the endface geometry parameters measured by different parties can be readily compared, and referenced to the requirements. The values established by the IEC

were used because this is the only widely accepted published standard. However, it is desirable for the averaging region on the fiber to be smaller ($\approx 10 \mu\text{m}$), in order to increase the accuracy of the measurement, and this is the preferred size of the measurement area. There are concerns about the repeatability of measurements taken over a smaller area, due to the smaller number of data points available for averaging. However, by fitting to a $50\mu\text{m}$ area, and then averaging over a $10 \mu\text{m}$ area on the fitted surface, more accurate, yet still repeatable measurements can be achieved. It is highly recommended that standards bodies consider moving toward a more accurate measurement method.

4.4.6 Connector Installation

A connector should be capable of functioning within a cabinet or other enclosure in which the space available is limited as illustrated in Figure 4-10. This is one desirable feature which might be compromised in an attempt to achieve conformance to the 135° Transmission With Applied Tensile Load Conditional Requirement.

Test procedure:

1. Mount the adapter on a vertical mounting surface, as illustrated in Figure 4-10. If there is more than one way to mount the adapter it should be mounted so as to maximize the distance from the end of the connector to the panel.
2. Insert a connector plug. The jumper cable that exits from the plug is to be dressed so that about one meter of cable is supported by the end of the connector boot.
3. Measure loss at 1550 nm.
4. Bring a panel parallel to mounting surface at a distance from the mounting panel, as illustrated in Figure 4-10.

x =70 mm (2.75 in.)

RATIONALE — This dimension has been changed to reflect “real world conditions”.

5. Measure loss at 1550nm.

R4-72 [224]Loss Increase Requirement

... The increase in loss, the difference between the loss in Steps 3 and 5, shall be ≤ 0.20 dB. No increase in loss is permitted for products with right angle boots.

RATIONALE — A loss requirement is needed with the increase of distance x in this test from 2.25 to 2.75 inches from Issue 2 of this document. A right angle boot

should not show any difference in its loss in this test.

O4-73 [83] Loss Increase Objective

... The increase in loss, the difference between the loss in Steps 3 and 5, should be ≤ 0.10 dB.

CR4-74 [225] Right Angle Boot Requirement

... No portion of a right angle boot shall come into contact with the panel parallel to the mounting surface. See Figure 4-10.

RATIONALE — Connectors with right angle boots should be able to fit into the same limited space in cabinets and fiber shelves as connectors with straight boots.

O4-75 [226] Maximum Length Objective

... The maximum length of the installed connector including boot should not exceed 57 mm (2.25 in.), dimension y as shown in Figure 4-10. This objective does not apply to right angle boots.

RATIONALE — The maximum length of the connector needs to be controlled to avoid excessive bend radius when used in FDF shelves with in-line attenuators. An excessive bend radius could result in large losses particularly at the longer wavelengths such as 1550 nm. This change is needed to clarify the need for an objective on the maximum length of the boot.

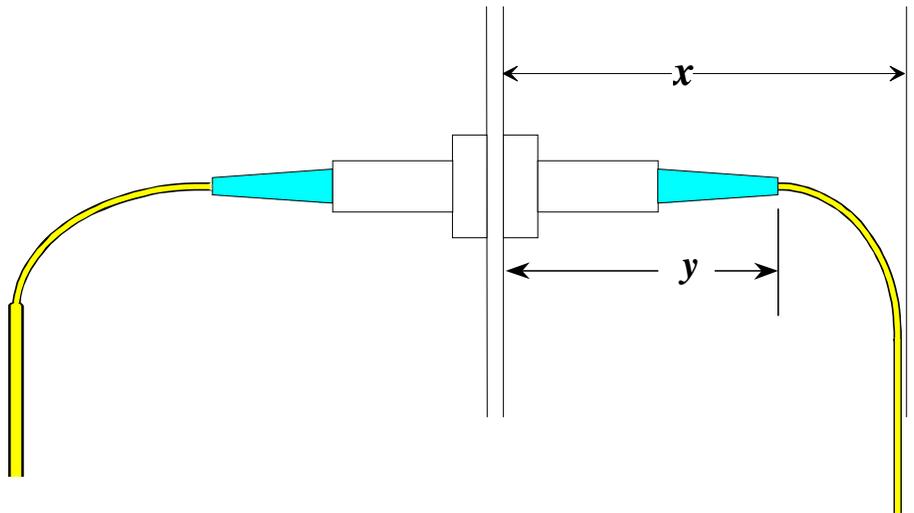


Figure 4-10. Connector Installation Test

5. Facilities for Product Testing

This section presents the following information:

- Requirements for the facilities used in testing optical fiber connectors
- Examples of facilities suitable for testing connectors
- Equations to be used in the calculation of loss and reflectance from the measured parameters.

5.1 Ambient Laboratory Conditions

Ambient laboratory conditions during tests that are conducted under the terms of this report shall be as follows.

Temperature: $23^{\circ} \pm 2^{\circ}\text{C}$ ($73^{\circ} \pm 4^{\circ}\text{F}$)

Humidity: less than 75% RH

5.2 Optical Measurements

An optical measurement facility is required to measure optical loss and reflectance while connector assemblies are subjected to the test procedures of Section 4.

The requirements for the optical measurement facility are the following:

- Capability of measuring optical loss and reflectance at both 1310 nm and 1550 nm
- Central wavelength of the sources: 1310 ± 20 nm and 1550 ± 20 nm
- Spectral width of the sources: less than 75 nm
- Accuracy in measurement of loss: ± 0.05 dB
- Accuracy in measurement of reflectance: ± 2 dB down to at least -64 dB and ± 5 dB for reflectance from -65 dB down to at least -80 dB.

Two examples of facilities for measuring optical loss and reflectance are presented. One example is a transmission measurement facility that employs an optical source and power meter; the other is an Optical Time Domain Reflectometer (OTDR) measurement system.

Both examples are multichannel systems which are capable of monitoring the performance of many test samples simultaneously. These examples illustrate the

principles in optical performance measurements. Single-channel or multiple sets may be used providing they meet the above objectives.

5.2.1 Transmission Measurement Facility

An example of a transmission measurement facility for measuring loss and reflectance using two multichannel switches is illustrated in Figure 5-1.

The major elements of this facility are the following:

- Two optical sources, 1310 nm and 1550 nm
- A two-way optical switch for selecting the wavelength at which measurements are made
- Two multichannel optical switches for selecting the test sample under test
- An optical coupler for reflectance measurements
- An optical power meter.

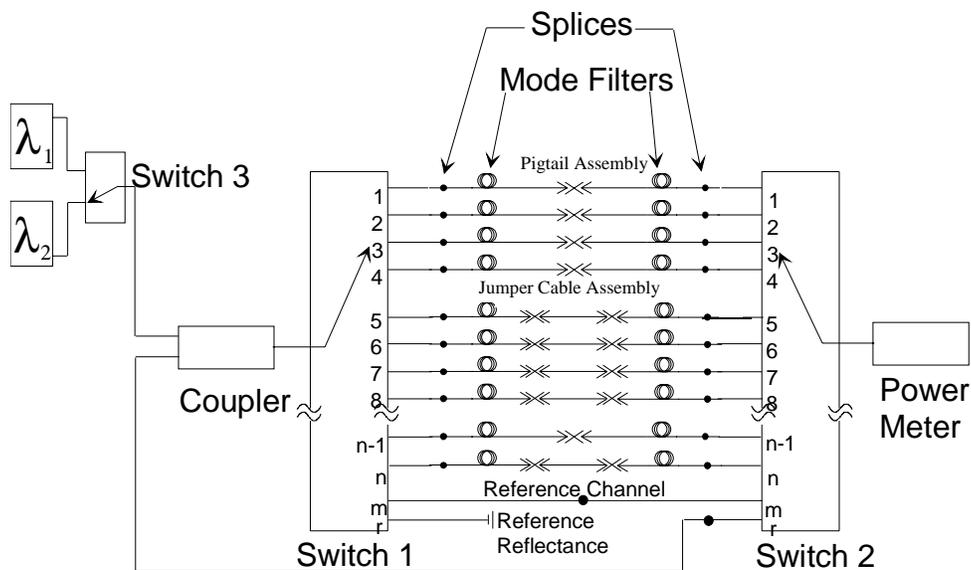


Figure 5-1. Transmission Measurement Facility

In the illustration the fiber in channel m is a reference. Measurements of the power in channel m are used to normalize the measurement of power in each channel (see equations 1 and 2). In practice, at least four reference fibers should be used for a

reference, and the value of $p_{m,t}$ in equation 2 should be the average for all the reference channels.

During the Thermal Age, Humidity, and Thermal Cycle Tests, the test samples are in the environmental chamber, and fiber leads from the test samples run to the respective switch ports. The reference fibers from switch ports m , however, should not run through the chamber.

The splices that join the test sample under test with the leads from the switches must be stable in both loss and reflectance. Fusion splices are recommended.

Mode filters are required on either side of the connectors under test as shown in Figure 5-1. For single-mode transmission, a 2-meter length of the jumper cable with two 360-degree loops will be a sufficient mode filter, provided that the cable conforms to the requirements of GR-409-CORE.

5.2.1.1 Measurement of Optical Loss with a Transmission Measurement Facility

Loss in the connector assembly at time t in channel i is based on power transmission measurements made both at time t and on cutback measurements made at the end of the test. Loss at time t is:

$$L_{i,t} = L_{i,CB} + P_{i,CB} - P_{i,t} \quad \text{dB (1)}$$

where

$$P_{i,t} = p_{i,t} - p_{m,t} \quad \text{normalized power in channel } i \text{ at time } t \quad \text{dB (2)}$$

$p_{i,t}$ power at time t with switches 1 and 2 both set to channel i . dBm

$p_{m,t}$ power at time t with switches 1 and 2 both set to the reference channel, channel m . Where more than one reference channel is used, the value of $p_{m,t}$ is the average of all of the reference channels. dBm

$L_{i,CB} = p_{i,b} - p_{i,a}$ loss in channel i as measured by a cutback measurement. dB

$p_{i,b}$ and $p_{i,a}$ are the cutback measurements of power in fiber i at points a and b (See Figure 5-2). dBm

$P_{i,CB}$ same as $P_{i,t}$ with t equal to the time dB at which the cutback measurement is made.

The uppercase letters are used to denote normalized power, and lowercase letters to denote measured values. Normalized power in channel i is the power transmitted through channel i , minus the average of the power transmitted through the reference channels. The use of normalized power allows the determination of loss to be independent of variations in source intensity.

Care must be taken to assure that no changes are made, during the time in which a set of measurements for the determination of $P_{i,t}$ are being made, that would change power levels in the system.

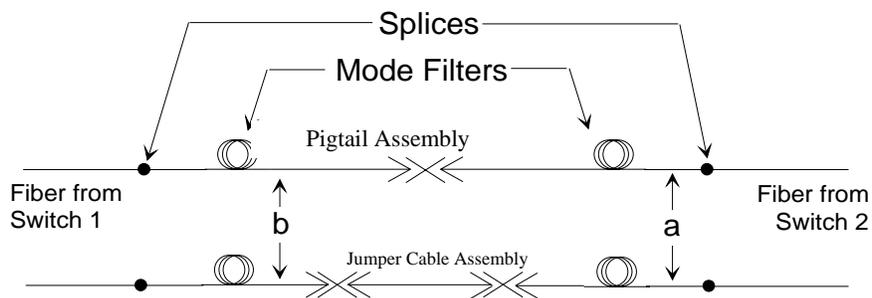


Figure 5-2. Cutback Measurement Location (Transmission)

Normalized power for the cutback measurements, $P_{i,CB}$, is measured just before the cutback measurements, $p_{i,a}$ and $p_{i,b}$. These measurements are made using a power meter with a bare fiber adapter. They are the only measurements that are not made with the power meter illustrated in Figure 5-1.

5.2.1.2 Measurement of Reflectance with a Transmission Measurement Facility

Reflectance can be determined for each of the connector assemblies under test from measurements of reflected power. Switch 1 is set to the channel for which reflectance is being measured, and switch 2 is set on channel r .

Reflectance of the connector assembly in channel i at time t is the following:

$$R_{i,t} = P_{i,t} - G_i + 10\log(1-10^{-\Delta P/10}) \quad (6) \quad \text{dB}$$

where

$$P_{i,t} = P_{i,t} - P_{m,t} \quad \text{normalized reflected power in channel } i. \quad \text{dBm}$$

$$P_{i,t} \quad \text{power measured with switch 1 on channel } i \quad \text{dBm}$$

and switch 2 on channel r .

$$P_{m,t} \quad \text{power measured with switches 1 and 2 on} \quad \text{dBm}$$

channel m .

$$\Delta P = P_{i,t} - P_{i,o} \quad \text{dB}$$

$$P_{i,o} \quad \text{normalized power measured with the fibers} \quad \text{dB}$$

from channel i of switches 1 and 2 spliced
 directly together without a connector
 between the switches

$$G_i \quad \text{a constant} \quad \text{dB}$$

When $\Delta P > 10$ the following approximation for reflectance may be used:

$$R_{i,t} \approx P_{i,t} - G_i \quad (7) \quad \text{dB}$$

NOTE In calculations for reflectance, normalized power is the power in channel i minus the power with switch 1 set to channel r .

The constant G_i is evaluated using measurements made with the fiber from channel i of switch 1 terminated with a reference reflectance. The reference reflectance is a length of fiber one end of which is terminated with a known reflectance. A fusion splice should be used to splice the reference to the fiber from switch 1.

$$G_i = P_{i,t} - S + 10\log(1-10^{-\Delta P/10}) \quad (8) \quad \text{dB}$$

where;

$$S \quad \text{is the reflectance of the reference} \quad \text{dB}$$

termination.

$$P_{i,t} \quad \text{is the normalized reflected power in channel} \quad \text{dB}$$

i terminated with reflectance S .

$$\Delta P = P_{i,t} - P_{i,o} \quad \text{dB}$$

$P_{i,o}$ is the normalized power with a mandrel wrap in the fiber between the reflectance termination and switch 1. Note the difference between this measurement, and the measurement of $P_{i,o}$ associated with equation 6. dB

The reflectance of the reference reflectance may be calibrated using the procedures in FOTP-107.

5.2.2 OTDR Measurement Facility

An example of a measurement facility for measuring loss and reflectance that employs an OTDR is illustrated in Figure 5-3.

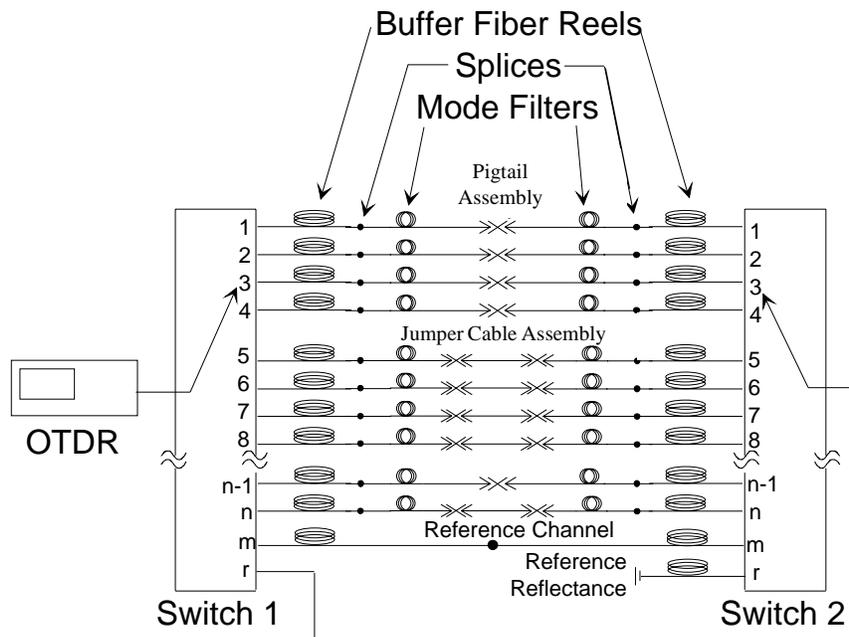


Figure 5-3. OTDR Measurement Facility

The major elements of this facility are

- An Optical Time Domain Reflectometer (OTDR)
- Two multichannel optical switches for selecting the connector assembly under test.

The connector assemblies under test are spliced to leads 1 through n from switches 1 and 2 as shown in Figure 5-3. Fusion splices are recommended for these splices, as they are stable and have very low reflectance.

Lengths of buffer fiber are located between each switch port and the connectors under test. The buffer fibers provide distance along the fiber to locate the markers required for making loss measurements with the OTDR. The buffer fibers must be somewhat longer than the distance required for these markers.

The jumper cables attached to the connectors under test are spliced to the buffer fibers. These splices must be stable and have very low reflectance. Fusion splices are recommended.

Mode filters between these splices and the connector assemblies under test ensure single-mode transmission to and from the connector under test. See Section 5.2.1.

5.2.2.1 Measurement of Optical Loss with an OTDR

Loss in the connector assembly in channel i at time t can be determined from measurements made in both directions through the connector as follows:

$$L_{i,t} = (Xf_{i,t} + Xr_{i,t})/2 + K_i \quad \text{dB}$$

Where;

$Xf_{i,t}$ is the change in power in the OTDR display dB
for the connector under test (see Figure 5-4)
with switch 1 set on channel i .

$Xr_{i,t}$ is the same as $Xf_{i,t}$, except that switch 2 is set dB
on channel i , and switch 1 is set on channel
 r .

K_i is the constant for channel i . dB

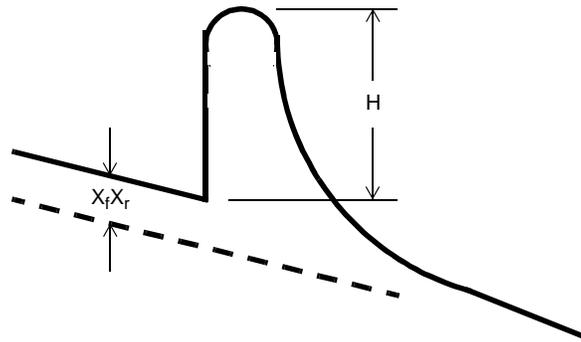


Figure 5-4. OTDR Response to a Connector

The values of X_f and X_r are values of loss as seen in both the forward and reverse directions of transmission plus loss in the splices and the mode strippers.

The constant K_i is determined with a cutback measurement made at the completion of the test sequence.

$$K_i = p_{i,b} - p_{i,a} - (X_{f_i,CB} + X_{r_i,CB})/2 \quad \text{dB}$$

where;

$p_{i,b}$ and $p_{i,a}$ are cutback measurements of power in fiber i at points b and a (See Figure 5-5) dBm

$X_{f_i,CB}$ and $X_{r_i,CB}$ are OTDR measurements made at the time of the cutback measurements dB

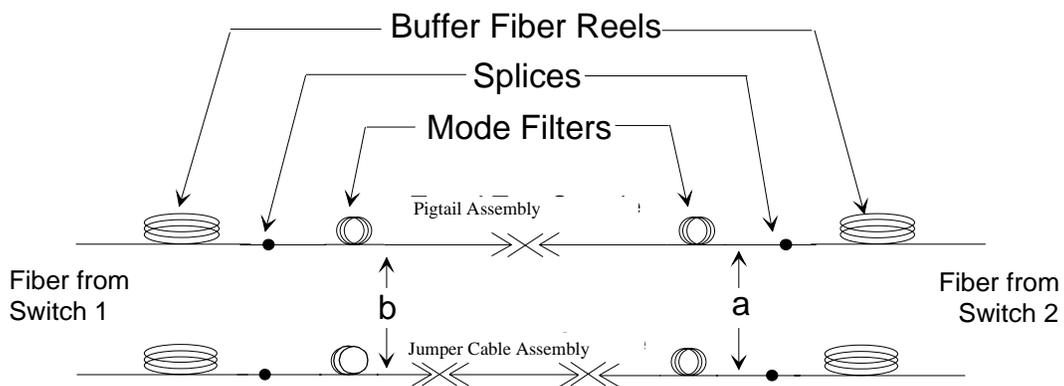


Figure 5-5. Cutback Measurement Location (OTDR)

The sequence of measurements in the determination of K_i is to make the measurements $X_{f_i,CB}$ and $X_{r_i,CB}$, replace the OTDR with a dual-wavelength

source, make cutback measurement A_i , and then cutback measurement B_i . The measurements of A_i and B_i are made using a bare fiber adapter and power meter. These are the only measurements that are not made with the OTDR.

5.2.2.2 Measurement of Reflectance with an OTDR

Reflectance can be determined for each of the connector assemblies under test from measurements of reflected power.

Reflectance of the connector assembly in channel i at time t is calculated as follows:

$$R_{i,t} = 2H_{i,t} - C_i + 10\log(1 - 10^{-2H_{i,t}/10})$$

where

$H_{i,t}$ is the height of the reflectance in the OTDR trace (Figure 5-4). dB
 C_i is a constant for channel i . dB

The constant C_i may be evaluated with the following equation:

$$C_i = B - 10\log T$$

where

B is the reflectance coefficient for the fiber, approximately 49 to 50 dB for dispersion-unshifted single-mode fibers around 1310 nm, and 51 to 52 dB around 1550 nm.
 T is the time duration of the OTDR pulse in microseconds.

When $H > 5$ dB the following approximation for reflectance may be used.

$$R_{i,t} = 2H_{i,t} - C_i$$

An alternate method for evaluating is to splice a known reflectance to the fiber from channel i of switch 1. The reference reflectance is a length of fiber, one end of which is terminated with a known reflectance. A fusion splice should be used to splice the reference to the fiber from switch 1.

$$C_i = 2H_{i,t} - S + 10\log(1 - 10^{-2H_{i,t}/10})$$

where

S is the value of the reference reflectance.

The reflectance of the reference may be calibrated using the procedures in FOTP-107.

5.3 Product Test Facilities

Some tests are conducted in an environmental chamber, and the remaining tests are conducted outside the chamber. A re-enterable splice organizer should be used for the splices on either side of the connectors under test (see Figures 5-1 and 5-3). Sufficient slack must be provided between the splice organizer and the connectors under test to allow the connector assemblies to be extended to the area in which the Product Tests are conducted without disconnecting the connector assemblies from the optical switches.

To perform the series of measurements that are required in this sequence of tests, the switches and optical power meter should be under computer control. To ensure coordination of the measurements and the temperature cycles, it is also advisable to put the operation of the chamber under computer control.

5.3.1 Environmental Tests

The environmental chamber used for the Product Tests must

- Have a range of at least -40°C to 85°C (-40° to 185°F)
- Hold temperature to an accuracy of $\pm 2^{\circ}\text{C}$ ($\pm 4^{\circ}\text{F}$)
- Maintain humidity at $95\% \pm 2\%$
- Be capable of following the temperature cycles in Figures 4-3 and 4-4.
- Have provision for access that will allow the cables from the splice organizer to pass into the chamber from the splice organizer.

The panel on which the connector assemblies are mounted for the tests in the Environmental Tests should also be used for the Vibration Test.

5.3.2 Vibration Test

The shaker unit used for this test should be capable of being brought to the area in which the test is being conducted and should have a control unit that maintains constant amplitude while sweeping between 10 and 55 Hz. Small bench top shakers are available that are suitable for this purpose.

5.3.3 Jumper Tension Test Fixture

The Mechanical Tests in Sections 4.4.3.1 through 4.4.3.4 may be conducted with a fixture as illustrated in Figure 5-6.

Jumper tension is applied with weights through a capstan. The jumper is flexed at the point of entrance to the connector plug by rotating the test arm. The position of the connector assembly along the test arm should be adjusted so that, when the arm is at 90°, the line along which the cable hangs passes through the test point. The fixture is to be designed to allow the capstan to be rotated about the axis of the section of cable under tension.

The bracket on which the adapter is mounted is to have provision for mounting the adapter in angular increments of 45° about the axis of the connector.

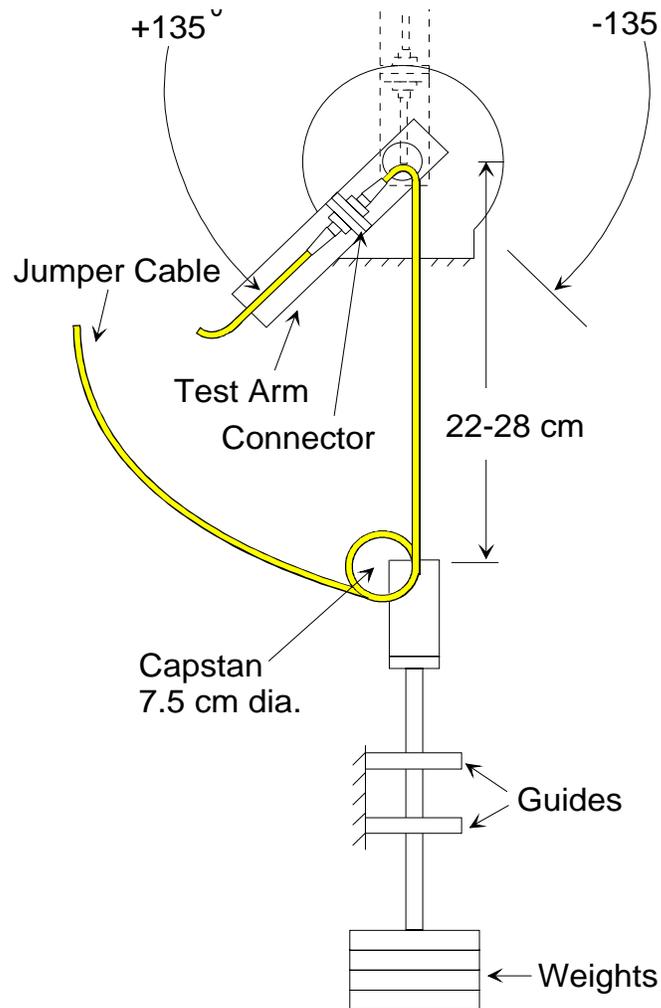


Figure 5-6. Jumper Test Facility

5.3.4 Durability Test

During the Durability Tests the adapters should be mounted on a vertical panel, and the operator should be in a standing position to simulate the stresses that are exerted on the connector in service.

5.3.5 Impact Test

The Impact Test Facility consists of a clamp for securing a single jumper cable and a concrete block as illustrated in Figure 5-7.

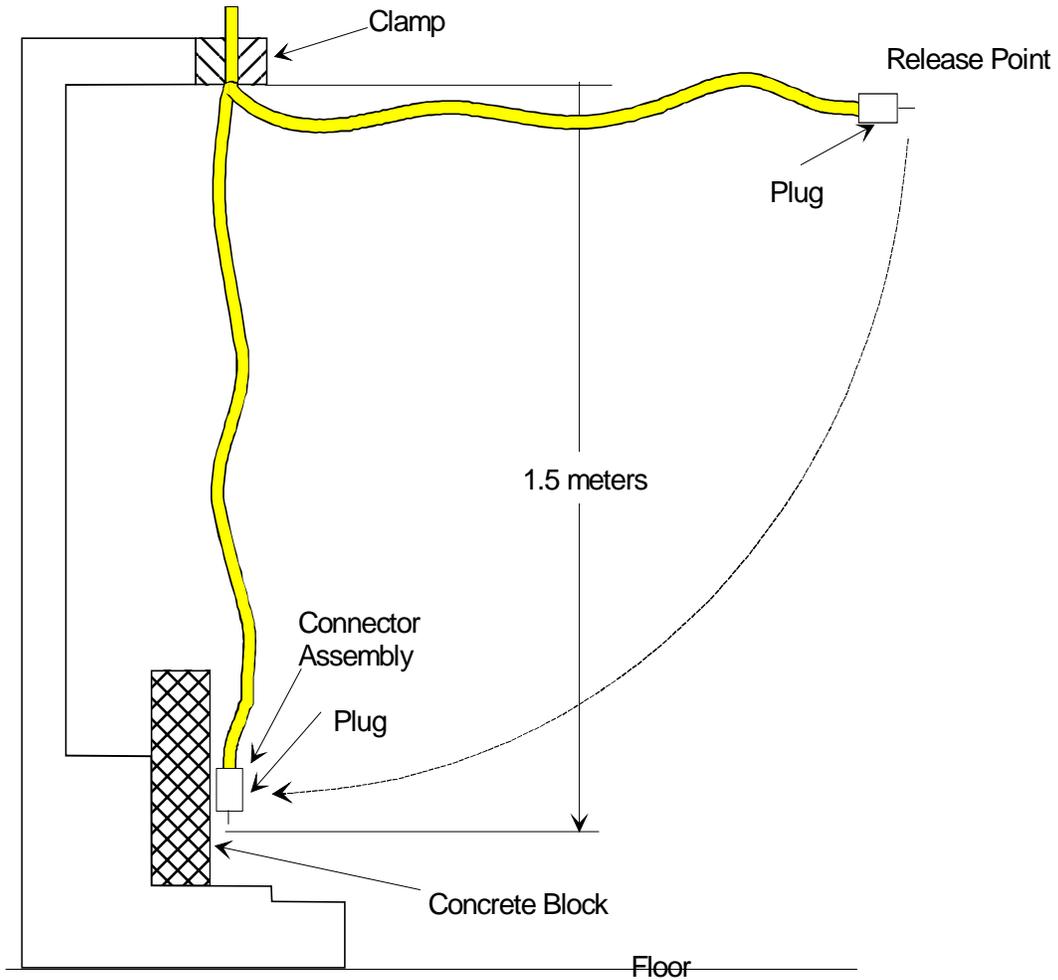


Figure 5-7. Impact Test Facility

In conducting the test, the cable is clamped so that, with the connector plug hanging under its own weight, the end of the plug is to extend to the center of the concrete block. The plug is then raised to the height of the clamp, and, with the cable extended, released so as to strike the block.

5.3.6 Adhesive Test

The basic concept for the Adhesive Test Facility is given in Figure 5-8. Figure 5-8 is not meant to be used as a detailed design plan, but rather it is designed to show the essential features that any designer must take into account when designing a test facility to perform the Adhesive Test. The guide sleeve insures that the ceramic blank and the ferrule being tested are properly aligned. Therefore the diameter of the ceramic blank must equal that of the ferrule. Additionally, the ceramic blank should be polished such that the area of the endface that contacts the ferrule should have a radius of curvature of 27 to 32 mm. The eccentricity of the dome to the axis of the ceramic blank should not exceed 50 μ m.

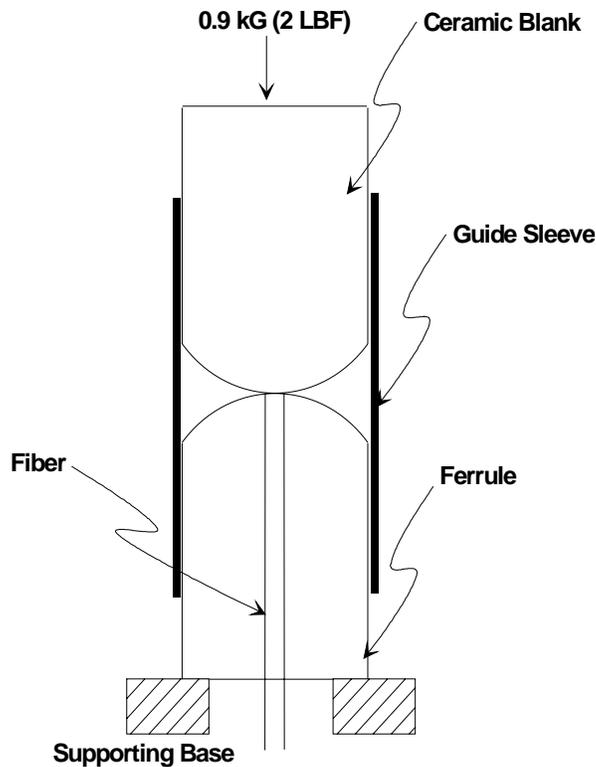


Figure 5-8. Adhesive Test Facility

5.3.7 Dust Test

With the consolidation of the tests in Issue 3 of GR-326-CORE, this test has been moved from the Service Life Tests to Section 7, "Reliability Tests". The Reliability Section requires a larger sample size than defined below for a 10% Lot Tolerance

Percent Defective (LTDP). However, either sample size may be chosen, depending on the reliability level required by the user.

A minimum of ten pigtail assembly samples (20 plugs) are required. They are separated into the following groups which are exposed to the dust chamber separately. Although it may be possible to expose all samples simultaneously in a larger chamber, the specifications given here were developed for a given chamber volume, and would need to be adjusted to give equivalent exposure. Either five pigtail assemblies from set A (Group I), five unmated pigtails from set B with adapters (Group II) or five pigtails from set B without adapters (Group III) will be exposed at one time. The open end of the adapter for Group II is capped. The five unmated plugs of Group III will be capped. These Groups are illustrated in Figure 5-9.

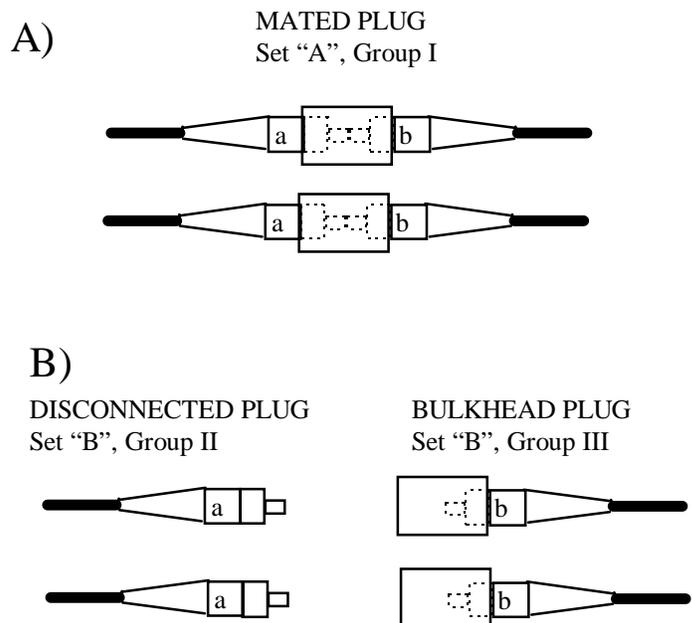


Figure 5-9. Dust Exposure Sample Groups

Samples are placed in a one cubic foot (12" by 12" by 12") desiccation box. Dust falls from the top of the box as an air source placed against one of the walls blows air into the far corners of the box to circulate the dust within the chamber. Figure 5-10 shows a schematic of the facility.

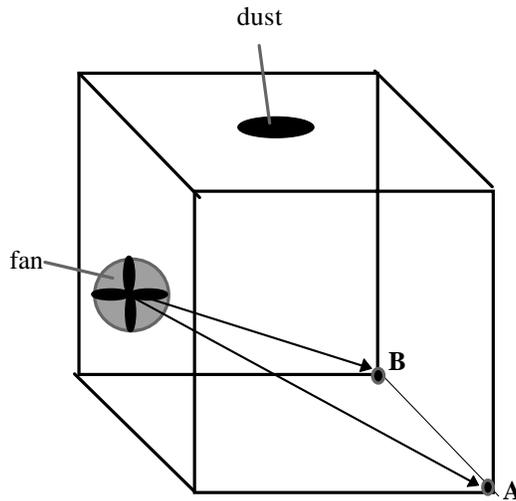


Figure 5-10. Dust Test Facility

The dust source will be “SAE Fine” or “Arizona Road Dust” [SAE J1669]. Tables 5-1 and 5-2 represent the particle size distribution and chemical composition of the dust to be used. Percentages are by weight.

Table 5-1. Particle Size Distribution

Particle Size μm	Weight Percent
0-5	39
5-10	18
10-20	16
20-40	18
40-80	9

Table 5-2. Chemical Composition

Component	Weight Percent
SiO_2	65-75
Al_2O_3	11-17
Fe_2O_3	2.5-5.0
Na_2O	2-4
CaO	2-5
MgO	1-2
TiO	0.5-1.0

This dust will be applied from the top of the desiccation box at a deposition rate of 8.5 ± 0.9 grams/min for two minutes. This will constitute one cycle of dust application. The deposition rate will be measured in still air.

An air source is centered horizontally with respect to the wall and vertically with its center approximately 3 inches above the box floor. The wind velocity of the air source should be 750 ft/min as measured outside the chamber in open space. The air source is positioned so that it blows the air into the far corners of the box, Point A and Point B in Figure 5-10. The air source alternates its direction from one corner to the next with each dust application cycle.

The samples will be exposed to 4 dust application cycles. All connectors and plugs should be positioned at least 1.5" from the side walls and floor, and 3" from the top of the box. The connectors should be spatially distributed throughout the box and may remain in the same position throughout the 4 cycles.

5.3.8 Groundwater Immersion Test

With the consolidation of the tests in Issue 3 of GR-326-CORE, this test has been moved from the Service Life Tests to Section 7, "Reliability Tests". The Reliability Section requires a larger sample size than defined below for a 10% Lot Tolerance Percent Defective (LTDP). However, either sample size may be chosen, depending on the reliability level required by the user.

A minimum of five connections per medium shall be completely immersed in the five media described below for the Groundwater Immersion Test. A separate set of five mated connector assemblies is required for each of the five immersion media, for a total of twenty-five (25) mated connector assemblies. An exposure of 7 days at a temperature of 22°C (72°F) $\pm 2^{\circ}\text{C}$ (4°F) is required. As a minimum, the loss and reflectance shall be measured immediately upon immersion, then re-measured after 24 hours and at the end of the 7-day test period while the connections are still immersed.

1) Organism Exposure

Connections shall be immersed in a medium containing a mixture of the following organisms prepared from cultures containing an average of 1×10^8 organisms per milliliter as listed in [Table 5-3](#).

Table 5-3. Organism Exposure for Completed Splices

Organism	ATCC No.
Streptococcus salivarius	13419
Candida albicans	60193
Escherichia coli	11775
Penicillium aurantiogiseum	16025

2) Detergent in Water

A suitable immersion medium shall consist of 1% by weight of Linear Alkyl Benzene Sulfonate (LAS) in tap water.

3) Chlorine in Water

The disinfection of manholes due to sewage infiltration involves the use of common laundry bleach added to the contaminated water. For purposes of exposure, a solution of 10 ml. fresh laundry bleach (sodium hypochlorite 5%) in a liter of distilled water should be used. This solution shall be replenished every four (4) days.

4) Fuels

A reproducible fuel for purposes of exposure shall be made from 60 parts by volume n-heptane, 20 parts by volume toluene and 20 parts by volume absolute ethanol.

5) Aqueous Ammonia

Due to the rural practice of direct soil injection of ammonia as a means of crop fertilization, an exposure to 10% aqueous ammonia is included. This concentration is intended to reflect the high solubility of ammonia in water.

6. Service Life Tests

6.1 Service Life Tests

The Service Life Tests are a set of tests that check the design of the connector assembly and simulate the stresses that connector assemblies may be subjected to while in service. The optical performance of the product is monitored throughout the tests. The test conditions have been selected to reveal weaknesses that are likely to have an adverse effect on performance.

A set of fifteen (15) pigtail assembly and five (5) jumper cable assembly test samples is subjected to the sequence of tests and measurement procedures in Table 6-1. The tests are to be conducted in the order presented in Table 6-1. Note that step #3, Thermal Age Test, is optional and is not required if the Adhesive Test is performed.

If a connector assembly becomes nonconforming in the course of a test, then the criteria for that test are *a priori* not met. However, rather than consider this specimen nonconforming for all subsequent tests, it is permissible to substitute for failed product to replenish the population to its original size, with the condition that substitute product has also been subjected to the conditions of the previous tests. It is therefore desirable to maintain a supply of unmonitored “hot spares” in the environmental chamber. Any product substitutions shall be noted clearly within any report issued under the guidelines of this document. “Hot spares” do not need to be monitored until they are substituted for failed product. No more than ten (10) initial test samples may be replaced by “hot spares”. This criteria does not apply to samples that are pre-screened to New Product criteria, see Section 4.4.1. For more information, see Section 4.2.2.5, “Handling of Nonconformance”.

Table 6-1. Service Life Tests

Test	Title	Section
1	Ferrule Endface Geometry	4.4.5
2	New Product Measurements	4.4.1
3	Thermal Age Test (Optional)	4.4.2.1
4	Thermal Cycle	4.4.2.2
5	Humidity Age	4.4.2.3
6	Humidity / Condensation Cycling Test	4.4.2.4
7	Dry-out Step (no criteria applied)	4.4.2.5
8	Post-Condensation Thermal Cycle	4.4.2.6
9	Vibration Test Test	4.4.3.1

Table 6-1. Service Life Tests (Continued)

Test	Title	Section
10	Flex Test Test	4.4.3.2
11	Twist Test Test	4.4.3.3
12	Proof Test Test	4.4.3.4
13	Transmission With Applied Tensile Load	4.4.3.5
14	Impact Test	4.4.3.7
15	Durability	4.4.3.8
16	Connector Installation Test	4.4.6
17	End of Test Criteria (Optical, Ferrule Geometry, Damage)	4.4.3.9, 4.4.5

6.2 New Product Measurements

The performance of the connector assemblies are measured before the Service Life Tests are conducted using the following procedures:

- a. Mount the adapters in the panel that will be used for the Temperature/Humidity/Condensation Cycling Tests.
- b. Clean the plugs and adapters using Cleaning Procedure A, and assemble the connector assemblies.
- c. Measure loss and reflectance of each assembly. These measurements are reportable, but criteria are not applied to them.
- d. Clean the connector assemblies using Procedure B.
- e. Measure loss and reflectance. The criteria for new product (see Section 4.4.1) are applied to the results of this measurement.

6.3 Tensile Tests

Each connector adapter is mounted in the Cable Test Facility at the start of the Flex Test and remains in the facility until the end of the Transmission with Applied Tensile Load Test. The test facility described in Section 5.3.3 has provision for mounting the adapter in angular increments of 45° about the axis of the adapter. The sample of product in a Service Life Test is to be distributed as evenly as possible between the eight angular positions.

The design of the connector may suggest that differences in the mounting will effect the ability of the connector to withstand side loads. Where this is the case, each

mounting condition should also be represented in the test. For example some designs have provision for mounting the connector with screws or with spring clips. For these designs approximately half of the adapters should be mounted with screws and the other half should be mounted with the clips.

7. Reliability Tests

7.1 Description of Reliability Tests

The Reliability Tests identify possible weaknesses in connector design or materials, and provide tangible assurance that the connector is capable of functioning reliably over a number of years in a wide variety of service environments.

During the Reliability Tests the test samples are subjected to the tests listed in Table 7-1. Test conditions are obtained by referring to GR-1221-CORE, *Generic Reliability Assurance Requirements for Passive Optical Components*.

Table 7-1. Reliability Tests

Test	Title	Section	Test Sample (Type)
1	Extended Thermal Age	GR-1221-CORE Section 6.2.4	Jumper Cable Assembly
2	Extended Humidity	GR-1221-CORE Section 6.2.5	Jumper Cable Assembly
3	Extended Thermal Cycle	GR-1221-CORE Section 6.2.7	Jumper Cable Assembly
4	Salt Spray	4.4.4.4	Pigtail Assembly
5	Airborne Contaminants	4.4.4.3	Pigtail Assembly
6	Dust	4.4.4.1	Pigtail Assembly
7	Ground Water Immersion	4.4.4.6	Pigtail Assembly
8	Immersion/Corrosion Test	4.4.4.5	Pigtail Assembly & Plugs

7.2 Reliability Test Samples

7.2.1 Type of Sample

The types of samples are listed in Table 7-1. See Section 4.1 for test sample definitions.

- Pigtail Assembly Sample, consists of two connector plugs mated with an adapter with unterminated leads as shown in Figure 4-1. Each of the unterminated leads should be 3 ± 0.5 meters long so that the splices may be located outside of the environmental test chamber.
- Jumper Cable Assembly Sample, consists of a jumper cable terminated with plugs on each end connected with adapters to two additional connector plugs with unterminated leads on either end as shown in Figure 4-2. The jumper cable shall be 3 ± 0.5 meters. Each of the unterminated leads should also be 3 ± 0.5 meters long so that the splices may be located outside of the environmental test chamber.

A new set of samples may be used for each of the tests in Table 7-1, or, at the user's option, samples may be used in more than one test. Samples that are reused must meet the respective criteria as though they were new samples.

7.2.2 Sample Size

The sample size is determined by the user from the Lot Tolerance Percent Defective (LTPD), (see Table 7-2) on the basis of a 10% LTPD. Tests 4 through 8 listed in Table 7-1, at the option of the user, may be tested to the lower sample sizes listed in the referenced sections. The use of a smaller sample size will result in a higher percent LTPD level as shown in Table 7-2. See Note, below.

The minimum sample size for a 10% LTPD level is 22. If, in a test of 22 samples, 1 defective was found, a second sample of 16 could be drawn from the original population and re-tested. If there were no defectives in the second sample, the product could be considered to have had 38 samples with one defective, and would pass at the 10% LTPD.

NOTE Historically, Service Life Tests have required the testing of 15 samples. If one sample was found to be nonconforming in any of the tests the product was to be considered nonconforming to the requirements of this document with no recourse other than a complete re-test. The tests listed as Test 4 through 8 in Table 7-1, have historically had a smaller sample size as defined in Section 4. However, with the consolidation of these tests into the

Reliability Section, they now only appear in the Reliability Section. If a user requires the higher reliability needed in this section, then the sample size would need to be increased to that required for a 10% LTPD Level as shown in Table 7-2. A 20% LTPD level historically has been required for most optical components.

Table 7-2. Lot Tolerance Percent Defective Table

LTPD	50	30	20	15	10	7	5	3	2	1.5
Allowable Number Defective	Minimum Sample Sizes									
0	5	8	11	15	22	32	45	76	116	153
1	8	13	18	25	38	55	77	129	195	258
2	11	18	25	34	52	75	105	176	266	354
3	13	22	32	43	65	94	132	221	333	444
4	16	27	38	52	78	113	158	265	398	531
5	19	31	45	60	91	131	184	308	462	617
6	21	35	51	68	104	149	209	349	528	700
7	24	39	57	77	116	166	234	390	589	783
8	26	43	63	85	126	184	258	431	648	864
9	28	47	69	93	140	201	282	471	709	945
10	31	51	75	100	152	218	306	511	770	1025

7.3 Criteria to be Applied to Reliability Tests

For a sample to meet the requirement or objective, (R) or (O), for a particular test, the sample must meet all the respective requirements or objectives at the 10% LTPD level.

Additionally, all samples are to be evaluated versus the criteria for damage in Section 4.2.3.

8. Reliability Assurance Program

The Reliability Assurance Program for fiber optic connectors is presented in two sections:

- Reliability Testing, Section 8.1
- Product Reliability Program, Section 8.2.

While the tests and observations for either section may be conducted independently, a complete Reliability Assurance Program consists of both Reliability Testing and a Product Reliability Program.

8.1 Reliability Testing

The Reliability Tests in Section 7 are to be conducted every two years as part of the Reliability Assurance Program. Interim tests are to be conducted whenever a design change is incorporated that would effect performance during the tests.

8.2 Manufacturing and Process Control

The Manufacturing and Process Control Program, presented in this section, has four elements:

- Materials and Components, Section 8.2.1
- Physical Design, Section 8.2.2
- Manufacturing and Assembly, Section 8.2.3
- Manufacturer Testing, Section 8.2.4.

8.2.1 Materials and Components

The selection of appropriate raw materials is critical to producing a product with long term reliability. This section describes some of the more critical requirements, as they relate to the manufacture of fiber optic connectors. A complete list of component and material requirements can be found in TR-NWT-000357, *Generic Requirements for Assuring the Reliability of Components Used in Telecommunication Systems*.

8.2.1.1 Quality Levels

The "quality level" is a measure of the scope and depth of a supplier's material and component reliability assurance program. There are three quality levels: Levels I, II, and III. These levels are defined in Table 8-1. Equipment produced under Quality Level III controls can be expected to have a higher level of reliability than material produced under Level I or II controls.

Because of the critical importance of fiber optic connectors to the telecommunications plant, Quality Level III is considered to be appropriate for fiber optic connectors. The reliability assurance program in this document is therefore based on Quality Level III. As the fiber optic connector technology matures, however, the requirements of Quality Level II may become appropriate for fiber optic connectors used in the telecommunications plant.

The criteria in the Reliability Assurance Program have been selected on the basis of Quality Level III.

8.2.1.2 Materials and Components Requirements

- R8-1** [85] The requirements of TR-NWT-000357, *Generic Requirements for Assuring the Reliability of Components Used in Telecommunication Systems*, as applicable to connectors, shall apply.

8.2.1.2.1 Vendor Qualification

- R8-2** [86] The connector supplier shall have the following records and procedures for the purchase of materials or components used in fiber optic connectors:
- ... 1. Documented procedures for the qualification of vendors.
 - ... 2. Requirements for vendor qualification.
 - ... 3. A vendor rating system that allows vendors performance to be analyzed.
 - ... 4. A rating system that indicates which vendors are exhibiting substandard performance.
 - ... 5. An approved vendor list that is updated periodically.
 - ... 6. Procedures for auditing of vendor performance.
 - ... 7. Records of vendors over at least the last 5 years.

O8-3 [87] The connector supplier should have a raw material inspection program that relies on vendor quality assurance, rather than incoming inspection. This program need not be in place if the connector manufacturer is developing such a program.

Table 8-1. Definition of Quality Levels

Quality Level	Description
I	This level is assigned to commercial-grade devices that are produced under the following controls: <ul style="list-style-type: none"> a. Steps are taken to ensure that the devices are compatible with the design application and manufacturing process. b. An effective feedback and corrective action program is in place that quickly identifies and resolves problems in manufacture and in the field.
II	Level II includes the controls of Level I plus the following controls: <ul style="list-style-type: none"> c. purchase specifications that explicitly identify important characteristics (optical, electrical and mechanical) and acceptable quality levels (AQLs) for lot controls. d. devices and vendors must be qualified and identified on approved parts/ vendor lists (device qualification includes appropriate life and endurance tests). e. lot-to-lot controls at adequate AQLs to assure consistent quality.
III	Level III includes the controls of Level II plus the following controls: <ul style="list-style-type: none"> f. periodic re-qualification of device families. g. lot-to-lot controls that include 100% screening (e.g., burn-in) which, <i>if the results warrant it</i>, may be reduced to a "reliability audit" (e.g., burn-in on a sample basis). h. where screening is used, the percent defective allowable (PDA) is to be based on the Lot Tolerance Percent Defective* (LTPD), see Table 7-2

* In this document, the percent defective allowable is based on the LTPD (see Table 7-2) due to the relatively small size of the production lots typically encountered in the production of connectors.

8.2.1.2.2 Part Qualification

R8-4 [88] Procedures for the qualification of parts shall be documented.

- O8-5** [89] Qualification of raw materials should be a program wherein product is manufactured and subsequently tested.

8.2.1.2.3 *Qualification of Epoxies*

Many of the connector designs in use utilize an epoxy to secure the fiber in the ferrule. The epoxy that is used is critical to the performance of the connector. Factors that are critical to the performance of the epoxy are

- the selection of the epoxy
- age of the epoxy at the time it is used and it's shelf life
- mixing the ingredients
- pot life
- curing cycle, time and temperature.

The following criteria shall apply to the purchase and use of epoxies used to secure the fiber in the ferrule:

- R8-6** [90] There shall be a detailed specification for the purchase of epoxy that is to be applied to the connector ferrule.
- R8-7** [91] Incoming product shall be inspected to the detail specification.
- R8-8** [92] Storage conditions and storage time shall be documented.
- R8-9** [93] Assembly operators shall be trained.
- R8-10** [94] There shall be documentation and operator instructions for mixing, application, curing, and pot life. These instructions shall be posted at each work station.
- R8-11** [95] A connectorized pigtail or patchcord shall be drawn from each lot or batch of epoxy that is used in connector assembly, and submitted for the following test: Adhesive Testing in Section 4.4.4.2.

8.2.1.2.4 *Raw Material Specifications*

- R8-12** [96] All parameters specified in the Material Specifications shall be inspected.

- R8-13** [97] Receiving Inspection Instructions shall reference the appropriate Material Specification.

8.2.1.2.5 *Determination of Acceptability of Raw Materials*

- R8-14** [98] The acceptability of all procured materials and components that are part of the product or used in the manufacture and assembly of the product is to be determined by one or more of the following methods:
- Vendor quality and reliability evidence
 - Inspection at the source
 - Inspection at receipt.

RATIONALE — A product-level test or inspection is ineffective or insufficient for determining whether the constituent parts or materials meet the stated requirements. In addition, defective parts and materials identified at or before the incoming stage will enter the manufacturing process and usually result in reduced manufacturing yields. It is believed that manufacturing yields and reliability are correlated and that lower manufacturing yields lead to lower reliability.

- R8-15** [99] Evidence of quality and reliability, such as certified data, shall include or be accompanied by actual test and inspection data of the received goods.
- R8-16** [100] Inspection instructions shall exist for all materials and components. Inspection instructions shall include
- ... • the procedures for inspection and test
 - ... • the sampling plan to be used
 - ... • the properties, characteristics, dimensions, or parameters to be examined or measured.
- R8-17** [101] Results of incoming inspection shall be recorded and retained for a minimum of 2 years.
- R8-18** [102] Results of incoming inspection or inspection at receipt shall be input into the vendor rating system.

- R8-19** [103] If any procured material is received with a "dock-to-stock" procedure, this action shall be justified by sufficient vendor history and adequate vendor performance.
- R8-20** [104] Procedures for detailed assessment of a first lot delivered from a vendor shall be documented.
- R8-21** [105] Certified data that is obtained in place of incoming inspection shall be periodically verified, by inspection at receipt, third-party testing, or witnessing testing at the vendor's location.
- R8-22** [106] Certified data that is obtained in place of incoming inspection shall be reviewed for conformance to requirements.
- R8-23** [107] Decisions to "use as is" any rejected raw materials shall have the concurrence of the reliability or quality organization.
- O8-24** [108] Sampling inspection plans used at incoming inspection should have switching rules in place that allow for reduced or tightened inspection of product.

8.2.1.2.6 *Reliability Controls*

- R8-25** [109] The program for assuring reliability controls shall be documented.
- O8-26** [110] The supplier should perform reliability tests on critical raw materials on a periodic basis. Raw materials from all approved vendors should be included in the program.

8.2.1.2.7 *Feedback and Corrective Action*

- R8-27** [111] The supplier shall have a program in place for informing raw material vendors of reliability and quality problems.
- R8-28** [112] A corrective action program shall be in place for those problems that are costly or repetitive.

8.2.2 Physical Design

Physical design relates to the specifications of, and procedures relating to, the materials, finishes, assembly, and workmanship used for product manufacture that can potentially affect long term reliability. This section lists some of the specific physical design criteria relating to fiber optic connectors. A complete list of physical design requirements can be found in GR-78-CORE, *Generic Requirements for the Physical Design and Manufacture of Telecommunications Products and Equipment (a module of RQGR, FR-796 and NEBS, FR-2063)*.

- R8-29** [113] The requirements of GR-78-CORE, as applicable to connectors, shall apply.
- R8-30** [114] At the request of an end user or its representative, the supplier shall identify all original equipment manufactured (OEM) products in or associated with its product.
- R8-31** [115] Deviations from requirements for OEM equipment shall be identified and documented.
- R8-32** [116] On request of an end user or its representative, the supplier shall provide a complete list of known and suspected deviations from requirements of OEM equipment.
- R8-33** [117] The supplier shall assess all OEM equipment against Telcordia component reliability assurance, physical design, and product reliability criteria.
- R8-34** [118] The supplier shall have in place physical design practices that are appropriate for the quality and reliability needed in telecommunications products.
- O8-35** [119] The supplier should assure that all physical design and workmanship requirements are met before volume production begins.

8.2.2.1 Contact of Dissimilar Metals

Dissimilar metals shall not be used in contact with each other unless the metal parts are suitably finished to prevent electrolytic corrosion.

- R8-36** [120] The composition and thickness of coatings and finishes on metal parts used to prevent electrolytic corrosion shall be specified.

- R8-37** [121] The supplier shall be able to show evidence of testing that shows that the coating or finish used to prevent electrolytic corrosion due to contact dissimilar metals is capable of preventing electrolytic corrosion during the service life of the product.

8.2.2.2 Flammability

- R8-38** [122] The supplier shall be able to provide a listing of the available fuel load of polymeric materials used in the connector product. The listing shall include the name of the part, the type of polymer, its mass, and the known flammability properties of the polymer.
- R8-39** [123] The supplier shall be able to provide evidence that all polymeric materials that are used have a rating of V-1 or better as determined by Underwriter Laboratory (UL) Standard 94 and an oxygen index of 28 percent or greater, as determined by ASTM D-2863-87.

8.2.3 Manufacturing and Assembly

The manufacturing and assembly practices used in the fabrication of fiber optic connectors can affect both quality and reliability. To have a product that has acceptable long term reliability, a supplier is expected to have certain practices in place to assure the consistent manufacture of the product. This section lists the reliability requirements for manufacture and assembly. For fiber optic connectors, eight areas are covered:

- Training
- Product Documentation
- Product Inspection
- Product Assembly
- Product Traceability
- Customer Complaints
- Statistical Process Control and Quality Data.

8.2.3.1 Training

- R8-40** [124] The supplier shall have an operator training program in place for assembly, test, and inspection personnel.
- O8-41** [125] The supplier should have a formal certification program in place.
- CR8-42** [126] If a certification program is in place, the supplier shall periodically recertify operators.
- R8-43** [127] All personnel involved in the manufacture of a new product shall be trained.
- O8-44** [128] The supplier should encourage management to participate in reliability and quality training.

8.2.3.2 Product Documentation

Documentation is important to manufacture a product with adequate reliability. The amount of documentation required is dependent on the type of product, and, to a larger degree, the number of personnel that will have access to the documentation. Controls need to be in place to formally update the documents as they are revised.

- R8-45** [129] The manufacturer shall document all of its manufacturing and assembly steps.
- R8-46** [130] The manufacturer shall have a flow chart that illustrates the manufacturing and assembly process and includes all test and inspection points.
- R8-47** [131] The supplier's reliability and quality organizations shall review and approve the in-process inspection and test plan.
- R8-48** [132] The manufacturer shall adhere to its own manufacturing and assembly documentation.
- R8-49** [133] Acceptance criteria shall be listed on data sheets that are used for test and inspection purposes.

R8-50 [134] All numerical values in the documentation that refer to nominal values for equipment settings or measurements shall include tolerances.

... Example: An instruction that states to adjust a variable attenuator so that -20 dBm of optical power is sensed at the detector shall also state the tolerance, e.g., -20 dBm \pm 0.10 dBm.

RATIONALE — A number is only as good as its tolerance.

R8-51 [135] All formal documents shall be under a revision control program, including forms and check sheets used in the collection of in-process and final test and inspection data.

R8-52 [136] Required approvals and distribution lists for all formal documents shall be specified.

R8-53 [137] The manufacturer shall have a formal program to ensure that outdated and obsolete manufacturing documentation is properly removed from use in the manufacturing, assembly, and test areas and that revised documentation replaces the old.

R8-54 [138] The supplier's documentation shall not contain hand-written changes, unless such changes are authorized (initialed and dated) by management. Any such changes shall be made to all working copies of the document.

R8-55 [139] The supplier shall document and establish a formal, statistically valid sampling plan for all in-process tests and inspections that the supplier does not perform on a 100% basis.

8.2.3.3 Product Inspection

R8-56 [140] The supplier shall prepare manufacturing test and inspection flow charts to document the appropriate sequence and location of these activities.

R8-57 [141] Product or associated paperwork shall show an indication of test and inspection activity at all points.

8.2.3.3.1 *Segregation of Nonconforming Material*

- R8-58** [142] Nonconforming materials shall be clearly labeled as such.
- R8-59** [143] Nonconforming material shall be segregated from both rejected material and product that is to be inspected or tested.
- R8-60** [144] Separate areas shall be set aside to store nonconforming materials.

8.2.3.3.2 *Storage and Handling of the Product*

- R8-61** [145] For identical raw materials, there shall be a program in place to use older stock before new stock.
- R8-62** [146] There shall be a documented program in place for the use of any raw materials that have a shelf life, such as (but not limited to) epoxies, paints, etc.

8.2.3.4 *Product Assembly*

Fracture of the stripped fiber within a connector plug is a well documented failure mechanism for connectors. To prevent this, the damage to the fiber caused by the stripping of the fiber's polymer coating must be minimized.

- R8-63** [147] The tool used for stripping fiber shall be replaced on a periodic basis according to the number of fibers stripped using the tool.
- R8-64** [148] The manufacturer shall maintain a count of the number of times a particular stripping tool is used, or shall replace the tool based on average production volumes.
- O8-65** [149] The stripped fiber ends should be proof tested to 100 kpsi before mounting the connector plugs. The rate at which the proof test load is removed must be sufficiently high to guarantee a minimum strength nearly equal to the proof test stress.
- O8-66** [150] A count of the fraction of proof test failures should be kept. Increases in the fraction of proof test failures should be used to determine how often the stripping tool is replaced.

8.2.3.5 Product Traceability

- R8-67** [151] For traceability purposes, customer information shall be retained for at least five years.
- R8-68** [152] For traceability purposes, date of manufacture shall be placed on the product (or its container, if impractical to place on the product).
- R8-69** [153] The supplier shall be able to trace key raw materials used in the manufacture of the product after the product has shipped.
- O8-70** [154] The supplier should be able to trace *all* raw materials used in the manufacture of the product after the product has shipped.

8.2.3.6 Customer Complaints

- R8-71** [155] The supplier shall have a customer complaint program in place, and the program shall be formally documented.
- R8-72** [156] The supplier shall have an organization that is assigned the responsibility for customer support.
- R8-73** [157] The supplier shall have a documented system in place for the return of defective a product that is in warranty.
- R8-74** [158] The supplier should have a documented system in place for the return of a defective product that is not in warranty.
- R8-75** [159] The supplier shall have a failure analysis program in place to determine the cause of product failures returned from the field.
- R8-76** [160] The supplier shall have procedures in place to feed the failure analysis results back to the cognizant department.
- R8-77** [161] A supplier shall have a documented corrective action program in place for the resolution of serious or repetitive customer complaints.
- O8-78** [162] The supplier should have a program in place for customer training, in the areas of engineering, ordering, installation, operation, and testing.

- R8-79** [163] Analysis of field failure data shall be used for identifying the dominant causes of in-service failures. This information shall be summarized periodically and reviewed by design, quality, and manufacturing organizations.
- O8-80** [164] Analysis of field failure data should be used for obtaining estimates of the field failure rate of the connector.

8.2.3.7 Field Trials

- O8-81** [165] The supplier should have conducted, or should be in the process of conducting, a field trial of the product.
- R8-82** [166] The program, *if in place*, shall be documented.

8.2.3.8 Statistical Process Control and Quality Data

- R8-83** [167] The supplier shall have a statistical process control (SPC) program in place to monitor critical steps in the manufacturing process.
- O8-84** [168] The supplier should document the rationale for the selection of these SPC areas.

8.2.4 Manufacturer Testing

The fiber optic connector manufacturer is expected to perform testing of the product before it ships. In addition, testing at intermediate points in the manufacturing process is recommended, where applicable, so that defects introduced early in the manufacturing process are found. Otherwise, these extra manufacturing costs associated with further assembly of defective products will be passed on to the end user.

This section lists reliability requirements for testing. For fiber optic connectors, five areas are covered:

- Test documentation - documentation requirements for a supplier's testing program
- In-process testing - testing requirements applicable to the product during its manufacture
- Finished goods testing - requirements applicable to the completed product

- Calibration - equipment calibration of test equipment
- Product qualification testing - requirements for testing of the product above and beyond acceptance testing, including both initially and periodically, to assure that the product meets its design intent.

8.2.4.1 Test Documentation

- R8-85** [169] Finished goods test and inspection procedures for the product shall be documented in a formal system. These procedures may be included with or as part of other documentation such as manufacturing and assembly documentation.
- R8-86** [170] Documented test procedures shall include performance specifications that are verifiable such that acceptance or rejection can be determined.
- R8-87** [171] Criteria for accepting and rejecting product shall be clearly specified.
- R8-88** [172] Finished goods test and inspection procedures shall include visual inspection for workmanship and appearance.
- R8-89** [173] Finished goods tests shall be conducted according to the manufacturer's test procedures.
- R8-90** [174] Documented test performance specifications for the product shall not be in conflict with any specifications for the identical product published in current advertising literature or internal engineering documents.

8.2.4.2 In-Process Testing

In-process tests include those that a supplier performs on a product up to, but not including, finished goods (or completed item) testing. For fiber optic connectors, it could include tests on components of the connector after it has been partially assembled.

In-process tests need to be performed on the product if subsequent manufacturing steps will likely change the parameter being tested.

- R8-91** [175] The supplier shall evaluate which in-process tests, if any, are necessary to assure final product quality and reliability.

8.2.4.3 Finished Goods Testing

Finished goods testing will assure that the product manufactured will meet customer requirements. Finished goods testing augments in-process testing. It is not cost effective to rely on finished goods testing to find defects that ordinarily would be detected during in-process testing, as product rework will drive up the cost of the product.

- R8-92** [176] Product shall be functionally tested at final test.
- R8-93** [177] Final acceptance testing of product shall simulate field use.
- R8-94** [178] Reference adapters and plugs used in testing shall simulate those in field use.
- O8-95** [179] The analysis of final tests and inspections should be documented in weekly and monthly summaries that are distributed to the affected areas and to upper management.
- R8-96** [180] Distributed summaries of analyses shall be retained (for reference in any possible manufacturing or field reliability problems) for a minimum of two years.
- R8-97** [181] The supplier shall document and establish a formal, statistically valid sampling plan for all final tests and inspections that the supplier does not perform on a 100% basis.
- R8-98** [182] Repaired product shall be tested to the same extent as new product.

8.2.4.3.1 Test Data

- R8-99** [183] Data from finished goods tests shall be analyzed and fed back into the process.
- R8-100** [184] Results of finished goods tests shall be retained for a minimum of two years.
- R8-101** [185] Control charts, trend charts, or other methods shall be used to provide feedback into the system at intervals of no greater than one week.

- O8-102** [186] A statistical process control (SPC) should be established to control the process.
- R8-103** [187] Accept/reject criteria shall be established for both loss and reflectance.
- R8-104** [188] Criteria shall not be in conflict with advertised specifications.

8.2.4.3.2 *Connector Adapters*

- R8-105** [189] Connector adapters shall be visually inspected for workmanship and appearance.
- R8-106** [190] Connector plugs and adapters shall be functionally tested to determine acceptable performance. This may be done on a sample basis by using a sample of adapters with other tests.

8.2.4.3.3 *Replacement of Testing Parts*

Testing Parts refer to those items that are used to test the product. Examples include test cables, test connectors, etc. These test plugs are often referred to as "golden plugs."

- O8-107** [191] The specified maximum number of times that reference parts are used in finished goods testing should be no greater than 1000 matings and dematings.
- R8-108** [192] The manufacture shall specify the maximum number of times that reference parts are used in finished goods testing.
- R8-109** [193] The manufacture shall have a method of determining how many times the reference parts have been used in finished goods testing.
- R8-110** [194] Reference cables shall be checked for wear.
- R8-111** [195] The manufacturer shall specify the frequency of the checks of the reference pieces before the maximum number of insertion is reached.

8.2.4.4 Calibration

An effective calibration program must be in place to assure that measurements are made using accurate equipment. Both product quality and product reliability are affected by using uncalibrated equipment in the test and measurement process.

- R8-112** [196] For each piece of equipment, detailed records shall be kept on maintenance, calibration, and re calibration dates. Calibration records shall contain the item identity number and name, the frequency of calibration, procedure for calibration, date calibrated and due date for calibration, personnel performing the calibration, identity of the standard or master used to calibrate, and deviations from standard values. Calibration certificates issued by outside calibration services shall be retained.
- R8-113** [197] All test equipment shall be validated to assure that sufficient accuracy and resolution exists to measure the parameters being tested.
- R8-114** [198] When automated equipment is used to make pass or fail decisions during the manufacturing or testing processes, such equipment shall be on a routine verification program.
- R8-115** [199] The accuracy and resolution of an instrument used to calibrate another instrument shall be greater than the accuracy and resolution of the instrument being calibrated.
- R8-116** [200] The supplier shall have a calibration system to ensure that tools, gauges, templates, and other measuring and testing equipment are calibrated against certified standards traceable to recognized national standards bodies (where possible).
- R8-117** [201] The quality or reliability organization shall audit the records or equipment to ensure that no equipment that is past-due for calibration is being used during testing and inspection.
- R8-118** [202] Calibration records shall include an indication of the as-received condition (in calibration or out of calibration) before re-calibration is done.
- R8-119** [203] All equipment used in manufacturing that requires maintenance shall be on a maintenance schedule. This includes machines used to form, clean, prepare, or test any part of the

product or the complete product, and tools such as cleavers and strippers.

- R8-120** [204] Maintenance intervals shall be appropriately established with inputs such as equipment manufacturer's recommendations and degree of usage considered.

8.2.4.5 Product Qualification Testing

There are two phases to product qualification testing:

- initial product testing
- periodic product re-qualification.

The same set of tests are normally used for both phases, but the objectives are different. Initial product testing is conducted on new products or product families, and when significant design changes are made to assure that the product meets the design intent. Periodic requalification tests are conducted on a periodic schedule to assure that subtle changes that may occur over time in the manufacturing process have not altered the product so that it no longer meets the design intent.

The following criteria apply to the qualification and re-qualification programs:

- R8-121** [205] The qualification or re-qualification program for the connector product or product family shall be documented.
- R8-122** [206] Documentation of the qualification or re-qualification program shall address:
- Scheduling for qualification tests
 - Test procedures
 - Criteria that determine whether a test has been passed or failed
 - Specification of the format for the retention of test data
 - Distribution of the results and reporting of test failures
 - Corrective action to be taken when test failures occur.

Service Life Tests and criteria in Section 6 are used for both the Initial Product Qualification Tests, and the Requalification Tests. The User as defined in Section 1 may add additional tests as required.

The sample of a product submitted for either initial or re-qualification testing shall be of products that are representative of the product normally being delivered to customers, has been randomly selected, and has not been subjected to screening following production. Where the manufacturer has more than one production line, the sample of the product shall be drawn equally from each production line.

8.2.4.5.1 *Repeat of Initial Qualification Testing*

- R8-123** [207] Product shall be subjected to initial qualification testing for any significant change in the form, fit, or function of the product.
- R8-124** [208] The supplier shall document those changes in the product that affect form, fit, or function.
- R8-125** [209] The supplier shall notify customers of anticipated design changes that will affect product form, fit, or function.

8.2.4.5.2 *Periodic Requalification Test Schedule*

Factors that must be considered when deriving a requalification schedule include

- Changes in manufacturing processes
- Stability of raw materials and controls over their procurement
- Personnel turnover
- Associated cost of the test, and its criticality and cost trade-off.

- R8-126** [210] The manufacturer shall have a re-qualification program that schedules each product or product family for re-qualification testing at least once a year.
- R8-127** [211] If requalification testing differs from qualification testing in scope, test procedures, performance criteria, or other area, the manufacturer shall specify these differences in the qualification/requalification documentation.

Requirement-Object List

- R3-1** [1]Test Reports
- ... Test Reports issued under the terms of this document shall include the following information:
- ... 1. The ordering information for the items being tested. This is to include as appropriate: the part number and model number for the adapter, connector plug, jumper cable assembly, etc.
 - ... 2. The specification for the media type, See the glossary for the definitions.
 - ... 3. The manufacturer and type of fiber being used.
 - ... 4. The base materials used in the connector plug and adapter.
 - ... 5. A list of the metallic materials which come into contact with each other, used in the adapter and the plug.
 - ... 6. The operating instructions included with the product, for example the cleaning instructions.
 - ... 7. A description of the training material the supplier recommends for training operators in the use of the product.

Page 3-1

- R3-2** [2]Product Documentation
- ... A complete set of documentation in accordance with GR-454-CORE, *Generic Requirements for Supplier-Provided Documentation*, shall be available from the manufacturer upon request and shall provide all related information, as applicable to the particular connector, alignment sleeve, or jumper assembly product, to describe:
- ... a. Use and application
 - ... b. Cleaning procedures
 - ... c. Bend radius limits at 1310 nm and 1550 nm
 - ... d. Operational limits (temperature, humidity, etc.)
 - ... e. Testing operations
 - ... f. Materials used for ferrule, sleeve, plug body, housing, etc.
 - ... g. Traceability information for critical components obtained from third party sources, e.g., ferrules and alignment elements

- ... h. Safety instructions
- ... i. Auxiliary equipment required and usage
- ... j. Storage and transportation instructions
- ... k. Packaging list of all items included in the shipping container.
- ... The documentation may require preparation in accordance with instructions from the individual customers.

Page 3-1

R3-3 [3]Packaging

- ... The packaging shall be adequate to ensure that the product will not be damaged under normal handling, shipping, and storage. Jumper cables shall be packaged individually.

Page 3-2

R3-4 [4]Metallic elements

- ... Metallic elements shall be corrosion resistant. Dissimilar metals shall not be used in contact with each other unless they are suitably finished to prevent electrolytic corrosion.

Page 3-2

R3-5 [5]Index Matching Fluid or Gel

- ... The connector product shall not incorporate an index matching fluid or gel which is designed to prevent glass-to-air contact or glass-to-glass contact nor require application of such material for use.

Page 3-2

R3-6 [6] Fungus Resistance

- ... Polymeric materials that are used shall not support fungus growth per ASTM-G21-70. A rating of 0 (zero) is required.

Page 3-3

R3-7 [7]Flammability

- ... Polymeric materials that are used shall have a rating of V-1 or better as determined by Underwriters Laboratories (UL) Standard 94, and an oxygen index of 28 percent or greater as determined by ASTM D-2863-87.

Page 3-3

R3-8 [8]Cable Media Types

... The media on which connector plugs are mounted shall meet the criteria in either GR-409-CORE, *Generic Requirements for Premises Fiber Optical Cable*, or GR-20-CORE, *Generic Requirements for Optical Fiber and Optical Fiber Cable*.

... Cable Media Types shall be defined as follows:

- Type I Media: Reinforced jacketed cable of any diameter used as jumper cordage.¹
- Type II Media: Cable with 900 μm buffer coating that may or may not be reinforced.
- Type III Media: Connectors mounted on fiber with a 250 μm coating.

Page 3-3

O3-9 [9]Cleanability

... The connector structure should allow the area of the ferrule that engages the alignment sleeve to be cleaned by means of the cleaning procedures in Section 4.3.

Page 3-3

CR3-10 [10]Intermateability

... The product (connectors, adapters) shall meet the requirements of the applicable FOCIS-n (ANSI/TIA/EIA-604-n), where “n” is a number designation assigned to a specific connector type. The requirements should be met both on new product and after the completion of Service Life Tests.

Page 3-4

CR3-11 [11]Ferrule extension contact force

... The ferrule extension distance and the spring loading force shall meet the conditional limits specified by TIA/EIA FOCIS documents.

Page 3-5

1. Type I media may include simplex, duplex or quad cable products.

CR3-12 [212]Length requirements for the distance between the mechanical and optical reference planes in connector adapters.

... The distance between the mechanical reference planes for connector adapters shall be within the limits specified by the TIA/EIA FOCIS documents.

Page 3–5

CR3-13 [213]Adapter Sleeve/Ferrule Frictional Forces

... The force required to remove a gauge pin from the adapter sleeve shall meet the requirements specified by TIA/EIA (FOCIS) documents.

Page 3–6

CR3-14 [214]Adapter Sleeve Latch Spacing

... The latch spacing for connector adapters shall meet the requirements specified by TIA/EIA (FOCIS) documents.

Page 3–6

CR3-15 [215]Glass Transition Temperature of Connector Adapter Latches

... The glass transition temperature of the latches in connector adapters shall be $> 100^{\circ}\text{C}$.

RATIONALE — If the glass transition temperature of the connector adapter latches is too low (within 20°C of the maximum operating range of the connector), and the connector plugs are not fully latched, the latches will spread apart during environmental aging, and will no longer be able to latch properly. If the glass transition temperature is sufficiently high, the adapters will still latch properly even after aging.

Page 3–7

CO3-16 [216]Latchability of Push-Pull Type Connectors

... No more than 30% of the connectors (a total of 43 connectors) shall fail the latchability test.

RATIONALE — Reflectance field failures have occurred due to the failure of the latching mechanism in SC connectors. Laboratory testing has determined that the failures occur when the connectors are not completely latched initially, and that certain products are more susceptible to this problem than others. This test allows users to identify products that are more robust against craft error, and to minimize field failures. Four operators are used to minimize the spread in the test results, and the

percent of acceptable failures has been increased to take into account the spread in the test results.

Page 3-8

R3-17 [12]Product Marking

... Connector plugs and adapters shall be marked to identify the supplier, the model or series of the parts, and a code that identifies the vintage of the parts. Vintage markings shall allow for the identification by date of the adapters to within 6 months and the plugs to within 3 months.

Page 3-8

O3-18 [13]Color Code

... Connector plugs, of non-angled polished connectors, should be color-coded on the basis of their typical maximum reflectance when mated to themselves, using the color code indicated in Table 3-1.

... The color code shall be applied to the connector boot.

Table 3-1. Reflectance Color Code

Color	Typical Maximum Reflectance
Red	< -30 dB
White	< -40 dB
Dark-Blue	< -55 dB
Green	Angled (APC)

Page 3-9

CR3-19 [14]Color Code APC

... Angled polished (APC) connectors shall have green plug body or green boots.

Page 3-9

O3-20 [15]Presence

... The connector plug should be keyed such that a particular angular orientation is required for insertion of the plug in the adapter.

RATIONALE — An unkeyed plug can assume any angular orientation with respect

to its mate, therefore insertion loss repeatability will depend on the concentricity of the components used (fiber, ferrule, ferrule bore, etc.)

Page 3-9

O3-21 [16]Visibility of Key Orientation

... The key orientation should be clearly visible either through the design of the connector plug and adapter or by means of marking on the plug and adapter.

RATIONALE — If the orientation is not visible then the plug will be rotated with respect to the alignment sleeve until the proper orientation is found, leading to generation of wear particles and erratic behavior.

Page 3-10

R3-22 [17]Radiation Hazard

... The instructions that describe the procedures for cleaning the adapters and plugs shall indicate the possible hazard due to the presence of invisible (infrared) radiation when examining connectors with the naked eye or using a microscope. The instructions shall also contain ordering information for an IR indicator card (Edmund Scientific part #53-031 or equivalent) to allow visualization of invisible IR light.

Page 3-11

R3-23 [18]Cleaning Materials

... The instructions that describe the procedures for cleaning the adapters and plugs shall contain the following information regarding any materials that are used for cleaning that may be considered hazardous to health or to the environment:

- ... 1. Warning as to the toxicity hazard
- ... 2. Instructions for handling and use
- ... 3. Instructions for disposal.

Page 3-11

R4-1 [217]If a connector assembly becomes nonconforming in the course of a test then the criteria for that test are a priori not met. However, rather than consider this specimen nonconforming for all subsequent tests (as was the case in Issue 1 of GR-326-CORE), it is permissible to substitute for the failed product to replenish the test group with product from the same production lot to its original size,

with the condition that substitute product has also been subjected to the conditions of the previous tests. It is therefore desirable to maintain a supply of unmonitored “hot spares” in the environmental chamber. Any product substitutions shall be noted clearly within any report issued under this document. “Hot spares” do not need to be monitored until they are substituted for failed product. No more than ten (10) initial test samples may be replaced by “hot spares”. This criteria does not apply to samples that are pre-screened to New Product criteria, see Section 4.4.1.

RATIONALE — All nonconformance to requirements shall be recorded, whether at the initial measurements or at any point in the testing. It also does not make sense to continue to test a product that has already failed and apply the failure to all subsequent tests. By allowing substitutions, the failure is only counted against the test in which it failed to meet requirements. It is necessary to limit the number of sample replacements because an unlimited number of replacements is not practical.

Page 4–8

R4-2 [19]New Product Maximum Loss Requirement

... All connections in the population shall meet the New Product Loss Requirement of 0.40 dB stated in Table 4-2.

Page 4–11

O4-3 [20]New Product Maximum Loss Objective

... All connections in the population should meet the New Product Loss Objective of 0.20 dB stated in Table 4-2.

Page 4–11

R4-4 [21]New Product Mean Loss Requirement

... The mean of the losses for the population of connections shall meet the New Product Mean Loss Requirement of 0.20 dB stated in Table 4-2.

Page 4–12

O4-5 [22]New Product Mean Loss Objective

... The mean of the losses for the population of connections should meet the New Product Mean Loss Objective of 0.15 dB stated in Table 4-2.

Page 4–12

R4-6 [23]New Product Reflectance (Digital)

... All connections in the population shall meet the New Product Reflectance Requirement of -40 dB stated in Table 4-3.

Page 4-12

CR4-7 [24]New Product Reflectance (Analog)

... Connectors intended for use in AM-VSB (analog video) systems shall meet the Conditional Requirement of -55 dB stated in Table 4-3.

Page 4-12

CO4-8 [25]New Product Reflectance (Analog)

... Connectors intended for use in AM-VSB (analog video) systems should meet the Conditional Objective of -60 dB stated in Table 4-3.

RATIONALE — For digital systems, the requirement is deemed sufficient. AM-VSB video systems are more susceptible to reflective impairments. The effects depend upon system configuration, including laser and fiber properties, and the number and spacings of splices along the fiber link. The maximum reflectance criteria are intended to reduce these impairments to a tolerable level. More stringent reflectance criteria might reduce the impairment further but this is deemed unnecessary at this point.

Some system specifications (e.g., SONET specifications in GR-253-CORE, *Synchronous Optical Network (SONET) Transport Systems: Common Generic Criteria*) allow relaxed point reflectances compared to the specifications in GR-1095-CORE, *Generic Requirements for Multi-Fiber Single-Mode Optical Splices and Splicing Systems*. The relaxed reflectance criteria, requiring increased system tolerance to reflections, enables use of some current embedded plant. The reflectance values given in GR-326-CORE are intended to enable graceful upgrades to future systems that may have reduced tolerance to reflections.

Page 4-12

R4-9 [26]Thermal Age Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load”

Page 4-14

O4-10 [27]Thermal Age Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load"

Page 4-14

R4-11 [28]Thermal Cycle Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

Page 4-16

O4-12 [29]Thermal Cycle Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

Page 4-16

R4-13 [30]Humidity Age Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

Page 4-16

O4-14 [31]Humidity Age Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

Page 4-16

R4-15 [32]Humidity / Condensation Cycling Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

Page 4-18

O4-16 [33]Humidity / Condensation Cycling Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

Page 4-18

R4-17 [34]Post-Condensation Thermal Cycle Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

Page 4-19

O4-18 [35]Post-Condensation Thermal Cycle Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

Page 4-19

R4-19 [36]Vibration Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

Page 4-20

O4-20 [37]Vibration Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

Page 4-20

R4-21 [38]Flex Test Requirements

... The product shall not become uncoupled under this load and shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."

Page 4-21

O4-22 [39]Flex Test Objectives

... The product shall not become uncoupled under this load and should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

Page 4-21

CO4-23 [218]Flex Test Objective for Small Form Factor Connectors

... When applying a 0.9 kgf. (2.0 lbf.) load to Small Form Factor Connectors, the product shall not become uncoupled under this load and should meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

RATIONALE — It was the consensus of the Telcordia Technical Forum that the Small Form Factor Connectors must be able to meet the loss and reflectance requirements with side loads at a level two-thirds that of the larger tradition connectors because of their smaller size. However, the Forum also felt it should be an objective that the Small Form Factor Connectors meet the same requirements for side loads as traditional connectors.

Page 4-21

R4-24 [40]Twist Test Requirements

... The product shall not become uncoupled and shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

Page 4-22

O4-25 [41]Twist Test Objectives

... The product shall not become uncoupled and should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

Page 4-22

R4-26 [42]Proof Test Requirements

... The product shall not become uncoupled under this load and it shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” when subjected to the lower loading level in Steps ‘c’ and ‘g’.

Page 4-23

O4-27 [43]Proof Test Objectives

... The product shall not become uncoupled under this load and it should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load" when subjected to the higher loading level in Steps 'e' and 'i'.

Page 4-23

CO4-28 [219]90° Side Pull Proof Test Objects for Small Form Factor Connectors

... The Small Form Factor Connector shall not become uncoupled under this load and it should meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load" when subjected to the higher loading level in Step 'g'.

Page 4-23

R4-29 [44]Transmission with Applied Load at 0° Requirements

... The product shall not become uncoupled under this load and shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Under Load", when subjected to all of the loading levels at an angle of 0° in Table 4-9, for Small Form Factor Connectors in Table 4-10. If the product fails to do so, then the highest load which was supported shall be reported.

Page 4-26

R4-30 [45]Transmission with Applied Load at 90° Requirements

... The product shall not become uncoupled under this load and shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Under Load", when subjected to all of the loading levels at an angle of 90° in Table 4-9 or for Small Form Factor Connectors in Table 4-10. If the product fails to do so, then the highest load which was supported shall be reported.

Page 4-27

O4-31 [46]Transmission with Applied Load at 0° Objectives

... The product shall not become uncoupled under this load and should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Under Load", when subjected to all of the loading levels at an angle of 0° in Table 4-9 or for Small Form Factor Connectors in Table 4-10. If the product fails

to do so, then the highest load which was supported shall be reported.

Page 4-27

O4-32 [47]Transmission with Applied Load at 90° Objectives

... The product shall not become uncoupled under this load and should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Under Load”, when subjected to all of the loading levels at an angle of 90° in Table 4-9 or for Small Form Factor Connectors in Table 4-10. If the product fails to do so, then the highest load which was supported shall be reported.

Page 4-27

CO4-33 [220]Transmission with Applied Load at 90° Objectives for Small Form Factor Connectors

... Small Form Factor Connectors shall not become uncoupled under this load and should meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Under Load”, when subjected to all of the loading levels at an angle of 90° in Table 4-9. If the product fails to do so, then the highest load which was supported shall be reported.

Page 4-27

R4-34 [48]Use in High Density Environment

... The supplier of a connector or jumper assembly product shall state if that product is intended for use in a “high density” environment. See Section 4.1.1 for definition.

Page 4-27

CR4-35 [49]Transmission with Applied Load at 135°

... If the product is intended for use in “high density” environments, then it should meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Under Load”, when subjected to all of the loading levels at an angle of 135° in Table 4-9 or for Small Form Factor Connectors in Table 4-10. If the product fails to do so, then the highest load which was supported shall be reported.

Page 4-28

CO4-36 [221]Transmission with Applied Load at 135° for Small Form Factor Connectors

... If the Small Form Factor Connector is intended for use in “high density” environments, then it should meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Under Load”, when subjected to all of the loading levels at an angle of 135° in Table 4-9. If the product fails to do so, then the highest load which was supported shall be reported.

Page 4–28

R4-37 [50]Impact Test Requirements

... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

Page 4–29

O4-38 [51]Impact Test Objectives

... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

Page 4–29

R4-39 [52]Remateability Requirement

... Of the entire body of measurements taken after either one-sided or two-sided cleaning (at insertions 25, 50....), 90% shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

Page 4–31

O4-40 [53]Remateability with Cleaning Objective

... Of the entire body of measurements taken after either one-sided or two-sided cleaning (at insertions 25, 50....), 95% shall meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load.”

Page 4–31

O4-41 [54]Remateability without Cleaning Objective

- ... Of the entire body of measurements taken without cleaning (at insertions 24, 49...), 90% shall meet the loss and reflectance **Requirements** (not Objectives) criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load."
Page 4-31
- R4-42** [55]Durability Requirement
- ... After having been subjected to the complete set of 200 insertions, the product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load." Up to two re-cleanings may be performed for each connection.
Page 4-32
- O4-43** [56]Durability Objective
- ... After having been subjected to the complete set of 200 insertions, the product shall meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "During Test, Not Under Load." Up to two re-cleanings may be performed for each connection.
Page 4-32
- O4-44** [57]Cleanability Objective
- ... The criterion is not met if connectors which are nonconforming after 200 insertions and the subsequent automatic two-sided cleaning are brought back into conformance by one or two re-cleanings.
Page 4-32
- R4-45** [58]Optical Requirements
- ... The product shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked "End of Test."
Page 4-33
- O4-46** [59]Optical Objectives
- ... The product should meet the loss and reflectance Objectives criteria listed in Tables 4-2 and 4-3 in the row marked "End of Test."
Page 4-33

R4-47 [60] Ferrule Endface Geometry
... The product shall meet the Ferrule Endface Geometry Requirement criteria stated in Section 4.4.5.1.

Page 4–33

R4-48 [61] Damage
... At the completion of the tests there shall be no damage that would impair the performance of either the connector plug or the adapter, as described in Section 4.2.3.

Page 4–33

R4-49 [62] Dust Test Requirements: Set “A”
... The product of Set “A” (Group I) shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” during the first measurement (before cleaning).

Page 4–35

R4-50 [63] Dust Test Requirements: Sets “A” and “B”
... The product of both Sets “A” and “B” (Groups II and III) shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after the last cleaning in Step “l.”

RATIONALE — At this point the product will have been thoroughly cleaned three times, so performance should be returned to conforming levels.

Page 4–37

O4-51 [64] Dust Test Objectives
... The product of both Sets “A” and “B” (Groups II and III) should meet the loss and reflectance **Requirements** (not Objectives) criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after the last cleaning in Step “i.”

Page 4–37

O4-52 [65] Dust Test Cleanability Objective
... The criterion is **not met** if connectors which are nonconforming to the loss and reflectance Requirements criteria listed in Tables 4-2

and 4-3 after the first cleaning in Step “G” or Step “J” are brought back into conformance during the subsequent two cleanings.

Page 4–37

O4-53 [66]Dust Resistance Objective

... The criterion is **not met** if product which is conforming after the first cleaning becomes nonconforming after a subsequent cleaning.

Page 4–37

R4-54 [67] Adhesive Test

... After subjecting the specimens to loading with a ceramic blank for 7 days at 65°C with uncontrolled humidity, the endface geometry shall still be within the tolerances allowed by the Fiber Undercut and Protrusion Requirement [80] (Section 4.4.5.1 or Section 4.4.5.2).

Page 4–38

R4-55 [68]Airborne Contaminants Requirements: Set “A”

... The product of Set “A” (Group I) shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” during the first measurement (before cleaning).

Page 4–40

R4-56 [69]Airborne Contaminants Requirements: Sets “A” and “B”

... The product of both Sets “A” and “B” (Groups II and III) shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after the last cleaning in Step “l.”

Page 4–40

O4-57 [70]Airborne Contaminants Objectives

... The product of both Sets “A” and “B” (Groups II and III) should meet the loss and reflectance **Requirements** (not Objectives) criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after the last cleaning in Step “i.”

Page 4–40

R4-58 [71]Airborne Contaminants Corrosion Requirement

... There shall be no visible evidence of the formation of corrosion under visual inspection.

Page 4–40

R4-59 [72]Salt Spray Requirements: Set “A”

... The product of Set “A” (Group I) shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” during the first measurement (before cleaning).

RATIONALE — At this point the product will not have been demated, so its performance should not be affected by dust exposure.

Page 4–42

R4-60 [73]Salt Spray Requirements: Sets “A” and “B”

... The product of both Sets “A” and “B” (Groups II and III) shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after the last cleaning in Step “l.”

RATIONALE — At this point the product will have been thoroughly cleaned three times, so performance should be returned to conforming levels.

Page 4–42

O4-61 [74]Salt Spray Objectives

... The product of both Sets “A” and “B” (Groups II and III) should meet the loss and reflectance **Requirements** (not Objectives) criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after the last cleaning in Step “i.”

RATIONALE — At this point the product will have been cleaned three times but with one plug still in the adaptor; i.e., not as thoroughly as possible.

Page 4–42

R4-62 [75]Salt Spray Corrosion Requirement

... There shall be no visible evidence of the formation of corrosion under visual inspection.

Page 4–42

R4-63 [76]Immersion/Corrosion Requirement for Ferrule Deformation

... The degradation factor shall be less than 0.015 after two weeks of aging in 85°C de-ionized water.

The Degradation Factor = $(R_{\text{final}} - R_{\text{initial}}) / (R_{\text{initial}} * R_{\text{final}})$, where R_{initial} and R_{final} are the initial and final radii of curvature, respectively.

Page 4-43

O4-64 [77] Immersion/Corrosion Objective for Fiber Dissolution

... The fiber core recess shall not increase by more than 10 nm with respect to the cladding during the two-week aging test.

RATIONALE — Any geometric instability in the connector endface is potentially performance-affecting and may be an indication of improperly stabilized zirconia used for the ferrule. A visible ring of easily cleaned residue (“moisture ring”) is often seen on ferrules after immersion at the point where the ferrules mate. This has not been seen to be performance-affecting, and does not constitute nonconformance to the Objective criteria.

Page 4-43

CR4-65 [78] Groundwater Immersion Test (Underground)

... Product intended for deployment underground shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after groundwater exposure.

Page 4-44

CR4-66 [79] Organism Exposure Test (Free-breathing)

... Product intended for deployment in free-breathing closures in the above-ground or aerial plant shall meet the loss and reflectance Requirements criteria listed in Tables 4-2 and 4-3 in the row marked “During Test, Not Under Load” after Organism Exposure.

Page 4-44

R4-67 [80] Fiber Undercut and Protrusion

... The Fiber Undercut (x) as shown in Figure 4-6 shall meet the requirements stated in IEC 60874-14-n, where “n” is any of the applicable (singlemode, single fiber, physical contact) released connector detailed specifications in the IEC 60874-14-n series. In those detail specifications, the radius of curvature of the ferrule is between 10 mm and 25 mm. That is, the value of fiber undercut (in units of nanometers) shall be no larger than $-0.02R^3 + 1.3R^2 - 31R + 325$, where R is the radius of curvature, expressed in millimeters.

... When the radius of curvature is between 7 mm and 10 mm, the value of the fiber undercut shall be no larger 125 nm. See Figure 4-7.
... The Fiber Protrusion (y) as shown in Figure 4-6 shall be ≤ 50 nm for all radii of curvature.

Page 4-45

R4-68 [81] Ferrule Endface Radius

... The Radius of Curvature of the ferrule shall be between 7 mm and 25 mm.

Page 4-47

R4-69 [82] Apex Offset

... The Apex Offset of the spherical endface to the axis of the ferrule shall be less than 50 μm .

Page 4-47

R4-70 [222] The endface geometry parameters for angled physical contact connectors must meet the requirements of IEC 60874-14-6 for an angle of 9° for untuned connectors, IEC 60874-14-7 for an angle of 9° for tuned connectors.

Page 4-47

R4-71 [223] Endface Geometry Measurement Areas

... The endface geometry measurement areas shall meet the requirements of IEC 61300-3-23 for measuring the radius of curvature and fiber undercut/protrusion.

Page 4-49

R4-72 [224] Loss Increase Requirement

... The increase in loss, the difference between the loss in Steps 3 and 5, shall be ≤ 0.20 dB. No increase in loss is permitted for products with right angle boots.

RATIONALE — A loss requirement is needed with the increase of distance x in this test from 2.25 to 2.75 inches from Issue 2 of this document. A right angle boot should not show any difference in its loss in this test.

Page 4-50

O4-73 [83] Loss Increase Objective

... The increase in loss, the difference between the loss in Steps 3 and 5, should be ≤ 0.10 dB.

Page 4-51

CR4-74 [225]Right Angle Boot Requirement

... No portion of a right angle boot shall come into contact with the panel parallel to the mounting surface. See Figure 4-10.

RATIONALE — Connectors with right angle boots should be able to fit into the same limited space in cabinets and fiber shelves as connectors with straight boots.

Page 4-51

O4-75 [226]Maximum Length Objective

... The maximum length of the installed connector including boot should not exceed 57 mm (2.25 in.), dimension y as shown in Figure 4-10. This objective does not apply to right angle boots.

RATIONALE — The maximum length of the connector needs to be controlled to avoid excessive bend radius when used in FDF shelves with in-line attenuators. An excessive bend radius could result in large losses particularly at the longer wavelengths such as 1550 nm. This change is needed to clarify the need for an objective on the maximum length of the boot.

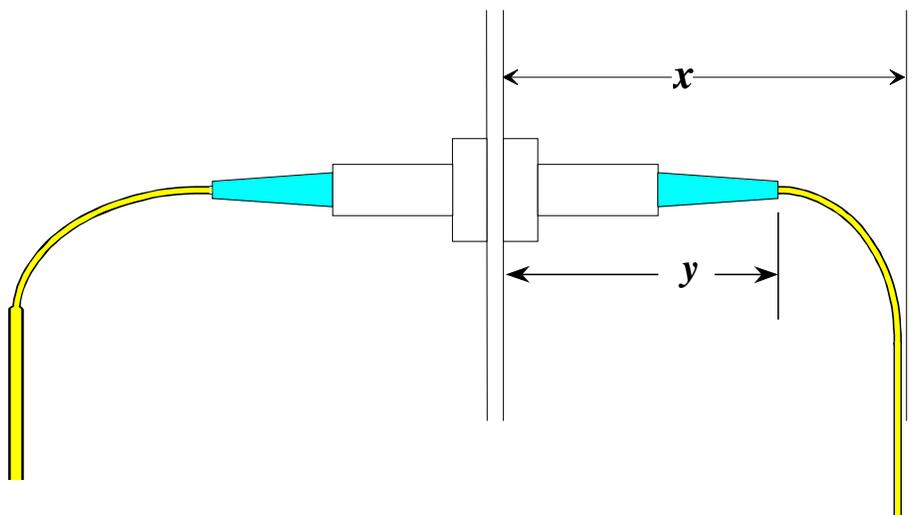


Figure 4-10. Connector Installation Test

Page 4-51

R8-1 [85] The requirements of Technical Reference TR-NWT-000357, *Generic Requirements for Assuring the Reliability of Components Used in Telecommunication Systems*, as applicable to connectors, shall apply.

Page 8–2

R8-2 [86] The connector supplier shall have the following records and procedures for the purchase of materials or components used in fiber optic connectors:

- ... 1. Documented procedures for the qualification of vendors.
- ... 2. Requirements for vendor qualification.
- ... 3. A vendor rating system that allows vendors performance to be analyzed.
- ... 4. A rating system that indicates which vendors are exhibiting substandard performance.
- ... 5. An approved vendor list that is updated periodically.
- ... 6. Procedures for auditing of vendor performance.
- ... 7. Records of vendors over at least the last 5 years.

Page 8–2

O8-3 [87] The connector supplier should have a raw material inspection program that relies on vendor quality assurance, rather than incoming inspection. This program need not be in place if the connector manufacturer is developing such a program.

Table 8-1. Definition of Quality Levels

Quality Level	Description
I	This level is assigned to commercial-grade devices that are produced under the following controls: <ul style="list-style-type: none"> a. Steps are taken to ensure that the devices are compatible with the design application and manufacturing process. b. An effective feedback and corrective action program is in place that quickly identifies and resolves problems in manufacture and in the field.

Table 8-1. Definition of Quality Levels (Continued)

Quality Level	Description
II	Level II includes the controls of Level I plus the following controls: <ul style="list-style-type: none"> c. purchase specifications that explicitly identify important characteristics (optical, electrical and mechanical) and acceptable quality levels (AQLs) for lot controls. d. devices and vendors must be qualified and identified on approved parts/ vendor lists (device qualification includes appropriate life and endurance tests). e. lot-to-lot controls at adequate AQLs to assure consistent quality.
III	Level III includes the controls of Level II plus the following controls: <ul style="list-style-type: none"> f. periodic re-qualification of device families. g. lot-to-lot controls that include 100% screening (e.g., burn-in) which, <i>if the results warrant it</i>, may be reduced to a "reliability audit" (e.g., burn-in on a sample basis). h. where screening is used, the percent defective allowable (PDA) is to be based on the Lot Tolerance Percent Defective* (LTPD), see Table 7-2

Page 8-3

R8-4 [88] Procedures for the qualification of parts shall be documented.

Page 8-3

O8-5 [89] Qualification of raw materials should be a program wherein product is manufactured and subsequently tested.

Page 8-4

R8-6 [90] There shall be a detailed specification for the purchase of epoxy that is to be applied to the connector ferrule.

Page 8-4

R8-7 [91] Incoming product shall be inspected to the detail specification.

Page 8-4

R8-8 [92] Storage conditions and storage time shall be documented.

Page 8-4

- R8-9** [93] Assembly operators shall be trained.
Page 8-4
- R8-10** [94] There shall be documentation and operator instructions for mixing, application, curing, and pot life. These instructions shall be posted at each work station.
Page 8-4
- R8-11** [95] A connectorized pigtail or patchcord shall be drawn from each lot or batch of epoxy that is used in connector assembly, and submitted for the following test: Adhesive Testing in Section 4.4.4.2.
Page 8-4
- R8-12** [96] All parameters specified in the Material Specifications shall be inspected.
Page 8-4
- R8-13** [97] Receiving Inspection Instructions shall reference the appropriate Material Specification.
Page 8-5
- R8-14** [98] The acceptability of all procured materials and components that are part of the product or used in the manufacture and assembly of the product is to be determined by one or more of the following methods:
Page 8-5
- R8-15** [99] Evidence of quality and reliability, such as certified data, shall include or be accompanied by actual test and inspection data of the received goods.
Page 8-5
- R8-16** [100] Inspection instructions shall exist for all materials and components. Inspection instructions shall include
- ... • the procedures for inspection and test
 - ... • the sampling plan to be used
 - ... • the properties, characteristics, dimensions, or parameters to be examined or measured.

Page 8-5

R8-17 [101] Results of incoming inspection shall be recorded and retained for a minimum of 2 years.

Page 8-5

R8-18 [102] Results of incoming inspection or inspection at receipt shall be input into the vendor rating system.

Page 8-5

R8-19 [103] If any procured material is received with a "dock-to-stock" procedure, this action shall be justified by sufficient vendor history and adequate vendor performance.

Page 8-6

R8-20 [104] Procedures for detailed assessment of a first lot delivered from a vendor shall be documented.

Page 8-6

R8-21 [105] Certified data that is obtained in place of incoming inspection shall be periodically verified, by inspection at receipt, third-party testing, or witnessing testing at the vendor's location.

Page 8-6

R8-22 [106] Certified data that is obtained in place of incoming inspection shall be reviewed for conformance to requirements.

Page 8-6

R8-23 [107] Decisions to "use as is" any rejected raw materials shall have the concurrence of the reliability or quality organization.

Page 8-6

O8-24 [108] Sampling inspection plans used at incoming inspection should have switching rules in place that allow for reduced or tightened inspection of product.

Page 8-6

R8-25 [109] The program for assuring reliability controls shall be documented.

Page 8-6

O8-26 [110] The supplier should perform reliability tests on critical raw materials on a periodic basis. Raw materials from all approved vendors should be included in the program.

Page 8-6

R8-27 [111] The supplier shall have a program in place for informing raw material vendors of reliability and quality problems.

Page 8-6

R8-28 [112] A corrective action program shall be in place for those problems that are costly or repetitive.

Page 8-6

R8-29 [113] The requirements of GR-78-CORE, as applicable to connectors, shall apply.

Page 8-7

R8-30 [114] At the request of an end user or its representative, the supplier shall identify all original equipment manufactured (OEM) products in or associated with its product.

Page 8-7

R8-31 [115] Deviations from requirements for OEM equipment shall be identified and documented.

Page 8-7

R8-32 [116] On request of an end user or its representative, the supplier shall provide a complete list of known and suspected deviations from requirements of OEM equipment.

Page 8-7

R8-33 [117] The supplier shall assess all OEM equipment against Telcordia component reliability assurance, physical design, and product reliability criteria.

Page 8-7

- R8-34** [118] The supplier shall have in place physical design practices that are appropriate for the quality and reliability needed in telecommunications products.
Page 8-7
- O8-35** [119] The supplier should assure that all physical design and workmanship requirements are met before volume production begins.
Page 8-7
- R8-36** [120] The composition and thickness of coatings and finishes on metal parts used to prevent electrolytic corrosion shall be specified.
Page 8-7
- R8-37** [121] The supplier shall be able to show evidence of testing that shows that the coating or finish used to prevent electrolytic corrosion due to contact dissimilar metals is capable of preventing electrolytic corrosion during the service life of the product.
Page 8-8
- R8-38** [122] The supplier shall be able to provide a listing of the available fuel load of polymeric materials used in the connector product. The listing shall include the name of the part, the type of polymer, its mass, and the known flammability properties of the polymer.
Page 8-8
- R8-39** [123] The supplier shall be able to provide evidence that all polymeric materials that are used have a rating of V-1 or better as determined by Underwriter Laboratory (UL) Standard 94 and an oxygen index of 28 percent or greater, as determined by ASTM D-2863-87.
Page 8-8
- R8-40** [124] The supplier shall have an operator training program in place for assembly, test, and inspection personnel.
Page 8-9
- O8-41** [125] The supplier should have a formal certification program in place.
Page 8-9

- CR8-42** [126] If a certification program is in place, the supplier shall periodically recertify operators.
Page 8–9
- R8-43** [127] All personnel involved in the manufacture of a new product shall be trained.
Page 8–9
- O8-44** [128] The supplier should encourage management to participate in reliability and quality training.
Page 8–9
- R8-45** [129] The manufacturer shall document all of its manufacturing and assembly steps.
Page 8–9
- R8-46** [130] The manufacturer shall have a flow chart that illustrates the manufacturing and assembly process and includes all test and inspection points.
Page 8–9
- R8-47** [131] The supplier's reliability and quality organizations shall review and approve the in-process inspection and test plan.
Page 8–9
- R8-48** [132] The manufacturer shall adhere to its own manufacturing and assembly documentation.
Page 8–9
- R8-49** [133] Acceptance criteria shall be listed on data sheets that are used for test and inspection purposes.
Page 8–9
- R8-50** [134] All numerical values in the documentation that refer to nominal values for equipment settings or measurements shall include tolerances.
- ... Example: An instruction that states to adjust a variable attenuator so that -20 dBm of optical power is sensed at the detector shall also state the tolerance, e.g., -20 dBm \pm 0.10 dBm.

RATIONALE — A number is only as good as its tolerance.

Page 8–10

R8-51 [135] All formal documents shall be under a revision control program, including forms and check sheets used in the collection of in-process and final test and inspection data.

Page 8–10

R8-52 [136] Required approvals and distribution lists for all formal documents shall be specified.

Page 8–10

R8-53 [137] The manufacturer shall have a formal program to ensure that outdated and obsolete manufacturing documentation is properly removed from use in the manufacturing, assembly, and test areas and that revised documentation replaces the old.

Page 8–10

R8-54 [138] The supplier's documentation shall not contain hand-written changes, unless such changes are authorized (initialed and dated) by management. Any such changes shall be made to all working copies of the document.

Page 8–10

R8-55 [139] The supplier shall document and establish a formal, statistically valid sampling plan for all in-process tests and inspections that the supplier does not perform on a 100% basis.

Page 8–10

R8-56 [140] The supplier shall prepare manufacturing test and inspection flow charts to document the appropriate sequence and location of these activities.

Page 8–10

R8-57 [141] Product or associated paperwork shall show an indication of test and inspection activity at all points.

Page 8–10

R8-58 [142] Nonconforming materials shall be clearly labeled as such.

Page 8–11

- R8-59** [143] Nonconforming material shall be segregated from both rejected material and product that is to be inspected or tested.
Page 8–11
- R8-60** [144] Separate areas shall be set aside to store nonconforming materials.
Page 8–11
- R8-61** [145] For identical raw materials, there shall be a program in place to use older stock before new stock.
Page 8–11
- R8-62** [146] There shall be a documented program in place for the use of any raw materials that have a shelf life, such as (but not limited to) epoxies, paints, etc.
Page 8–11
- R8-63** [147] The tool used for stripping fiber shall be replaced on a periodic basis according to the number of fibers stripped using the tool.
Page 8–11
- R8-64** [148] The manufacturer shall maintain a count of the number of times a particular stripping tool is used, or shall replace the tool based on average production volumes.
Page 8–11
- O8-65** [149] The stripped fiber ends should be proof tested to 100 kpsi before mounting the connector plugs. The rate at which the proof test load is removed must be sufficiently high to guarantee a minimum strength nearly equal to the proof test stress.
Page 8–11
- O8-66** [150] A count of the fraction of proof test failures should be kept. Increases in the fraction of proof test failures should be used to determine how often the stripping tool is replaced.
Page 8–11
- R8-67** [151] For traceability purposes, customer information shall be retained for at least five years.

Page 8–12

R8-68 [152] For traceability purposes, date of manufacture shall be placed on the product (or its container, if impractical to place on the product).

Page 8–12

R8-69 [153] The supplier shall be able to trace key raw materials used in the manufacture of the product after the product has shipped.

Page 8–12

O8-70 [154] The supplier should be able to trace *all* raw materials used in the manufacture of the product after the product has shipped.

Page 8–12

R8-71 [155] The supplier shall have a customer complaint program in place, and the program shall be formally documented.

Page 8–12

R8-72 [156] The supplier shall have an organization that is assigned the responsibility for customer support.

Page 8–12

R8-73 [157] The supplier shall have a documented system in place for the return of defective a product that is in warranty.

Page 8–12

R8-74 [158] The supplier should have a documented system in place for the return of a defective product that is not in warranty.

Page 8–12

R8-75 [159] The supplier shall have a failure analysis program in place to determine the cause of product failures returned from the field.

Page 8–12

R8-76 [160] The supplier shall have procedures in place to feed the failure analysis results back to the cognizant department.

Page 8–12

- R8-77** [161] A supplier shall have a documented corrective action program in place for the resolution of serious or repetitive customer complaints.
Page 8–12
- O8-78** [162] The supplier should have a program in place for customer training, in the areas of engineering, ordering, installation, operation, and testing.
Page 8–12
- R8-79** [163] Analysis of field failure data shall be used for identifying the dominant causes of in-service failures. This information shall be summarized periodically and reviewed by design, quality, and manufacturing organizations.
Page 8–13
- O8-80** [164] Analysis of field failure data should be used for obtaining estimates of the field failure rate of the connector.
Page 8–13
- O8-81** [165] The supplier should have conducted, or should be in the process of conducting, a field trial of the product.
Page 8–13
- R8-82** [166] The program, *if in place*, shall be documented.
Page 8–13
- R8-83** [167] The supplier shall have a statistical process control (SPC) program in place to monitor critical steps in the manufacturing process.
Page 8–13
- O8-84** [168] The supplier should document the rationale for the selection of these SPC areas.
Page 8–13
- R8-85** [169] Finished goods test and inspection procedures for the product shall be documented in a formal system. These procedures may be included with or as part of other documentation such as manufacturing and assembly documentation.

Page 8–14

R8-86 [170] Documented test procedures shall include performance specifications that are verifiable such that acceptance or rejection can be determined.

Page 8–14

R8-87 [171] Criteria for accepting and rejecting product shall be clearly specified.

Page 8–14

R8-88 [172] Finished goods test and inspection procedures shall include visual inspection for workmanship and appearance.

Page 8–14

R8-89 [173] Finished goods tests shall be conducted according to the manufacturer's test procedures.

Page 8–14

R8-90 [174] Documented test performance specifications for the product shall not be in conflict with any specifications for the identical product published in current advertising literature or internal engineering documents.

Page 8–14

R8-91 [175] The supplier shall evaluate which in-process tests, if any, are necessary to assure final product quality and reliability.

Page 8–14

R8-92 [176] Product shall be functionally tested at final test.

Page 8–15

R8-93 [177] Final acceptance testing of product shall simulate field use.

Page 8–15

R8-94 [178] Reference adapters and plugs used in testing shall simulate those in field use.

Page 8–15

- O8-95** [179] The analysis of final tests and inspections should be documented in weekly and monthly summaries that are distributed to the affected areas and to upper management.
Page 8–15
- R8-96** [180] Distributed summaries of analyses shall be retained (for reference in any possible manufacturing or field reliability problems) for a minimum of two years.
Page 8–15
- R8-97** [181] The supplier shall document and establish a formal, statistically valid sampling plan for all final tests and inspections that the supplier does not perform on a 100% basis.
Page 8–15
- R8-98** [182] Repaired product shall be tested to the same extent as new product.
Page 8–15
- R8-99** [183] Data from finished goods tests shall be analyzed and fed back into the process.
Page 8–15
- R8-100** [184] Results of finished goods tests shall be retained for a minimum of two years.
Page 8–15
- R8-101** [185] Control charts, trend charts, or other methods shall be used to provide feedback into the system at intervals of no greater than one week.
Page 8–15
- O8-102** [186] A statistical process control (SPC) should be established to control the process.
Page 8–16
- R8-103** [187] Accept/reject criteria shall be established for both loss and reflectance.
Page 8–16

- R8-104** [188] Criteria shall not be in conflict with advertised specifications.
Page 8–16
- R8-105** [189] Connector adapters shall be visually inspected for workmanship and appearance.
Page 8–16
- R8-106** [190] Connector plugs and adapters shall be functionally tested to determine acceptable performance. This may be done on a sample basis by using a sample of adapters with other tests.
Page 8–16
- O8-107** [191] The specified maximum number of times that reference parts are used in finished goods testing should be no greater than 1000 matings and dematings.
Page 8–16
- R8-108** [192] The manufacture shall specify the maximum number of times that reference parts are used in finished goods testing.
Page 8–16
- R8-109** [193] The manufacture shall have a method of determining how many times the reference parts have been used in finished goods testing.
Page 8–16
- R8-110** [194] Reference cables shall be checked for wear.
Page 8–16
- R8-111** [195] The manufacturer shall specify the frequency of the checks of the reference pieces before the maximum number of insertion is reached.
Page 8–16
- R8-112** [196] For each piece of equipment, detailed records shall be kept on maintenance, calibration, and re calibration dates. Calibration records shall contain the item identity number and name, the frequency of calibration, procedure for calibration, date calibrated and due date for calibration, personnel performing the calibration, identity of the standard or master used to calibrate, and deviations

from standard values. Calibration certificates issued by outside calibration services shall be retained.

Page 8–17

R8-113 [197] All test equipment shall be validated to assure that sufficient accuracy and resolution exists to measure the parameters being tested.

Page 8–17

R8-114 [198] When automated equipment is used to make pass or fail decisions during the manufacturing or testing processes, such equipment shall be on a routine verification program.

Page 8–17

R8-115 [199] The accuracy and resolution of an instrument used to calibrate another instrument shall be greater than the accuracy and resolution of the instrument being calibrated.

Page 8–17

R8-116 [200] The supplier shall have a calibration system to ensure that tools, gauges, templates, and other measuring and testing equipment are calibrated against certified standards traceable to recognized national standards bodies (where possible).

Page 8–17

R8-117 [201] The quality or reliability organization shall audit the records or equipment to ensure that no equipment that is past-due for calibration is being used during testing and inspection.

Page 8–17

R8-118 [202] Calibration records shall include an indication of the as-received condition (in calibration or out of calibration) before re-calibration is done.

Page 8–17

R8-119 [203] All equipment used in manufacturing that requires maintenance shall be on a maintenance schedule. This includes machines used to form, clean, prepare, or test any part of the product or the complete product, and tools such as cleavers and strippers.

Page 8–17

R8-120 [204] Maintenance intervals shall be appropriately established with inputs such as equipment manufacturer's recommendations and degree of usage considered.

Page 8–18

R8-121 [205] The qualification or re-qualification program for the connector product or product family shall be documented.

Page 8–18

R8-122 [206] Documentation of the qualification or re-qualification program shall address:

- ... • Scheduling for qualification tests
- ... • Test procedures
- ... • Criteria that determine whether a test has been passed or failed
- ... • Specification of the format for the retention of test data
- ... • Distribution of the results and reporting of test failures
- ... • Corrective action to be taken when test failures occur.

Page 8–18

R8-123 [207] Product shall be subjected to initial qualification testing for any significant change in the form, fit, or function of the product.

Page 8–19

R8-124 [208] The supplier shall document those changes in the product that affect form, fit, or function.

Page 8–19

R8-125 [209] The supplier shall notify customers of anticipated design changes that will affect product form, fit, or function.

Page 8–19

R8-126 [210] The manufacturer shall have a re-qualification program that schedules each product or product family for re-qualification testing at least once a year.

Page 8–19

R8-127 [211] If requalification testing differs from qualification testing in scope, test procedures, performance criteria, or other area, the manufacturer shall specify these differences in the qualification/requalification documentation.

Page 8-19

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Glossary

Alignment Sleeve: A feature within a connector adapter which mechanically aligns two ferrules or two fibers.

Adapter: A component of a connector joint which contains the alignment sleeve and also features necessary to mate with the fixation feature of the plug (screw thread, bayonet, snap-fit, etc.).

Angled Connector: Connector with a plane of contact at the fiber that is not perpendicular to the axis of the connector.

Attenuation: In an optical waveguide, the diminution of average optical power.

Note: In optical waveguides, attenuation results from absorption, scattering, and other radiation. Attenuation is generally expressed in dB; however, attenuation is often used as a synonym for attenuation coefficient, expressed in dB/km. This assumes the attenuation coefficient is invariant with length.

Backscatter: The radiant energy in an optical fiber that is reflected back toward its source.

Cladding: The dielectric material surrounding the core of an optical waveguide.

Cladding mode stripper: A device that encourages the conversion of cladding modes to radiation modes; as a result of its use, cladding modes are stripped from the fiber. A cladding mode stripper

often uses a material having a refractive index equal to or greater than that of the waveguide cladding to induce this conversion. See also: Cladding.

Connector: An optical joint which is intended to be remated many times with no change in performance, consisting of three components: two plugs and one adapter.

Decibel (dB): The standard unit used to express gain or loss of optical power.

$dB = 10 \log_{10} (\text{Power Transmitted} / \text{Power Received})$

Detector: A transducer that provides an electrical output signal in response to an incident optical signal. The current is dependent on the amount of light received and the type of device. Detectors are sometimes referred to as receivers.

Fiber (optical): Any filament or fiber, made of dielectric materials, that guides light.

Fusion splice: A splice accomplished by the application of localized heat sufficient to fuse or melt the ends of two lengths of optical fiber, forming a continuous, single fiber.

Index matching material: A material, often a liquid, grease, gel or adhesive, whose refractive index is nearly equal to the core index, used to reduce Fresnel reflections from an optical fiber's end face.

Insertion loss: The total optical power loss caused by the insertion of an

optical component such as a connector, splice, or coupler.

Jumper — A product consisting of a length of optical fiber terminated by connector plugs on both ends.

Jumper Cable Assembly: A test sample consisting of a jumper cable terminated with plugs on each end connected with adapters to two additional connector plugs with unterminated leads on either end.

Laser: A device that produces optical radiation using a population inversion to provide Light Amplification by Stimulated Emission of Radiation and (generally) an optical resonant cavity to provide positive feedback. Laser radiation may be highly coherent temporally, or spatially, or both.

Launch Fiber: An optical fiber used to couple and condition light from an optical source into an optical fiber. Often the launch fiber is used to create an equilibrium modal distribution in multimode fiber.

LED: Light emitting diode.

Light emitting diode (LED): A p-n junction semiconductor device that emits incoherent optical radiation when biased in the forward direction.

Light source: A light emitting diode (LED) or laser diode (LD) that emits light with a controlled and constant spectral width, central wavelength, and peak power with respect to time and temperature.

Loose Buffered Fiber: Fiber that is protected with a layer of material that may be readily stripped with conventional mechanical stripping tools.

Loss: Synonymous with attenuation.

Mechanical splice: A fiber splice accomplished by fixtures or materials, rather than by thermal fusion. Index matching material may be applied between the two fiber ends.

Mode filter: A device used to attenuate, select, or reject a certain mode or modes. In particular it is usually desirable to filter out all but the fundamental mode in a single-mode fiber.

Mode stripper: A device that causes higher order modes of light propagating in the optical fiber to be fully attenuated or radiated from the fiber. After mode stripping, the optical fiber is free of extraneous light in the core and the cladding.

Optical cable: A fiber, multiple fibers, or fiber bundle in a structure fabricated to meet optical, mechanical, and environmental specifications.

OTDR: An Optical Time Domain Reflectometer is a test set used to measure fiber length, loss, and reflectance in optical fiber networks. Measurements can be made with access to only one end of the fiber.

Optical fiber: Any filament or fiber, made of dielectric materials, that

guides light, whether or not it is used to transmit signals.

Pigtail: A product consisting of a length of optical fiber terminated by a connector plug on one ends only.

Pigtail Assembly: A test sample consisting of two connector plugs mated with and adapter with unterminated leads.

Plug: A component of a connector joint which contains the ferrule and also features necessary to mate with the fixation feature of the adapter (screw thread, bayonet, snap-fit, etc.).

Reflectance: Defined as the ratio of reflected power compared to the incident power. The optical reflectance (R) in decibels (dB) is expressed as: $R = 10 \log [\text{Reflected Power} / \text{Forward-Moving Power}]$

Reflection: The abrupt change in direction of a light beam at an interface between two dissimilar media so that the light beam returns into the medium from which it originated. Reflection from a smooth surface is termed specular, whereas reflection from a rough surface is termed diffused.

Splice: The resulting joint(s) of a splicing action. A splice can consist of one or more splice joints.

Splice Joint: The interface were two optical fibers are permanently joined together (fused or mechanically aligned) to form a continuous optical path.

Splice Module: The resulting joint(s) of a splicing action that are housed

in a mechanical assembly. A splice module can consist of one or more splice joints.

Splice Protector: A strength element applied to fusion splices to prevent the transmission of stresses applied to the fiber to the bare glass of a fusion splice joint.

Tight Buffered Fiber: Fiber protected with a layer(s) of material that cannot be readily stripped with conventional stripping tools (without damaging the fiber).

Transmitter: The piece of optical equipment that contains the light source that couples light into the fiber optic cable. It contains the circuitry that converts electrical energy to optical energy and controls the stability of the light source.

Requirement-Object Index

[1]	R3-1	Page 3-1	[40]	R4-24	Page 4-22
[2]	R3-2	Page 3-1	[41]	O4-25	Page 4-22
[3]	R3-3	Page 3-2	[42]	R4-26	Page 4-23
[4]	R3-4	Page 3-2	[43]	O4-27	Page 4-23
[5]	R3-5	Page 3-2	[44]	R4-29	Page 4-26
[6]	R3-6	Page 3-3	[45]	R4-30	Page 4-27
[7]	R3-7	Page 3-3	[46]	O4-31	Page 4-27
[8]	R3-8	Page 3-3	[47]	O4-32	Page 4-27
[9]	O3-9	Page 3-3	[48]	R4-34	Page 4-27
[10]	CR3-10	Page 3-4	[49]	CR4-35	Page 4-28
[11]	CR3-11	Page 3-5	[50]	R4-37	Page 4-29
[12]	R3-17	Page 3-8	[51]	O4-38	Page 4-29
[13]	O3-18	Page 3-9	[52]	R4-39	Page 4-31
[14]	CR3-19	Page 3-9	[53]	O4-40	Page 4-31
[15]	O3-20	Page 3-9	[54]	O4-41	Page 4-31
[16]	O3-21	Page 3-10	[55]	R4-42	Page 4-32
[17]	R3-22	Page 3-11	[56]	O4-43	Page 4-32
[18]	R3-23	Page 3-11	[57]	O4-44	Page 4-32
[19]	R4-2	Page 4-11	[58]	R4-45	Page 4-33
[20]	O4-3	Page 4-11	[59]	O4-46	Page 4-33
[21]	R4-4	Page 4-12	[60]	R4-47	Page 4-33
[22]	O4-5	Page 4-12	[61]	R4-48	Page 4-33
[23]	R4-6	Page 4-12	[62]	R4-49	Page 4-35
[24]	CR4-7	Page 4-12	[63]	R4-50	Page 4-37
[25]	CO4-8	Page 4-12	[64]	O4-51	Page 4-37
[26]	R4-9	Page 4-14	[65]	O4-52	Page 4-37
[27]	O4-10	Page 4-14	[66]	O4-53	Page 4-37
[28]	R4-11	Page 4-16	[67]	R4-54	Page 4-38
[29]	O4-12	Page 4-16	[68]	R4-55	Page 4-40
[30]	R4-13	Page 4-16	[69]	R4-56	Page 4-40
[31]	O4-14	Page 4-16	[70]	O4-57	Page 4-40
[32]	R4-15	Page 4-18	[71]	R4-58	Page 4-40
[33]	O4-16	Page 4-18	[72]	R4-59	Page 4-42
[34]	R4-17	Page 4-19	[73]	R4-60	Page 4-42
[35]	O4-18	Page 4-19	[74]	O4-61	Page 4-42
[36]	R4-19	Page 4-20	[75]	R4-62	Page 4-42
[37]	O4-20	Page 4-20	[76]	R4-63	Page 4-43
[38]	R4-21	Page 4-21	[77]	O4-64	Page 4-43
[39]	O4-22	Page 4-21	[78]	CR4-65	Page 4-44

[79]	CR4-66	Page 4-44	[121]	R8-37	Page 8-8
[80]	R4-67	Page 4-45	[122]	R8-38	Page 8-8
[81]	R4-68	Page 4-47	[123]	R8-39	Page 8-8
[82]	R4-69	Page 4-47	[124]	R8-40	Page 8-9
[83]	O4-73	Page 4-51	[125]	O8-41	Page 8-9
[85]	R8-1	Page 8-2	[126]	CR8-42	Page 8-9
[86]	R8-2	Page 8-2	[127]	R8-43	Page 8-9
[87]	O8-3	Page 8-3	[128]	O8-44	Page 8-9
[88]	R8-4	Page 8-3	[129]	R8-45	Page 8-9
[89]	O8-5	Page 8-4	[130]	R8-46	Page 8-9
[90]	R8-6	Page 8-4	[131]	R8-47	Page 8-9
[91]	R8-7	Page 8-4	[132]	R8-48	Page 8-9
[92]	R8-8	Page 8-4	[133]	R8-49	Page 8-9
[93]	R8-9	Page 8-4	[134]	R8-50	Page 8-10
[94]	R8-10	Page 8-4	[135]	R8-51	Page 8-10
[95]	R8-11	Page 8-4	[136]	R8-52	Page 8-10
[96]	R8-12	Page 8-4	[137]	R8-53	Page 8-10
[97]	R8-13	Page 8-5	[138]	R8-54	Page 8-10
[98]	R8-14	Page 8-5	[139]	R8-55	Page 8-10
[99]	R8-15	Page 8-5	[140]	R8-56	Page 8-10
[100]	R8-16	Page 8-5	[141]	R8-57	Page 8-10
[101]	R8-17	Page 8-5	[142]	R8-58	Page 8-11
[102]	R8-18	Page 8-5	[143]	R8-59	Page 8-11
[103]	R8-19	Page 8-6	[144]	R8-60	Page 8-11
[104]	R8-20	Page 8-6	[145]	R8-61	Page 8-11
[105]	R8-21	Page 8-6	[146]	R8-62	Page 8-11
[106]	R8-22	Page 8-6	[147]	R8-63	Page 8-11
[107]	R8-23	Page 8-6	[148]	R8-64	Page 8-11
[108]	O8-24	Page 8-6	[149]	O8-65	Page 8-11
[109]	R8-25	Page 8-6	[150]	O8-66	Page 8-11
[110]	O8-26	Page 8-6	[151]	R8-67	Page 8-12
[111]	R8-27	Page 8-6	[152]	R8-68	Page 8-12
[112]	R8-28	Page 8-6	[153]	R8-69	Page 8-12
[113]	R8-29	Page 8-7	[154]	O8-70	Page 8-12
[114]	R8-30	Page 8-7	[155]	R8-71	Page 8-12
[115]	R8-31	Page 8-7	[156]	R8-72	Page 8-12
[116]	R8-32	Page 8-7	[157]	R8-73	Page 8-12
[117]	R8-33	Page 8-7	[158]	R8-74	Page 8-12
[118]	R8-34	Page 8-7	[159]	R8-75	Page 8-12
[119]	O8-35	Page 8-7	[160]	R8-76	Page 8-12
[120]	R8-36	Page 8-7	[161]	R8-77	Page 8-12

[162]	O8-78	Page 8-12	[203]	R8-119	Page 8-17
[163]	R8-79	Page 8-13	[204]	R8-120	Page 8-18
[164]	O8-80	Page 8-13	[205]	R8-121	Page 8-18
[165]	O8-81	Page 8-13	[206]	R8-122	Page 8-18
[166]	R8-82	Page 8-13	[207]	R8-123	Page 8-19
[167]	R8-83	Page 8-13	[208]	R8-124	Page 8-19
[168]	O8-84	Page 8-13	[209]	R8-125	Page 8-19
[169]	R8-85	Page 8-14	[210]	R8-126	Page 8-19
[170]	R8-86	Page 8-14	[211]	R8-127	Page 8-19
[171]	R8-87	Page 8-14	[212]	CR3-12	Page 3-5
[172]	R8-88	Page 8-14	[213]	CR3-13	Page 3-6
[173]	R8-89	Page 8-14	[214]	CR3-14	Page 3-6
[174]	R8-90	Page 8-14	[215]	CR3-15	Page 3-7
[175]	R8-91	Page 8-14	[216]	CO3-16	Page 3-8
[176]	R8-92	Page 8-15	[217]	R4-1	Page 4-8
[177]	R8-93	Page 8-15	[218]	CO4-23	Page 4-21
[178]	R8-94	Page 8-15	[219]	CO4-28	Page 4-23
[179]	O8-95	Page 8-15	[220]	CO4-33	Page 4-27
[180]	R8-96	Page 8-15	[221]	CO4-36	Page 4-28
[181]	R8-97	Page 8-15	[222]	R4-70	Page 4-47
[182]	R8-98	Page 8-15	[223]	R4-71	Page 4-49
[183]	R8-99	Page 8-15	[224]	R4-72	Page 4-50
[184]	R8-100	Page 8-15	[225]	CR4-74	Page 4-51
[185]	R8-101	Page 8-15	[226]	O4-75	Page 4-51
[186]	O8-102	Page 8-16			
[187]	R8-103	Page 8-16			
[188]	R8-104	Page 8-16			
[189]	R8-105	Page 8-16			
[190]	R8-106	Page 8-16			
[191]	O8-107	Page 8-16			
[192]	R8-108	Page 8-16			
[193]	R8-109	Page 8-16			
[194]	R8-110	Page 8-16			
[195]	R8-111	Page 8-16			
[196]	R8-112	Page 8-17			
[197]	R8-113	Page 8-17			
[198]	R8-114	Page 8-17			
[199]	R8-115	Page 8-17			
[200]	R8-116	Page 8-17			
[201]	R8-117	Page 8-17			
[202]	R8-118	Page 8-17			

