Verizon NEBS™ Compliance: Hardened Multi-Fiber Optical Connectors (HMFOC)

Verizon Technical Purchasing Requirements

VZ.TPR.9432

Issue 5, March 2011

CHANGE CONTROL RECORD:

Version	Date	Action*	Reason for Revision
1	*10/31/2007*	New	New Document.
2	*08/11/2008*	Change	Multiple changes
3	*04/10/2009*	Change	Editorial changes
4	*04/22/2010*	Add	Clarified IL and RL Pass/Fail Criteria
5	03/10/2011	Change	R3-5 Clarified no use of index matching fluid in connector
			R3-7 Clarified sample size for Flammability
			R3-8 and O3-9, CR3-10, CR3-11, CR3-12, CR3-14, CR3-15, CO3-16, R3-17 Added Clarification
			Eliminated CR3-19
			R4-60, R4-61 Endface Geometry, Added Clarification
			R4-6, Corrected "Mean Reflectance" to "Max Reflectance"
			Changed test Method
			Durability R4-51, 4-52, R4-53 R4-54, O4-55, added clarification
			5.2 Optical Measurements Corrected reference to TPR.9413.
			Extended Thermal Age, Extended Humidity, Extended Thermal Cycle, Dust, Airborne, Salt Spray, Corrected Sample definition
			Extended Thermal cycling, Changed dwell time
			Changed Chemical Resistance Changed Stress Cracking soak time.
			Immersion O7-16, added clarification
			Repeatability and Accuracy – added reference documents
			CIT/CIR Clarification for IL and RL increases
			Corrected Table 2 (Reliability) Order of tests. Clarified importance of test order.
			Corrected Table 3 and Table 4, IL/RL Test Criterion. Eliminated RL increase objective.
			Note 3: Clarification for preferred bend direction.
			R7-5 and Extended Thermal Cycling (Reliability) Test criteria detail, Clarified When measurements are taken
***New,Add, Delete, Change, Reissue**			

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Table of Contents

1.0 PURPOSE

The purpose of this Verizon Technical Purchasing Requirement (VZ.TPR) document is to provide FOC testing requirements for Hardened Multi-Fiber Optical Connectors.

2.0 SCOPE

Hardened Multi-Fiber Optical Connectors (HMFOC)

3.0 REFERENCES

ASTM D2863	Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
ASTM G21	Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi
FOC Memo # 32 Rev.1 2006	Applicable to Hardened Multi-Fiber Optical Connectors
FOC Memo # 43, Oct. 2006	Applicable to Extended Thermal Cycling
GR-326-CORE, Issue 3, September 1999	Generic Requirements for Singlemode Optical Connectors and Jumper Assemblies
GR-771-CORE, Issue 1, July 1994	Generic Requirements for Fiber Optic Splice Closures
GR-1221-CORE, Issue 2, January 1999	Generic Reliability Assurance Requirements for Passive Optical Components
GR-3120-CORE, Issue 1, March 2005	Generic Requirements for Hardened Fiber Optic Connectors
IEC 61300-3-30	Fiber optic interconnecting devices and passive components. Basic test and measurement procedures. Examinations and measurements. Polish angle and fiber position on single ferrule multifiber connectors
IEC 61755-3-3	Fiber optic interconnecting devices and passive components - Fiber optic connector optical interfaces - Part 3-3: Optical interface angled PC end face rectangular ferrule, single mode fibers
VZ.TPR.9405	Generic Reliability Assurance Requirements for Passive Optical Components
VZ.TPR.9407	Freeze/Thaw Test Setup and Procedure
VZ.TPR.9430	Optical Fiber and Optical Fiber Cable
VZ.TPR.9431	Multi-Fiber Optical Connectors
VZ.TPR.9437	Premises Fiber Optic Cable
VZ.TPR.9445	Factory Audit Requirements

4.0 ACRONYMS

A	After
B	Before
CIR	Change in Reflectance
CIT	Change in Transmittance
D	During
FOC	Fiber Optic Components
HMFOC	Hardened Multi-Fiber Optic Connector
IL	Insertion Loss
ITL	Independent Test Laboratory
RL	Return Loss
TPR	Technical Purchasing Requirement

5.0 TEST REQUIREMENTS FOR HARDENED MULTI-FIBER OPTICAL CONNECTORS (HMFOC)

Verizon purchases Hardened Multi-Fiber Optical Assemblies for various applications.Hardened Multi-Fiber Optical Assembliesshall meet the requirements specified in the following tables. All the testing must be completed by a Verizon approved ITL:

FOC Test Requirements for HARDENED Multi-Fiber Optical Connectors (HMFOC)– based on GR-326, 771& 3120 (Task references from GR-326)					
Task	**Test Group**	**Reference Spec.**	**Samples**	**Optical Monitor**	**Comments**
3.0 General Requirements					
3.1 Documentation					
Test Reports		R3-1			
Product Documentation		R3-2			Per GR-326
3.2 Packaging and Shipping		R3-3			Samples shall be packaged and shipped to the ITL as shipped to the field
3.3 Design Features					Per GR-326
3.3.1 Materials					
Metallic Elements		R3-4			Verified from Salt Fog and Thermal Cycling/Humidity results
Index Matching Fluid or Gel		R3-5			Not allowed in connector gap
Fungus Resistance		R3-6	5 plugs & adapters		ASTM-G21-70. Rating of 0

FOC Test Requirements for HARDENED Multi-Fiber Optical Connectors (HMFOC)– based on GR-326, 771& 3120 (Task references from GR-326)					
Task	**Test Group**	**Reference Spec.**	**Samples**	**Optical Monitor**	**Comments**
Flammability		R3-7	*"A minimum of ten test specimens, 125+/-5mm long by 13+/-0.5mm wide, and provided in the minimum and maximum thicknesses for each type of polymeric material used in the DUT. The maximum thickness of the test samples is not to exceed 13mm. See UL 94 for additional sample preparation information."*		V-1 or better / UL 94, Oxygen index of 28% or > per ASTM D-2863-87. If test bars are not available, testing can be performed using UL 746 "End Product Flame Testing" as an alternative to the material UL 94 tests.
Cable Media		R3-8			The cable media must meet VZ.TPR.9430 and/or VZ.TPR.9437 cable and VZ.TRP.9431
3.3.2 Cleanability		O3-9	5 plugs/jacks		5 jumpers with minimum length jumper cords
3.4 Intermateability					
Intermateability		CR3-10	5 Plugs/jacks		FOCIS-n (new product and after service life) or manufacturers drawings of the product. If the FOCIS document is not available the dimensional criteria shall be per the manufacturer's production specification.
Ferrule Extension Contact Force		CR3-11	5 plugs/jacks		Per FOCIS-n doc If the FOCIS document is not available, Contact force is per the manufacturer's production specification.

FOC Test Requirements for HARDENED Multi-Fiber Optical Connectors (HMFOC)– based on GR-326, 771& 3120 (Task references from GR-326)					
Task	**Test Group**	**Reference Spec.**	**Samples**	**Optical Monitor**	**Comments**
Length Requirements		CR3-12	5 plugs/jacks		Per FOCIS-n doc. If the FOCIS document is not available the length requirements shall be per the manufacturer's production specifications.
Adapter Sleeve Latch Spacing		CR3-14	5 plugs/jacks		This criterion is applicable only to push/pull type designs. Latch spacing per FOCIS-n
Glass Transition		CR3-15	5 plugs/jacks		Measure glass transition of body material, Glass Transition > 100ºC
3.4.1 Latching Intermateability		CO3-16	144 plugs & 144 jacks		This criterion is applicable only to push pull designs.
3.5 Product Marking and Packaging					
Product Marking		R3-17			Supplier, model or series, vintage code (adapters - 6 months; plugs – 3 months) - date code.
3.5.1 Keying		O3-21			Connector plug should be keyed
3.6 Safety					
Radiation Hazard		R3-22			Documentation Review
Cleaning Materials		R3-23			Documentation Review
General Safety		R3-24			No sharp edges, burrs or hazards
3.7 Quality					
TL-9000		R3-25			Must be TL-9000 certified
4.0 Connector Tests and Criteria (Service Life)					
4.2.2.5 Handling of Nonconformance		R4-1			

FOC Test Requirements for HARDENED Multi-Fiber Optical Connectors (HMFOC)– based on GR-326, 771& 3120 (Task references from GR-326)					
Task	**Test Group**	**Reference Spec.**	**Samples**	**Optical Monitor**	**Comments**
4.4 Statement of Criteria					
GR-326 4.4.5 Geometry Requirements					
4.4.5.1 Ferrule Endface Geometry: per IEC 61755-3.3 (Verizon modified)	A-1	R4-60	All		Per IEC 61755-3.3 (Verizon modified): Fiber Height H, Ha, Hb, Coplanarity, Endface Angle (Must be performed during assembly, prior to the final assembly of the plug)
4.4.5.3 Endface Geometry Measurements: Per IEC 61300-3-30	A-1	R4-61	All		Per IEC 61755-3.3 (Verizon modified): Fiber Height H, Ha, Hb, Coplanarity, Endface Angle
4.4.1 Performance of New Product	A-2	R4-2	All	IL	Table 1: New Product (Max Loss - Requirement)
		O4-3		IL	Table 1: New Product (Max Loss - Objective)
		R4-4		IL	Table 1: New Product (Mean Loss - Requirement)
		O4-5		IL	Table 1: New Product (Mean Loss - Objective)
		R4-6		RL	Table 2: New Product (Max Reflectance - Requirement)
4.4.2 Temp/Hum/Cond Test					
4.4.2.1 Thermal Age Testing	A-3		16 pigtail pairs, 5 hot spares	IL/RL (B/A);CIT/ CIR	85ºC/168h
		R4-7*			
		O4-8**			
4.4.2.2 Thermal Cycle Test	A-4		16 pigtail pairs, 5 hot spares	IL/RL (B/D/A); CIT/CIR	−40°C to +75°C; 7 days; Dwell Time:1 hour (per GR-326, Figure 4-3) - see note[1]
		R4-9*			
		O4-10**			

FOC Test Requirements for HARDENED Multi-Fiber Optical Connectors (HMFOC)– based on GR-326, 771& 3120 (Task references from GR-326)					
Task	**Test Group**	**Reference Spec.**	**Samples**	**Optical Monitor**	**Comments**
4.4.2.3 Humidity Aging Test	A-5	R4-11* O4-12**	16 pigtail pairs, 5 hot spares	IL/RL (B/D/A); CIT/CIR	75º C / 95% RH, 7 days - Measurements every 6hrs minimum
4.4.2.4 Humidity/Condensation Cycling Test	A-6	R4-13* O4-14**	16 pigtail pairs, 5 hot spares	IL/RL (B/D/A); CIT/CIR	−10°C to +65°C, 90% - 100% RH; 7 days; (per GR-326, Figure 4-4) see note[2]
4.4.2.5 Dry-Out Step	A-7		16 pigtail pairs, 5 hot spares		24 hrs @ 75°C, uncontrolled humidity
4.4.2.6 Post-Condensation Thermal Cycle Test	A-8	R4-15* O4-16**	16 pigtail pairs, 5 hot spares	IL/RL (B/D/A); CIT/CIR	−40°C to +75°C; 7 days; Dwell Time:1 hour (per GR-326, Figure 4-3) see note[1]
GR-771 5.4.4: Freeze/Thaw	A-9	R4-17* O4-18**	16 pigtail pairs, 5 hot spares	IL/RL (B/D/A); CIT/CIR	10 cycles of Freeze Thaw per VZ.TPR.9407; Place half of the samples fully mated and half with dust caps four inches from the bottom in the middle of the handhole. See note[8]
GR-771 5.4.6: Water Resistance	A-10	R4-19	16 pigtail pairs, 5 hot spares	None Required	No Water Intrusion after 7 days, 10ft water head.
4.4.3 Mechanical Tests: For all mechanical tests besides the optical pass/fail criteria defined below, there shall be no damage to cable, connector and clamping hardware					
4.4.3.1 Vibration Test	A-11	R4-20* O4-21**	16 pigtail pairs, 5 hot spares	IL/RL (B/A); CIT/CIR	10 - 55 Hz, 45 Hz/min, 2 hours @ amplitude of 1.5mm; X/Y/Z Axis (Measurements before and after each axis). See note[8]
4.4.3.2 Flex Test	A-12	R4-22*	16 pigtail pairs, 5 hot	IL/RL	8 flex cycles @ 0º, 90º, 0º, -90º, 0º: - 10.0 lbf load; -

FOC Test Requirements for HARDENED Multi-Fiber Optical Connectors (HMFOC)– based on GR-326, 771& 3120 (Task references from GR-326)					
Task	**Test Group**	**Reference Spec.**	**Samples**	**Optical Monitor**	**Comments**
		O4-23**			
GR-771 6.3.4: Cable Torsion	A-13	R4-24*	16 pigtail pairs, 5 hot spares	IL/RL (B/A); CIT/CIR	10 Torsion cycles @ 0º, 90º, 0º, -90º, 0º: -30ºC and 40ºC; 1 meter back. See note[8]
		O4-25**			
4.4.3.4 Proof Test	A-14	R4-26*	16 pigtail pairs, 5 hot spares	IL/RL (B/A); CIT/CIR	-30ºC & 40ºC @ 0º; 25lbf (Req) for 1 minute See note[8]
		O4-27**			
		R4-28*			-30ºC & 40ºC @ 90º; 10lbf (Req) for 1 minute. See note[8]
		O4-29**			
		R4-30*			-30ºC & 40ºC @ 0º; 50 lbf (Obj) for 1 minute. See note[8]
		O4-31**			
		R4-32*			-30ºC & 40ºC @ 90º; 20 lbf (Obj) for 1 minute. See note[8]
		O4-33**			
		R4-34*			-30ºC & 40ºC @ 0º; 100 lbs for 1 minute - Plug/Cap Pull. See note[8]
		O4-35**			
4.4.3.5 Transmission With Applied Tensile Load	A-15	R4-35***	16 pigtail pairs, 5 hot spares	IL/RL (B/D/A); CIT/CIR	0º, 90º and 135º@ 10.0 lbf load for 30 minutes; -30ºC and 40ºC. See note[8]
		O4-36****			

FOC Test Requirements for HARDENED Multi-Fiber Optical Connectors (HMFOC)– based on GR-326, 771& 3120 (Task references from GR-326)					
Task	**Test Group**	**Reference Spec.**	**Samples**	**Optical Monitor**	**Comments**
4.4.3.7 Impact	A-16	R4-37*	16 pigtail pairs, 5 hot spares	IL/RL (B/A); CIT/CIR	1. Test Jacks from first 8 samples and Plugs from second 8 samples. 2. Test are performed with HMFOC endcaps installed on DUT 3. Impact hammer surface shall be rigid (concrete or steel) flat surface approximately 10”x10” Mass = 2 lbs (mass) 4. Impact velocity 9.46 m/s 5. Impact Method – Spring Impact 6. Connector Plug is aligned such that center of hammer surface is aligned with the center of the connector plug 7. The hammer surface shall be perpendicular to the motion of the hammer prior to striking the DUT surface 8. DUT is suspended vertically with 1 meter of cable, cable end is fixed, the connector end is free to swing. 9. Five Impacts at –40°C 10. Impact 4 times, every 90° around connector axis and one on the end. (Connector suspended horizontally for end impact.) 11. Inspect for Damage.
		O4-38**			
		R4-39*			If DUT does not comply at –40°C perform test at –20°C,
		O4-40**			

FOC Test Requirements for HARDENED Multi-Fiber Optical Connectors (HMFOC)– based on GR-326, 771& 3120 (Task references from GR-326)					
Task	**Test Group**	**Reference Spec.**	**Samples**	**Optical Monitor**	**Comments**
		R4-41*			If DUT does not comply at –20°C perform test at 0°C.
		O4-42**			
4.4.3.8 Durability	A-17		16 pigtail pairs, 5 hot spares	IL/RL (B/D/A); CIT/CIR	50 cycles durability @ -18ºC & 40ºC, measure every 5 cycles - clean every 10 matings. See note[8]
		R4-43*			1 sided or 2 sided cleaning - 90% of samples shall meet
		O4-44**			1 sided or 2 sided cleaning - 95% of samples shall meet
		R4-45*			Without cleaning - 90% of samples shall meet
		R4-46*			After 50 Insertions, all samples shall meet
		O4-47**			After 50 Insertions, all samples shall meet
		O4-48			Cleanability Objective: Not met if recleaning required
GR-3120 4.3.7 Seal under Load (Followed by O-Ring Change)	A-18	R4-49	16 pigtail pairs, 5 hot spares	None Required	7 days @ 23ºC: 10ft water head; 2.5lb (Req) - 90º; No damage. See note[8]
		O4-50			7 days @ 23ºC: 10ft water head; 5lb (Obj) - 90º; No damage. See note[8]
4.4.3.8 Durability (with O-Ring Change)	A-19		16 pigtail pairs, 5 hot spares	IL/RL (B/D/A); CIT/CIR	50 cycles durability @ -18ºC & 40ºC, measure every 5 cycles - clean every 10 matings. See note[8]
		R4-51*			1 sided or 2 sided cleaning – 90% of samples shall meet
		O4-52**			1 sided or 2 sided cleaning – 95% of samples shall meet

FOC Test Requirements for HARDENED Multi-Fiber Optical Connectors (HMFOC)– based on GR-326, 771& 3120 (Task references from GR-326)					
Task	**Test Group**	**Reference Spec.**	**Samples**	**Optical Monitor**	**Comments**
		R4-53*			Without cleaning - 90% of samples shall meet
		R4-54*			After 50 Insertions, all samples shall meet
		O4-55**			After 50 Insertions, all samples shall meet
		O4-56**			Cleanability Objective: Not met if recleaning required
GR-3120 4.3.7 Seal under Load (with O-Ring Change)	A-20	R4-57	16 pigtail pairs, 5 hot spares	None Required	7 days @ 23ºC: 10ft water head; 2.5lb (Req) - 90º; No damage. See note[8]
		O4-58			7 days @ 23ºC: 10ft water head; 5lb (Obj) - 90º; No damage. See note[8]
4.4.3.9 End of Test Criteria	A-21	R4-59*****	16 pigtail pairs, 5 hot spares	IL/RL/CIT/ CIR	Optical Requirements "End of Test"
		O4-60******			Optical Objectives "End of Test"
		R4-61			Geometry per IEC 61755-3.3 (Verizon modified):
		R4-62			No damage that would impair the performance of either the connector plug or the adapter.
GR-771 4.3.8 Crush Test	B	R4-63*	5 pigtail pairs	IL/RL (B/A)	300 lbs for 15 minutes: If not met, provide matrix for pass levels. See note[8]
		O4-64**			
GR-771 5.5.3 Rodent Resistance/Rockwell Hardness	C	R4-65	5 Test Bars	None Required	Rockwell hardness (R87)
5.0 Facilities for Product Testing					
5.1 Ambient Laboratory Conditions					Temperature:23°C ±2°C, Humidity: < 75%RH
5.2 Optical Measurements					Per VZ.TPR.9413 (system validation)
7.0 Reliability Test					

FOC Test Requirements for HARDENED Multi-Fiber Optical Connectors (HMFOC)– based on GR-326, 771& 3120 (Task references from GR-326)					
Task	**Test Group**	**Reference Spec.**	**Samples**	**Optical Monitor**	**Comments**
4.4.5 Geometry Requirements					
4.4.5.1 Ferrule Endface Geometry: Per IEC 61755-3.3 (Verizon modified):	All	R4-60	All		Per IEC 61755-3.3 (Verizon modified): Fiber Height, Coplanarity, Endface Angle
4.4.5.3 Endface Geometry Measurements: Per IEC 61300-3-30	All	R4-61	All		Per IEC 61755-3.3 (Verizon modified): Fiber Height, Coplanarity, Endface Angle
GR-326 4.4.1 Performance of New Product	All	R4-2	All	IL	Table 1: New Product (Max Loss - Requirement)
		O4-3		IL	Table 1: New Product (Max Loss - Objective)
		R4-4		IL	Table 1: New Product (Mean Loss - Requirement)
		O4-5		IL	Table 1: New Product (Mean Loss - Objective)
		R4-6		RL	Table 2: New Product (Max Reflectance - Requirement)
Extended Thermal Age	D	R7-1*	22 Jumper Cable Assemblies (44 connectors) (LTPD 10%)	IL/RL (B/D/A)	85°C (±5°C), < 40% RH, 2,000 hrs. for qualification and ≥ 5000 hrs (optional) for information. IL measurements initially, and then at 168- (optional), 500-, 1000-, and 2000-hour intervals. Per GR-1221, section 6.24 (See note[8])
		O7-2**			
Extended Humidity	E	R7-3*	22 Jumper Cable Assemblies (44 connectors) (LTPD 10%)	IL/RL (B/D/A)	75°C (±5°C), 95% (± 5%) RH, 2,000 hrs. for qualification and ≥ 5000 hrs (optional) for information. IL measurements initially, and then at 168- (optional) 500-, 1000-, 2000-hour intervals. Per GR-1221, section 6.25 (See note[8])
		O7-4**			
Extended Thermal Cycling	F	R7-5*	22 Jumper Cable	IL/RL	- 40°C to 85°C (± 2°C) ≥ 30 minutes dwell time at

FOC Test Requirements for HARDENED Multi-Fiber Optical Connectors (HMFOC)– based on GR-326, 771& 3120 (Task references from GR-326)					
Task	**Test Group**	**Reference Spec.**	**Samples**	**Optical Monitor**	**Comments**
		O7-6**			
GR-326 4.4.4.1 Dust Test	G	R7-7*	10Pigtail Assemblies 10 Plugs and 10 Jacks	IL/RL (B/A)	Perform testing per GR-326, section 4.4.4.1 (configure: 5 Plug to Jack, 5 Plug to Dust Cap and 5 Jack to Dust Cap)
		O7-8**			
4.4.4.3 Airborne Contaminants	H	R7-10*	10Pigtail Assemblies 10 Plugs and 10 Jacks	IL/RL (B/A)	Perform testing per GR-326, section 4.4.4.3 (configure: 5 Plug to Jack, 5 Plug to Dust Cap and 5 Jack to Dust Cap)
		O7-11**			
GR-326 4.4.4.4 Salt Spray	I	R7-12*	10 Pigtail Assemblies 10 Plugs and 10 Jacks	IL/RL (B/A)	Perform testing per GR-326, section 4.4.4.4 (configure: 5 Plug to Jack, 5 Plug to Dust Cap and 5 Jack to Dust Cap)
		O7-13**			
GR-326 4.4.4.6 Groundwater Immersion	J	R7-15*	20 Pigtail Assemblies: 5 per fluid and 20 mating adapters	IL/RL (I/D/E)	4 immersion media (organism not required), 22°C ±2°C for 7 days: Measure before immersion, upon immersion, after 24 hours, after 7 days (while in fluid)
		O7-16**			
GR-326 4.4.3.9 End of Test Criteria	ALL	R4-57*****	ALL	IL/RL/CIT/ CIR	Optical Requirements "End of Test"
		O4-58******			Optical Objectives "End of Test"
		R4-60			Geometry Per IEC 61755-3.3 (Verizon modified)
		R4-59			No damage that would impair the performance of either the connector plug or the adapter.
GR-3120, 4.9.10 Chemical Resistance - Stress Cracking	K	R7-17	10 test bars	None Required	24 hours - chemicals as specified, no damage, no change in weight greater than 10 % nor Tensile/Elongation greater than 20%

FOC Test Requirements for HARDENED Multi-Fiber Optical Connectors (HMFOC)– based on GR-326, 771& 3120 (Task references from GR-326)					
Task	**Test Group**	**Reference Spec.**	**Samples**	**Optical Monitor**	**Comments**
GR-3120, 4.9.11Chemical Resistance - Product Immersion	L	R7-18	3 dogbone samples and 3 pigtailed samples per chemical	None Required	Immerse 3 dogbones and 3 pigtailed samples in each chemical for 7 days. No change in weight > 10% or tensile and elongation > 20% for dogbones allowed. No damage to pigtails.
GR-771, 5.4.9: UV Resistance	M	R7-19	10 test bars	None Required	90 days, no damage, no damage, no change in weight greater than 10 % nor Tensile/Elongation greater than 20%
8.0 Reliability Assurance Program					
8.2 Manufacturing and Process Control					Per VZ.TPR.9445
Repeatability & Accuracy requirement					Bench Top Optical System TPR.9413 Switch Based Optical System TPR.9413 End Face Geometry TPR.9458

Optical Measurements

- Loss (100% of channels to be monitored)
- B – Before IL & RL Optical Testing @ (1310, 1490, 1550 & 1625 nm)
- D – During IL & RL Optical Testing @ (1310, 1490, 1550 & 1625 nm)
- A – After IL & RL Optical Testing @ (1310, 1490, 1550 & 1625 nm)
- I initial (under load) IL & RL Optical Testing @ (1310, 1490, 1550 & 1625 nm)
- E – End of test (under load) IL & RL Optical Testing @ (1310, 1490, 1550 &1625 nm)
- CIT (Change in Transmittance)[1] Calculation - CIT = A^{IL}-B^{IL}
- CIR (Change in Reflectance)[2] Calculation - CIR = A^{RL} – B^{RL}
- No measurements are required on hot spares until they become replacements.
- Concatenation of test samples is not allowed.

*	Table 1 & 2: "During Test, Not Under Load" (Requirements)
**	Table 1 & 2: "During Test, Not Under Load" (Objectives)
***	Table 1 & 2: "During Test, Under Load" (Requirements)
****	Table 1 & 2: "During Test, Under Load" (Objectives)
*****	Table 1 & 2: "End of Test" Requirements
******	Table 1 & 2: "End of Test" Objectives

Geometry Criteria:

Product Geometry is to be performed per the most recent revision of IEC 61755-3.3 (Verizon-modified) and measurements are to be performed to the most recent revision of IEC 61300-3-30

FOCIS-n Document to be utilized in conjunction with IEC 61755-3.3 (Verizon-modified). If requirement is not specified in either document, utilize the manufacturer's specifications.

Sample configuration:

- Add 5 unmated jacks and 5 unmated plugs with caps and subject to all environmental tests. No optical are required. These are to be used for the impact matrix as needed.
- Mechanical Testing: Test both plugs and jacks
- HMFOC with a minimum of 25 feet of cable.
- If there are different types of stubs used that are based on length, then both types must be tested. Splitting sample sets is acceptable.
- All connector variations and cable variations must be tested. Evaluation of one connector with a specific cable does not carry over to all cable types.
- Current Verizon requirement of 10 and 12-fiber connectors. (4 and 8 fiber connectors are to be built from the center out using the 12-fiber connector footprint)

[1]Only increases in Insertion Lossare a concern. A decrease in Insertion Loss is not a concern.
[2]Only increases in reflectance are an issue. A decrease in reflectance is not a concern.

- Product must meet the geometry requirements as specified in this document and supporting documentation. If product geometry is not met, supplier must provide documentation to Verizon supporting their values with reasoning why their product will meet the intermateablility testing requirements.
- A 12-fiber connector would cover a 4 and 8 fiber product provided the 12-fiber ferrule is utilized for all products.

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 the specified Cleaning Procedure, 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.

Testing Sequences:

The following table will define the test sequences for the Service Life testing requirements.

Table 1 (Service Life)			
Sample Group	**Test Sequence**	**Title**	**Section**
A	1	Ferrule Endface Geometry	4.4.5
A	2	New Product Measurement	4.4.1
A	3	Thermal Age Test	4.4.2.1
A	4	Thermal Cycling	4.4.2.2
A	5	Humidity Age	4.4.2.3
A	6	Humidity / Condensation Cycling Test	4.4.2.4
A	7	Dry-out Step	4.4.2.5
A	8	Post-Condensation Thermal Cycle	4.4.2.6
A	9	Freeze/Thaw	GR-771 5.44
A	10	Water Resistance	GR-771 5.46
A	11	Vibration Test	4.4.3.1
A	12	Flex Test	4.4.3.2
A	13	Cable Torsion	4.4.3.3
A	14	Proof Test	4.4.3.4
A	15	Transmission With Applied Tensile Load	4.4.3.5
A	16	Impact Test	4.4.3.7
A	17	Durability	4.4.3.8
A	18	Seal Under Side Load (Followed by O-ring Change)	GR-3120 4.4.3.8
A	19	Durability (with O-ring Change)	4.4.3.8
A	20	Seal Under Side Load (with O-ring Change)	GR-3120 4.4.3.8
A	21	End of Test Criteria (Optical, Ferrule Geometry and Damage)	4.4.3.9 & 4.4.5
B		Crush Test	
C		Rockwell Hardness	

Testing is to be performed sequentially as defined in the above table.

The following table will define the test sequences for the Reliability testing requirements.

Table 2 (Reliability)			
Sample Group	**Title**	**Section**	**Sample Type**
ALL	Ferrule Endface Geometry (Initially - all samples)	4.4.5	
D	Extended Thermal Age	GR-1221, Section 6.2.4	Pigtail Assembly
E	Extended Humidity Age	GR-1221, Section 6.2.5	Pigtail Assembly
F	Extended Thermal Cycling	GR-1221, Section 6.2.7	Pigtail Assembly
G	Dust	4.4.4.1	Pigtail Assembly
H	Airborne Contaminants	4.4.4.3	Pigtail Assembly
I	Salt Spray	4.4.4.4	Pigtail Assembly
J	Ground Water Immersion	4.4.4.6	Pigtail Assembly
ALL	EOT (Il/RL, Ferrule Endface Geometry, Damage)	4.4.5	
K	Chemical Resistance - Stress Cracking (material)	GR-3120 4.9.10	Test Bars
L	Chemical Resistance - Product Immersion	GR-3120 4.9.11	Pigtail Assembly (Plug/Jack)
M	UV Resistance	GR-771 5.4.9	Test Bars

Testing is to be performed per the sequences defined in the above table. Please note that since each test (except for initials and finals) use separate sample sets the order of testing is not important.

- Initially, all samples must meet the new product measurement requirements as defined in Tables 1 and 2 and the End Face Geometry requirements as defined in of IEC 61755-3.3 (Verizon modified).
- At the completion of test, all samples must the optical requirements as specified in Tables 1 and 2, the Damage requirements as specified in this document and the Endface Geometry requirements as specified in of IEC 61755-3.3 (Verizon modified).

Optical Requirements:

Insertion Loss Criteria

Table 3: Summary of Optical Performance Criteria: Loss						
Test	**Maximum Loss**		**Mean Loss[3]**		**Loss Increase**	
	(R)	**(O)**	**(R)**	**(O)**	**(R)**	**(O)**
New Product	0.65	0.50	0.35	0.30	---	---
During Test, Not Under Load	0.85	0.65	0.40	0.35	0.40	0.30
During Test, Under Load	---	---	---	---	0.60	0.40
End of Test	0.85	0.65	0.40	0.35	---	---

RL Test Criteria

Table 4: Summary of Optical Performance Criteria: RL		
Test	**Reflectance**	**Increase in Reflectance**
	(R)	**(R)**
New Product	-65	---
During Test, Not Under Load	-65	5
During Test, Under Load	-65	5
End of Test	-65	5

[3] See Note 8 on p.23.

Notes:

Note 1: Measurement to be preformed at every plateau - wait minimum of 30 minutes into cycle before starting. (Cycle may be modified by decreasing transition time and increasing hold times if need to complete measurements.)

Note 2: Humidity is only controlled above freezing (0°C).

Note3: (Service Life) The tensile test fixturing is to be designed with a bracket to hold the coupling adapter in angular increments of 45° about the axis of the connector. During testing, the sample of product is to be rotated as evenly as possible between the eight angular positions to ensure all angles are tested. (i.e.- sample 1@0°, sample 2@45°, sample4@90°, etc.). Tensile Testing encompasses Flex, Twist, Proof and Transmission with Applied Load. . The 45° connector rotation criterion is only applicable to assemblies that utilize round cable. For assemblies that utilize rectangular cable, the connector cable assembly is to be tested with the cable in its two preferred bend direction. Square cable is to be tested in the four flat edged directions.

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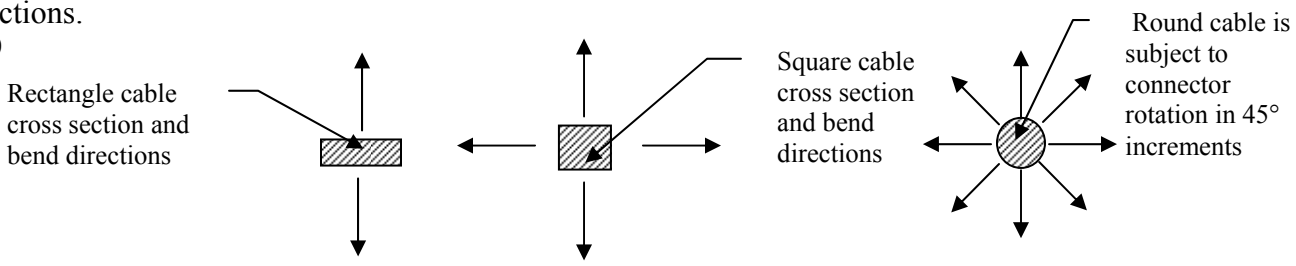

Note 4: Decrease in reflectance is not of concern. Note that the definition of "reflectance" is that of a negative number, as opposed to Optical Return Loss, which is a positive number. The terms "greater than" and "less than" are applied to the numerical values of the reflectance, and not the absolute values of these numbers. Thus, a -50 dB reflectance is greater than a -60 dB reflectance.

Note 5: RL readings of >65 db are usually outside of the test set-ups capability and the resultant delta value may be outside the allowable range, thus technically interpreted as a failure. Since the value is excellent and readings are not reliable above the 65 db level for many set-ups, the delta should not be considered as a failure.

Note 6: Optical readings - during are to be taken at the maximum sampling rate.

Note 7: The most stringent criteria is to be used as the pass/fail criteria i.e.: GR criteria, Verizon specifications, or supplier's specifications. The suppliers spec sheet is to be included in the test plan and report in the product description section of the document**.**

Note 8: Mean of total population (16 samples). The mean value shall be calculated per connection for 16 samples. For example mean value for port-1 will be mean of port-1 values

from sample 1 to 16 and for port-2 will be mean value of port-2 values from sample 1 to 16. Measurements are taken at each test condition.

Extended Thermal Cycling (Reliability) Test
The test conditions for the Extended Thermal Cycle Test are shown in Figure 1 below.

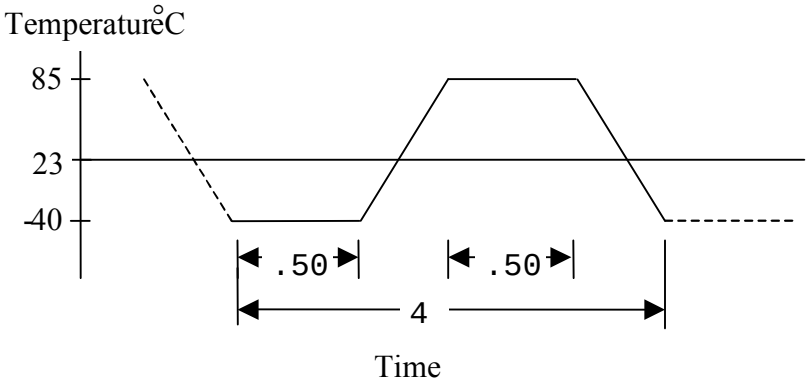

Figure 1: Temperature Profile for Extended Thermal Cycle Test

Extended Thermal Cycle Test Conditions

Temperature: Cycle in Figure 1 (-40°C to 75°C).

All ramp times are 1.4°C per minute, all plateaus are 30 minutes

Humidity: Uncontrolled

Duration: 500 cycles in 2000 hours

Measurement of Insertion Loss and Reflectance: Data shall be taken initially, and then at the completion of 125 cycles and at the completion of 500 cycles.

FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS

61755-3-3: Fibre optic connector optical interfaces - Part 3-3: Optical interface angled PC endface rectangular ferrule, single mode fibre (Verizon Modified)

1 Scope

IEC 61755 Part 3-3 defines certain dimensional limits that an angled PC endface multifiber rectangular ferrule having two guide-holes for positioning two alignment pins and using typically plastic material with a Young's modulus of less than 25 GPa has to meet in order to meet specific requirements for fibre-to-fibre interconnections. Ferrules made from the material specified in this document are suitable for use in category C as defined in IEC61753-1.

2 Description

The performance of optical interface for an angled PC endface multi-fiber rectangular ferrule is determined by the accuracy with which the optical datum targets of two mating ferrules are aligned with each other. There are three conditions affecting the alignment of two optical datum targets, lateral alignment, angular alignment and axial alignment.
Parameters influencing the lateral and angular alignment of the optical fiber axes.

- Fiber hole position deviation from designated distance
- Clearance between fiber hole diameter and fiber cladding diameter
- Fiber hole angular misalignment
- Fibercore concentricity relative to the cladding diameter
- Clearance between guide hole diameter and alignment pin diameter
- The amount of angled PC polishing in axial direction

Parameters influencing the axial alignment of the optical fiber axes.

- Endface flatness
- Endface angle in the X-axis
- Endface angle in the Y-axis
- Fiber protrusion/undercut
- Maximum difference in fiber height among all fibers
- Maximum adjacent fiber height differential

Ferrule compression force and ferrule material must be considered together with these parameters.

3 Optical interface parameters

This standard defines the dimensional limits of the angled PC endfacemulti-fiber rectangular ferrule with singlemode fibers. It is applicable for up to 12 fibers with an alignment pitch of 0.25 mm.
The optical interface parameters are defined as shown in Figures 1, 2 and 3.
The parameter values are described as shown in Tables 1and 2.

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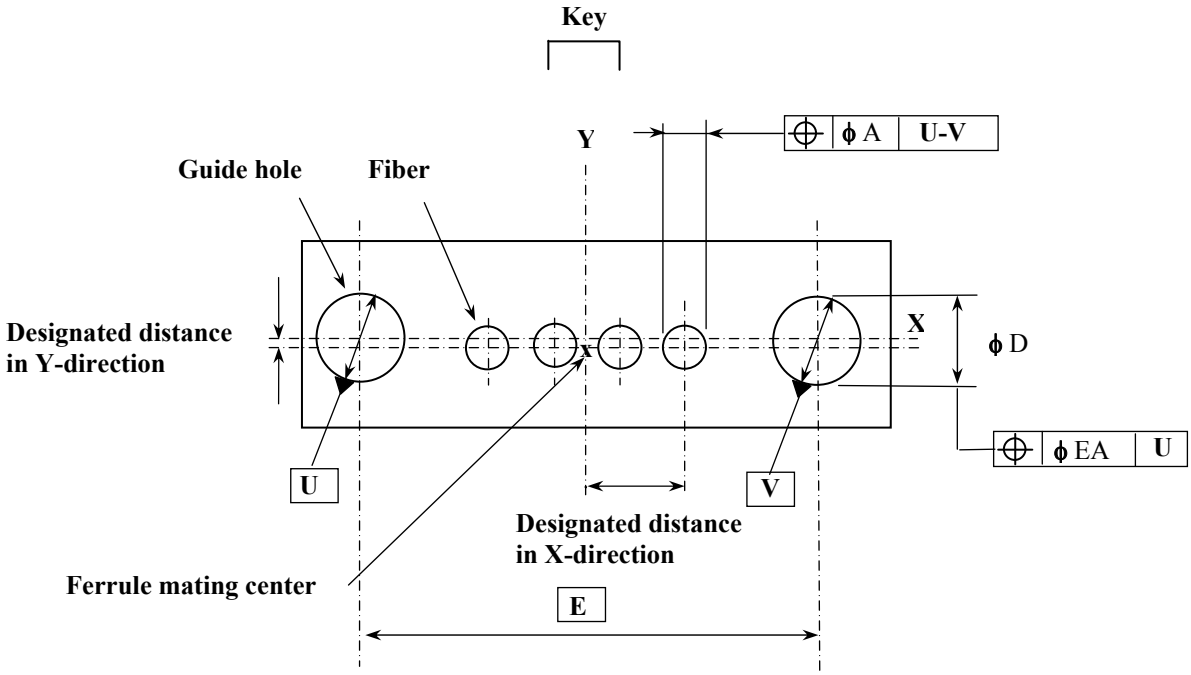

X-axis: the line passing through two guide hole centers.

Y-axis: the line perpendicular to X-axis and passing through the midpoint of the line connecting the two guide hole centers.

Designated distance in X-direction: (0,125 + (n/2 - 1)x 0,25) mm in the right and left directions, where n = 2, 4, 8, 10, 12 (number of fibers)for 6,4 mm x 2,5 mm rectangular ferrules, and n = 2, 4 for 4,4 mm x 2,5 mm rectangular ferrules.

Designated distance in Y-direction:
(Basic dimension of guide hole diameter **D** – basic dimension of alignment pin diameter **I**) / 2.

Here, the basic dimension of **I** is 0,6985 mm. The basic dimension of **D** is usually a nominal value which is an average of the minimum and maximum values in tables 1and 2, and it may be slightly shifted according to the designed minimum and maximum values.

A: position tolerance of fiber core center

EA: position tolerance of guide holecenter

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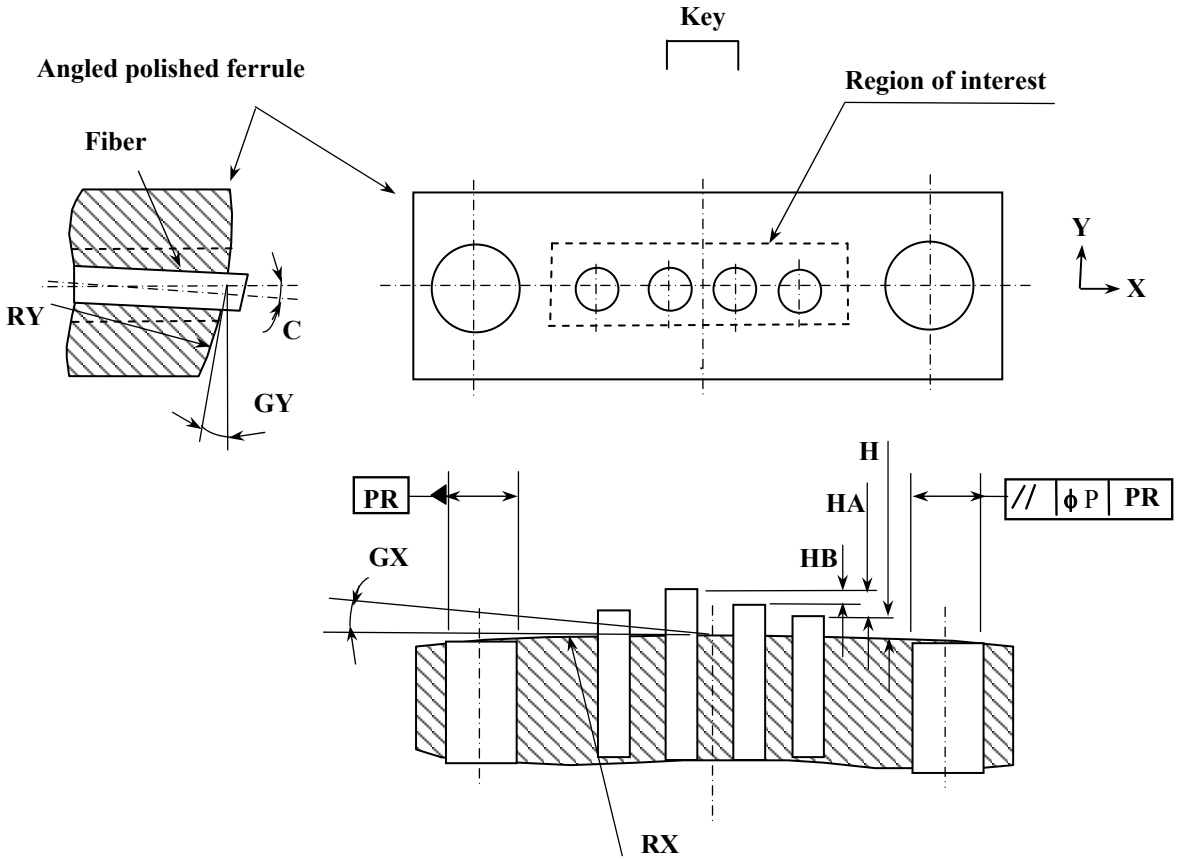

Figure 1 -Fiber core lateral location

H: Fiber protrusion/undercut.
HA: Maximum difference in fiber height among all fibers.
HB: Maximum adjacent fiber height differential.

Note: The region of interest is set on the ferrule surface and defined by a rectangular region, which is chosen to cover the intended contact zone of the ferrule endface when the ferrules are mated.

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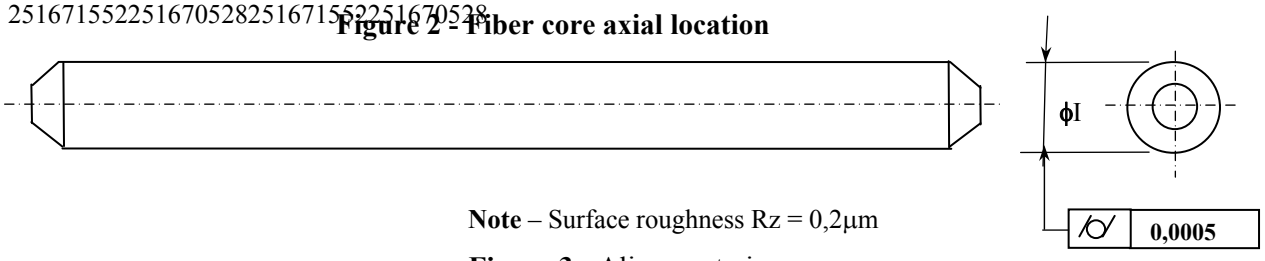
Figure 2 - Fiber core axial location



Note – Surface roughness Rz = 0,2µm

Figure 3 - Alignment pin

Table 1 - Optical interface parameter values on attenuation for 4,4 mm x 2,5 mm rectangular ferrules with two and four fibres fixed

Reference	Parameter values						Notes
	Grade B		Grade C		Grade D		
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	
A	0	0,0016mm	0	0,0024mm	0	0,0034mm	
C	-	0,2 °	-	0,2 °	-	0,5°	
D	0,6990mm	0,6996mm	0,699 mm	0,700 mm	0,699 mm	0,700 mm	1
E	2,6 mm		2,6 mm		2,6 mm		Basic dimension, 1
EA	-	0,004 mm	-	0,004 mm	-	0,004 mm	1
P	-	0,002 mm	-	0,002 mm	-	0,002 mm	2,3
RX	2000mm	-	2000mm	-	2000mm	-	2, 3
RY	5mm	-	5mm	-	5mm	-	2, 3
GX	- 0,2 °	+ 0,2 °	- 0,2 °	+ 0,2 °	- 0,2 °	+ 0,2 °	2, 3
GY	7,8 °	8,2 °	7,8 °	8,2 °	7,8 °	8,2 °	2, 3
H	+0,001mm	+0,005mm	+0,001mm	+0,005mm	+0,001mm	+0,005mm	2, 3
HA	-	0,0005mm	-	0,0005mm	-	0,0005mm	2, 3
HB	-	0,0003mm	-	0,0003mm	-	0,0003mm	2, 3
I	0,6984mm	0,6986mm	0,698 mm	0,699 mm	0,698 mm	0,699 mm	

NOTES

1 Each guide-hole shall accept a gauge pin as shown in figure 4 of IEC 61754-10 to a depth of 5,5 mm with a maximum force of 1,7 N. In addition, two guide-holes shall accept a gauge as shown in figure 5 of IEC 61754-10 to a depth of 5,5 mm with a maximum force of 3,4 N.

2 These values shall be specified in the central surface region surrounding fibers of 0,900 mm wide and 0,675 mm high. Furthermore, the outside surface region must be lower than the central surface region of interest.

3 These values shall be applied to ferrule materials with a Young's modulus of less than 25 GPa. Contact force shall be 7,8 N minimum and 11,8 N maximum.

Table 2 - Optical interface parameter values on attenuation for 6,4 mm x 2,5 mm rectangular ferrules with two, four, eight, ten and twelve fibres fixed

Reference	Parameter values						Notes
	Grade B		Grade C		Grade D		
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	
A	0	0,0016mm	0	0,0024mm	0	0,0034mm	
C	-	0,2 °	-	0,2 °	-	0,5°	
D	0,6990mm	0,6996mm	0,6985 mm	0,6990 mm	0,699 mm	0,700 mm	1
E	4,6 mm		4,6 mm		4,6 mm		basic dimension, 1
EA	-	0,004 mm	-	0,004 mm	-	0,006 mm	1
P	-	0,002 mm	-	0,002 mm	-	0,002 mm	2,3
RX	2000mm	-	2000mm	-	2000mm	-	2,3
RY	5mm	-	5mm	-	5mm	-	2, 3
GX	- 0,2 °	+ 0,2 °	- 0,2 °	+ 0,2 °	- 0,2 °	+ 0,2 °	2, 3
GY	7,8 °	8,2 °	7,8 °	8,2 °	7,8 °	8,2 °	2, 3
H							See table 2a, 2, 3
HA							See table 2a, 2, 3
HB							See table 2a, 2, 3
I	0,6984mm	0,6986mm	0,6984 mm	0,6986 mm	0,698 mm	0,699 mm	

NOTES

1 Each guide-hole shall accept a gauge pin as shown in figure 2a of IEC 61754-5 to a depth of 5,5 mm with a maximum force of 1,7 N. In addition, two guide-holes shall accept a gauge as shown in figure 2e of IEC 61754-5 to a depth of 5,5 mm with a maximum force of 3,4 N.

2 These values shall be specified in the central surface region surrounding fibers of 2,900 mm wide and 0,675 mm high. Furthermore, the outside surface region must be lower than the central surface region of interest.

3 These values shall be applied to ferrule materials with a Young's modulus of less than 25 GPa. Contact force shall be 7,8 N minimum and 11,8 N maximum.

Table 2a – Fibre protrusion parameter values

Reference	Fibre protrusion parameter values				Notes
	Fibre count: 2, 4 and 8		Fibre count: 10 and 12		
	Minimum	Maximum	Minimum	Maximum	
H	+0,001mm	+0,005mm	+0,003mm	+0,015mm	
HA	-	0,0005mm	-	0,00040mm	See Coplanarity definition in the draft FOTP-219 update
HB	-	0,0002mm	-	0,0002mm	Agreed to at 2/22 meeting

Annex table for understanding attenuation grades

Single mode attenuation performance grade			
Grade	Attenuation at 97 percentile (Maximum, dB)	Attenuation Mean (Maximum, dB)	Notes
B	0,25	0,12	IECE specification doesn't refer to the sample size used in testing. Hence, these criteria are applicable to each connector individually and not to the whole sample group. For example in case of a 12 fiber connector if one fiber doesn't meet the specification then only 92% of the fibers on that connector are compliant. Hence the connector is not compliant.
C	0,50	0,25	
D	1,0	0,5	

Intermateability Testing of (MFC) Multi-Fiber Connector Jacks and Plugs

Connector Intermateability

- **Test Requirements:**

- **Endface Geometry Readings**
  See: IEC 61755-3.3 (Verizon modified) contained in this document for Hardened Multi-Fiber Optic Connector and IEC 61300-3-30 for measurement methodology.

- **Insertion Loss and Reflectance Testing**
  Insertion Loss and Reflectance readings are conducted for New Product, during the test and End of Test Criteria at four wavelengths (1310 nm, 1490 nm, 1550 nm, and 1625 nm).
  New Product measurements will be conducted with each vendor/ manufacturer's HMFOC/MFOC plug and jack. All fiber joints are to be measured for the New Product, during the test and End of Test Criteria.
  The appropriate manufacturer's launch cable (reference jumper) will be used for each connector. Reference Figure for configuration.

- **Environmental Cycle (Modified)**
  Please refer to Figure 3 for the temperature profile and data acquisition times.

- **Vibration Test.**
  Conducted in accordance with the test matrix contained within this TPR

- **Proof Test**
  Conducted in accordance with the test matrix contained within this TPR

- **Durability Test**
  Conducted in accordance with the test matrix contained within this TPR

- **Seal Under Load Test (HMFOC only)**
  Conducted in accordance with the test matrix contained within this TPR

- **End of Test Criteria**
  Insertion Loss, Reflectance, and Endface readings will only be conducted on nonconforming samples. The appropriate manufacturer's launch jumper cable assemblies (same as 1.1.2 above) will be used for each assembly, if necessary.

NOTE 1: All test samples will be tested sequentially to the tests list above.
NOTE 2: Each combination of plugs and jacks will have a sample lot as defined in Table 1.
NOTE 3: All testing to be performed at 1310 nm, 1490 nm, 1550 nm, and 1625 nm wavelengths except where noted.
NOTE 4: ITL will use manufacturer service provider specific cleaning procedures for the plugs and jacks. Only this specific cleaning procedure will be used on the DUT (Device Under Test). As an example Alcohol and Kim-Wipes and/or Cleatops will be used on surfaces not undergoing testing.
NOTE 5: The manufacturer's plugs and jacks specific installation and maintenance instructions shall be provided prior to testing.

- **Samples:**

Sample Requirements for Program Participation: The number of samples required for participating in the HMFOC Intermateability test program is given in Table 1. The sample configurations are based on the connector definitions given in Figure 4 of this document and assume two initial participants. Each succeeding program candidate "rookie" (connector) is tested against the two most recently approved connectors in reverse chronological[4] order for a maximum of three (3) participants per test program. Each test program requires ten (10) full connectors and five (5) hot spares of the new participant test samples and five (5) samples and three (3) hot spares of each of the two previously tested "veteran" participants.

NOTE - * A hot spare is defined as a mated plug and jack that is not optically monitored.

Table 1 Program Sample Requirement

Order of Participation	Manufacturer	Test Combination Plug → Jack	Number of Test Samples
Initial 2 participants	A	A → B	A - 10 + 5 for Hot Spares*
	B	B → A	B - 10 + 5 for Hot Spares*
3rd participant	A	A → C – 5 per	A - 5 + 3 for Hot Spares*
	B	B → C – 5 per	B - 5 + 3 for Hot Spares*
	C	C → A – 5 per C → B - 5 per	C - 10 + 5 for Hot Spares*
4th participant	B	B → D – 5 per	B - 5 + 3 for Hot Spares*
	C	C → D – 5 per	C - 5 + 3 for Hot Spares*
	D	D → B – 5 per D → C - 5 per	D - 10 + 5 for Hot Spares*

[4] If A, B, and C are already approved and D wishes to participate, then D is tested against B and C.

Order of Participation	Manufacturer	Test Combination Plug → Jack	Number of Test Samples
5th participant	C	C → E – 5 per	C - 5 + 3 for Hot Spares*
	D	D → E – 5 per	D - 5 + 3 for Hot Spares*
	E	E → C – 5 per E → D - 5 per	E - 10 + 5 for Hot Spares*

The following list of samples and supplies are required from each supplier participating in the program:

- Four (4) sets – Hybrid jumpers capable of interfacing with the test measurement equipment with a HMFOC 1-meter launch fiber optic cable are required. Two (2) styles of launch cables will be needed, one for the plug and one for the jack for a total of eight (8) test cables. The manufacturing process and end face geometry on the MFC launch cable connector shall be representative of all other test samples.

- New Participant samples requirements – 15 each (plugs and jacks) jumper cable assembly's hybrid jumpers capable of interfacing with the test measurement equipment. Please see Figure 1, for plug/jack assembly details. (10 samples required with 5 spares).

- Veteran Participant Sample Requirements: 8- hybrid jumpers capable of interfacing with the test measurement equipment. Please see Figure 4, for plug/jack assembly details. (5 required with 3 spares for each participant).

- To prevent water seepage through the length of the cable during the seal under load test sequence, the drop cable portion of the plug and jack connector may be sealed with silicone or other appropriate means as shown in Figure 1 below. Alternatively, if equipped with water blocking capability, lengthening the plug and jack drop cable may be used as a method for preventing cable water seepage during the "Seal Under Load" test. See Insertion loss and reflectance testing of this document for the cable length impact on "Reflectance Test Results".

- Supplies and specific instructions as used by the service provider for the cleaning system for the MF-HFOC plug and jack.

- Specific Instructions for installing and maintaining the MF-HFOC connector and/or adapter.

- 1 extra set of O-rings/seals for each connector under test.

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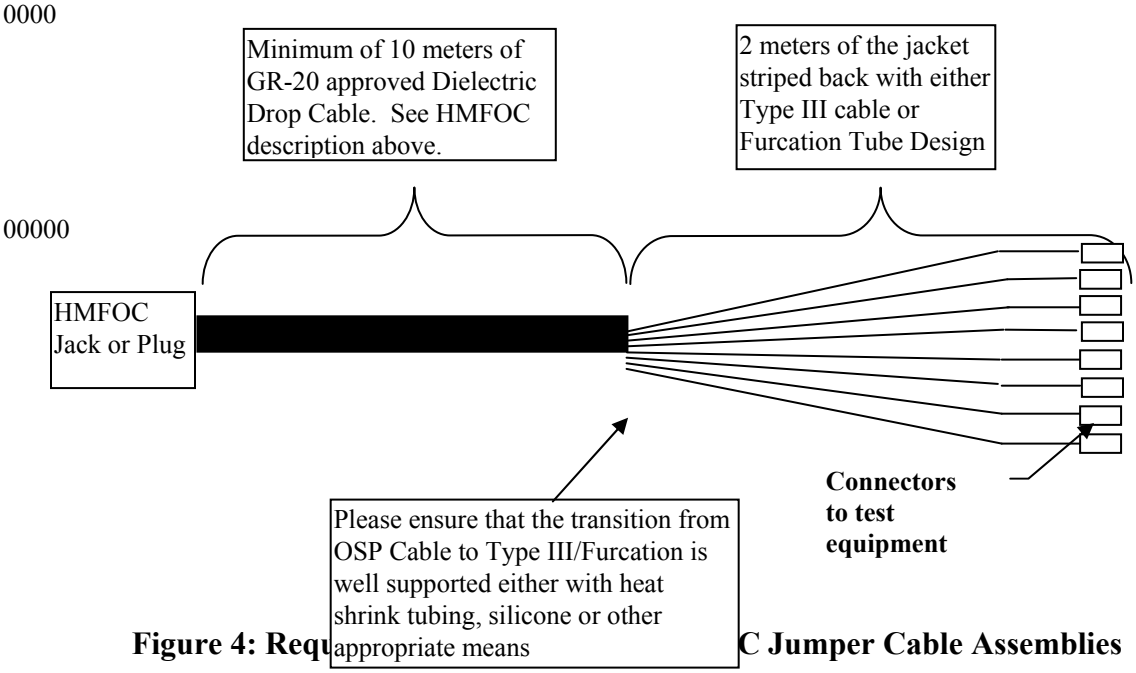

Figure 4: Requ C Jumper Cable Assemblies

- **Test Specifics:**

- **Endface Geometry Readings**

  Endface geometry readings will be performed on all DUT samples (Jacks and Plugs) as an out of the box "New Product".

- **Insertion Loss and Reflectance Testing**

  New Product Insertion Loss and Reflectance readings will be conducted on all HMFOC jumpers utilizing the appropriate launch cable. Please refer to Figure 5, for configuration specifications.

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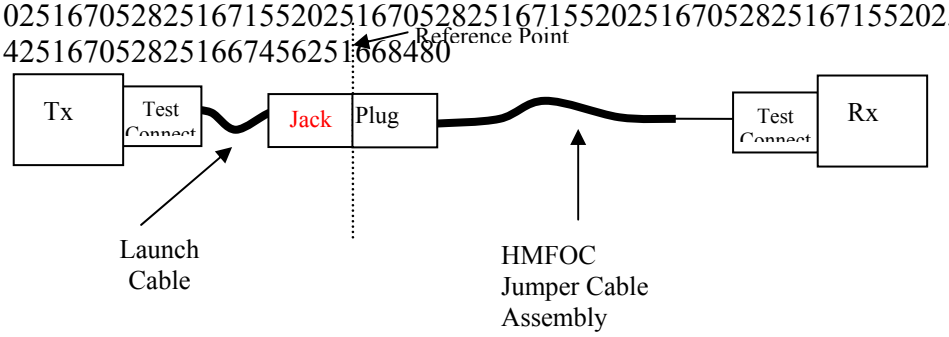

Figure 5: Test Setup

If the length of the HMFOC drop cable is increased beyond the required minimum (such as to prevent cable water seepage), then the reflectance measurements conducted during the intermatability test sequence may be adjusted to compensate for the added BR of the additional HMFOC fiber length. All correction factors and data calculations shall be included in the test report.

- **Environmental Cycle**

  The connector assembly, which includes a minimum of 25 feet of the connector cable and an extra set of O-rings from each of the participating manufacturers will be placed in a conditioning chamber and subjected to the temperature profile shown in Figure 6 below. Insertion Loss and Reflectance Readings shall be taken every two hours throughout the test.

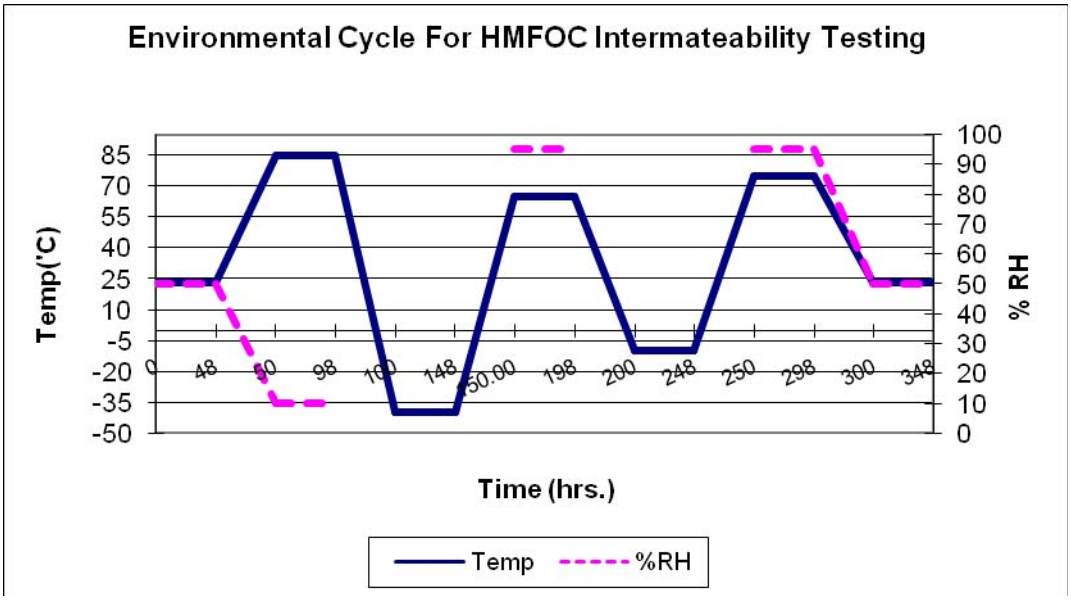

Figure 6: Environmental Cycle for HMFOC Intermateability Testing

- **Vibration Testing**

  Conducted in accordance with the test matrix contained within this TPR. Please note that the samples will not be monitored during the actual vibration sweeps.

- **Proof Test**

  Conducted in accordance with the test matrix contained within this TPR.

- **Durability Test**

  Fifty cycles will be performed at -18°C (0°F) and fifty cycles will be performed at 40°C (115°F) as per the combinations shown in Table 1. Conducted in accordance with the test matrix contained within this TPR.

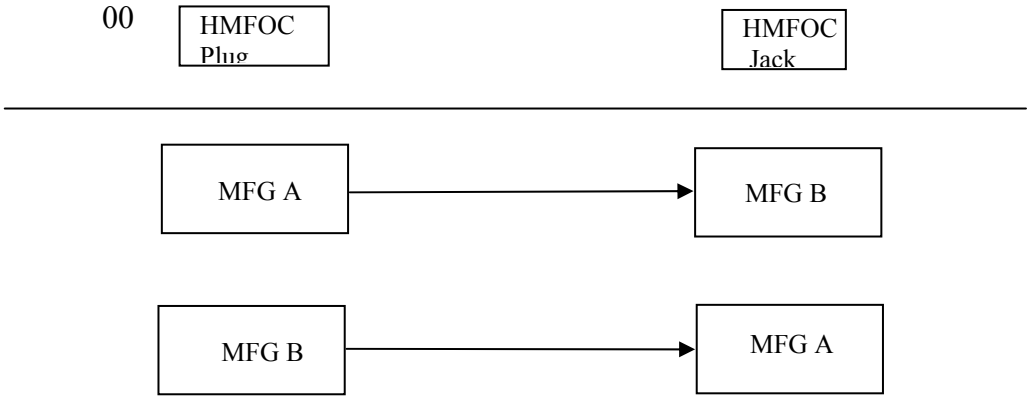

Figure 7: Combination for the Durability Test

a. The required number of connector assemblies as shown in the Table 1 shall be tested.
b. The connectors shall then be conditioned at –18° C for two hours.
c. Each connector shall be disconnected and re-connected.
d. Insertion loss and reflectance are measured at 1310 nm, 1490 nm, 1550nm and 1625 nm wavelength after each disconnect and re-connect operation.
e. The test sequence is continued until all connectors have been cycled (removed and inserted) 50 times. Clean using the service provider instructions every 10 mating/cycles and optically monitor. A seal under load test is performed at the end of the 50th cycle. See section 1.3.7 below. The O-rings shall not be replaced prior to the seal under load test.
f. The test sequence is repeated with a spare (aged) set of O-rings and a test environment of 40°C.

- **Seal Under Load Test (HMFOC only)**

  Conducted in accordance with the test matrix contained within this TPR.

- **End of Test Criteria**

  On nonconforming samples, end-face geometry shall be re-measured as described in Section 1.3.1 above. Final measurements of Insertion Loss and Reflectance (nonconforming samples) shall be repeated using the same methods as described in Section 1.3.2 above.

- **Acceptance Criteria**

Conducted in accordance with the test matrix contained within this TPR, except as noted below.

- **End Face Geometry**
- **Initial and Final (if necessary) Loss Measurements**
- **Environmental Conditioning**
  - Custom temperature profile, please refer to Figure 6.
- **Vibration Test**
- **Proof Test**
- **Durability Test**
- **Seal Under Load Test**
- **End of Test Criteria (if necessary)**