ALL-DIELECTRIC LOOSE TUBE FIBER OPTIC CABLE

PRODUCT SPECIFICATIONS

City of Denver

March 2006

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1. Scope

This specification covers the general design requirements and performance standards for fiber optic cables intended primarily for use in the outside plant environment. The purpose of this document is to provide the essential requirements for All-Dielectric Loose TubeTube Fiber Optic cable to be used in the City of Denver networks.

The product requirements and features described in this specification are those considered useful for ensuring proper selection and manufacturing of fiber optic outside plant cables.

In this specification, all observed or calculated values are rounded off "to the nearest unit" in the last right hand place of figures used in expressing the limiting value. The round-off method of ASTM E 29 is used.

These cables should comply with industry standards such as Telcordia Technologies GR-20 (formerly Bellcore), Electronic Industries Association (EIA), Telecommunications Industry Association (TIA), International Telecommunications Union (ITU), International Electrotechnical Commission (IEC), and American Society for Testing and Materials (ASTM).

2. Optical Fiber Characteristics

High quality optical fibers should be made with pure silica-based glass to have very low loss for infrared wavelengths and to be used to carry large amounts of information for very long distances in optical communication systems.

The proposed cable should contain Zero Water Peak Fiber for Single-Mode applications, or 62.5 um Multimode fibers. All fibers should comply with specific fiber requirements outlined in Appendix 2.

3. Cable Core Characteristics

3.1 Color Code

The individual colors for fibers and buffer tubes in loose tube cable cores should comply with EIA/TIA-598 as given in the following table.

Table 1 - Fiber and Tube Color Code

Fiber or Tube No.	**Color**	***Tube No.***	**Color**
1	Blue (BL)	13	Blue-Dash (BL-DS)
2	Orange (OR)	14	Orange-Dash (OR-DS)
3	Green (GR)	15	Green-Dash (GR-DS)
4	Brown (BR)	16	Brown-Dash (BR-DS)
5	Slate (SL)	17	Slate-Dash (SL-DS)
6	White (WH)	18	White-Dash (WH-DS)
7	Red (RD)	19	Red-Dash (RD-DS)
8	Black (BK)	20	Black-Dash (BK-DS)
9	Yellow (YL)	21	Yellow-Dash (YL-DS)
10	Violet (VI)	22	Violet-Dash (VI-DS)
11	Rose (RS)	23	Rose-Dash (RS-DS)
12	Aqua (AQ)	24	Aqua-Dash (AQ-DS)

3.2 Central Strength Member

The central member functions as an anti-buckling element, and should be a glass/epoxy composite dielectric rod. A polyethylene overcoat may be applied to the central member to provide the proper spacing between buffer tubes during stranding.

3.3 Loose Tube Cable Dry Buffer Tubes

Optical fibers are enclosed within buffer tubes that have a diameter several times larger than the diameter of the fibers. The optical fibers are loose within the buffer tubes allowing the fibers to move freely. The buffer tubes are protected against water ingress by the use of water blocking yarns placed adjacent to the fibers. The water blocking yarns form a gel compound upon exposure to water which serves to block the moisture ingress into the cable. The loose buffer tubes should have a 2.5 mm diameter, with a nominal wall thickness of 0.4 mm. For composite cable designs when both and multi-mode fibers are contained within the same cable, the single-mode fibers will be contained in the first buffer tubes. The multi-mode fibers will be contained in the sequenced buffer tubes following the multi-mode buffer tubes.

Table 2 - Buffer Tubes

Fiber Count	**Buffer Tube OD (mm)**	**Fibers per Tube**
1-288	2.5	12

The buffer tubes (and filler rods, if necessary) must be stranded in a reverse oscillation lay (ROL) technique around the central member to allow for easy mid-span access. The core of buffer tubes should be wrapped with two counter helically applied threads to bind together the cable core.

3.4 Filler Rods

In order to create a round cable, filler rods of the same diameter as the buffer tubes may be used to fill empty positions. Filler rods are made out of HDPE and are natural in color.

3.5 Core Water Blocking System

Water blocking of the core outside and around the buffer tubes must be accomplished via "dry" elements. **In addition, water-blocking inside the buffer tubes must be accomplished via "dry" elements as well.**

These "dry" water blocking elements form a gel compound when in contact with water. The gel should effectively fill the interstices of the core and the inside of the tubes to prevent water penetration along the length of the cable. This dry water blocking significantly reduces cable core access time by eliminating the step of cleaning the buffer tubes and fibers upon entry. Additionally, this technology reduces the cable weight.

Dry water blocking elements should be in the form of binders, tapes, or yarns depending on where they are being applied.

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4. Cable Sheath Characteristics

The sheaths described in this section are:

- All-Dielectric Single Jacket: one polyethylene jacket, no metallic elements (SJ)

4.1 Strength Elements

Sheath strength elements are applied over the cable core to provide the cable with the required tensile strength. These elements are made of fiberglass

4.2 Outer Jacket

An outer polyethylene jacket is applied over the cable to provide overall mechanical protection. This jacket is made of MDPE (or HDPE upon request) and is usually black. If required, the jacket could have two co-extruded colored tracer stripes located 180 degrees apart to aid in cable identification. The jacket will be continuous, free from pinholes, splits, blisters, or other imperfections.

4.3 Ripcords

For ease of jacket removal, one clearly identifiable polyester ripcord is provided under the outer jacket.

4.4 Cable Cross-Section
Single Jacket (SJ)

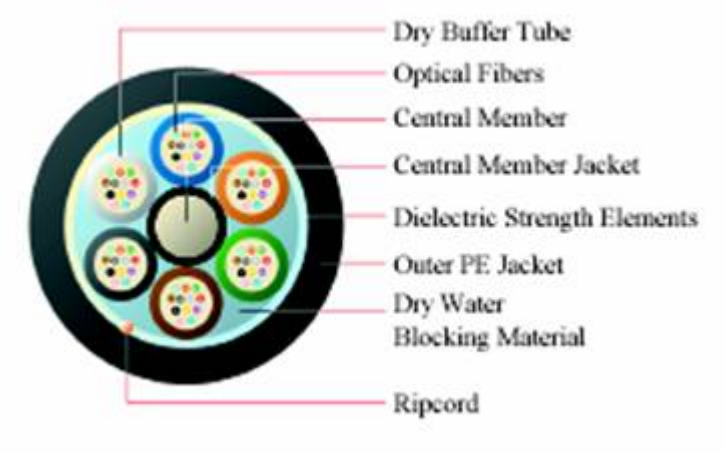


Figure 1 - Single Jacket

Table 3 - Target Cable Outer Diameters

NUMBER OF FIBERS								
	2 - 60 (5 Pos.)	**2 - 72 (6 Pos.)**	**73 - 96 (8 Pos.)**	**97 - 120 (10 Pos.)**	**121 - 144 (12 Pos.)**	**145 - 216 (18 Pos.)**	**217 - 240 (20 Pos.)**	**241 - 288 (24 Pos.)**
SHEATH TYPE	**Cable OD in. (mm)**	**Cable OD in. (mm)**	**Cable OD in. (mm)**	**Cable OD in. (mm)**	**Cable OD in. (mm)**	**Cable OD in. (mm)**	**Cable OD in. (mm)**	**Cable OD in. (mm)**
Single Jacket Dielectric	0.398 (10.1)	0.421 (10.7)	0.492 (12.5)	0.555 (14.1)	0.618 (15.17)	0.606 (15.4)	0.638 (16.2)	0.709 (18.0)

5. MECHANICAL, ENVIRONMENTAL, AND ELECTRICAL REQUIREMENTS

These cables must meet the requirements of *Telcordia GR-20-CORE* with all testing performed based on *EIA/TIA-455* standards. The manufacturing company must provide proof of their quality control standards with *ISO 9001* and *TL9000* certifications. The cables should comply with the following temperature ranges:

Operation:	-40°C to 70°C (-40°F to 158°F)
Installation:	-30°C to 60°C (-22°F to 140°F)
Storage/Shipping:	-40°C to 75°C (-40°F to 167°F)

5.1 Single-Mode Fibers

Per *Telcordia GR-20*, the magnitude of the attenuation change shall be less than or equal to 0.05 dB for 90% of the test fibers and less than or equal to 0.15 dB for the remaining 10% of test fibers. Cable aging allows for 0.10 dB/km average attenuation change with a magnitude of the maximum attenuation change for each individual fiber to be less than 0.25 dB/km. These attenuation values include a 0.05 dB allowance for measurement repeatability.

During mechanical and environmental testing evidence of cracking, splitting or other failure of the sheath components when examined under 5X magnification would result in failure of the proposed test requirements. In addition, no fiber shall lose optical continuity because of the test.

Table 4 - Testing for Single Mode Fibers

Cable Test	Test Method	Requirement
Tensile Loading and Bending	EIA/TIA-455-33 IEC 794-1-E1	90% < 0.05 dB Max. Added Loss 100% < 0.15 dB Max. Added Loss
Cyclic Flexing	TIA/EIA-455-104 IEC 794-1-E6	90% < 0.05 dB Max. Added Loss 100% < 0.15 dB Max. Added Loss
Cyclic Impact	EIA/TIA-455-25 IEC 794-1-E4	90% < 0.05 dB Max. Added Loss 100% < 0.15 dB Max. Added Loss
Compressive Loading	TIA/EIA-455-41 IEC 794-1-E3	90% < 0.05 dB Max. Added Loss 100% < 0.15 dB Max. Added Loss
Twist	TIA/EIA-455-85 IEC 794-1-E7	90% < 0.05 dB Max. Added Loss 100% < 0.15 dB Max. Added Loss
Low and High Temperature Bend	EIA/TIA-455-37 IEC 794-1-E11	90% < 0.05 dB Max. Added Loss 100% < 0.15 dB Max. Added Loss
External Freezing	EIA/TIA-455-98 IEC 794-1-F6	< 0.05 dB Mean Added Loss < 0.15 dB Max. Added Loss
Temperature Cycling	EIA/TIA-455-3 IEC 794-1-F1	≤ 0.05 dB/km Mean Added Loss ≤ 0.15 dB/km Max Added Loss
Cable Aging	EIA/TIA-455-3 IEC 794-1-F1	≤ 0.10 dB/km Mean Added Loss ≤ 0.25 dB/km Max Added Loss
Water Penetration	EIA/TIA-455-82 IEC 794-1-F5	No flow after 24 hours from one meter length of cable

5.2 Multimode Fibers

Per *Telcordia GR-20*, the allowable attenuation increase during the mechanical and environmental testing is 0.20 dB. Cable aging allows for the maximum attenuation change for each individual fiber to be less than 0.40 dB/km.

During mechanical and environmental testing evidence of cracking, splitting or other failure of the sheath components when examined under 5X magnification would result in failure of the proposed test requirements. In addition, no fiber shall lose optical continuity because of the test.

Table 5 - Testing for Multi-Mode Fibers

Cable Test	**Test Method**	**Requirement**
Tensile Loading and Bending	EIA/TIA-455-33 IEC 794-1-E1	0.20 dB Max. Mean Added Loss
Cyclic Flexing	TIA/EIA-455-104 IEC 794-1-E6	0.20 dB Max. Mean Added Loss
Cyclic Impact	EIA/TIA-455-25 IEC 794-1-E4	0.40 dB Max. Mean Added Loss
Compressive Loading	TIA/EIA-455-41 IEC 794-1-E3	0.20 dB Max. Mean Added Loss
Twist	TIA/EIA-455-85 IEC 794-1-E7	0.20 dB Max. Mean Added Loss
Low and High Temperature Bend	EIA/TIA-455-37 IEC 794-1-E11	0.40 dB Max. Mean Added Loss
External Freezing	EIA/TIA-455-98 IEC 794-1-F6	0.20 dB Max. Mean Added Loss
Temperature Cycling	EIA/TIA-455-3 IEC 794-1-F1	≤ 0.5 dB/km Max Added Loss 80 % ≤ 0.25 dB/km Added Loss
Cable Aging	EIA/TIA-455-3 IEC 794-1-F1	≤ 1.0 dB/km Max Added Loss 80 % ≤ 0.5 dB/km Added Loss
Water Penetration	EIA/TIA-455-82 IEC 794-1-F5	No flow after one hour from one meter length of cable

Note:

The tensile rating for the cable described should be 2.7 kN (600 lbf), with a compression rating of at least 220 N/cm under GR-20 requirements.

6. CABLE MARKING

6.1 Printed Characters

For standard outer jackets, printed characters shall be indent printed with white characters for black jackets, black characters for non-black jackets, or as otherwise specified.
For standard striped outer jackets, printed characters shall be indent printed with white characters for red, green, orange, yellow, blue striped cables, light-blue characters for white striped cables, or as otherwise specified by the customer. The characters shall be of proper height and space to produce good legibility. Character heights of 2 mm should facilitate adequate readability. An occasional illegible marking is permitted if there is a legible marking on either side.

6.2 Markings

The cable shall be sequentially marked at one meter, or two-foot intervals depending on specific requirements issued by the City of Denver. The length marks shall not be reset to zero on any length of the cable. The actual length of cable shall be within +1, -0% of the marked length.
Each length of cable shall be marked with the following legend:
"(Manufacturer name) OPTICAL CABLE (product part number) (month and year of manufacture [MM-YY]) (telephone symbol [ ]) (fiber count [XXX F]) (manufacturer's serial number) ", where XXX is number of optical fibers in the cable.

6.3 Re-Markings

Only one remarking is permitted. If required, either of the following methods for remarking shall be used:
Method A: Completely remove the defective marking and remark the characters with the original color.
Method B: Leave the defective marking on the jacket and remark on a different portion of the cable jacket with yellow character print. The new number sequence shall differ from any other existing marking by at least 5000. Any cable that contains two sets of markings shall be labeled to indicate the color and sequential numbers to be used. The labeling shall also be applied to the reel tag.

7. Cable Packaging

7.1 Reels

The manufacturer shall supply the product using their standard reel sizes, methods, apparatus, and reel wood lagging, but stenciled according to these specifications. The specifications outlined here are guidelines on what is expected with respect to packaging.

Reels are assumed to be in good working condition, firm, and be able to support the product through shipping and final installation. Reels shall be clean, dry and free of excessive dirt. All reels shall be checked for high nails, stave fit and proper stenciling.

7.2 Reel Labels

Each wooden reel shall be permanently marked with the following information (see Appendix 1):

- "(Manufacturer's name)" (red paint)
- "OPTICAL CABLE" (black paint)
- An arrow and the wording "cable end" to indicate the position of the outside cable end. (red paint)
- An arrow and the wording "ROLL THIS WAY" to indicate the direction the reel should be rolled to prevent loosening of the cable. (black paint)
- Reel Number (red paint)

Cable handling stickers/cards must be attached to both flanges of every reel. Each sticker must be stapled to the flange. See Figure 4 for illustrations of the stickers to be used.

7.3 Reel Lagging

7.3.1 Thermal Protection

Outer layers of the reel shall be covered with a protective wrap to limit the solar heating of the cable. This helps limit the cable surface temperature so that it will not exceed 10 C (18 F) above ambient temperature under maximum solar radiation according to Telcordia GR-20 requirements. All foil wrap shall be securely fastened to the cable by at least 2 pieces of strapping tape.

7.3.2 Composite & Wood Lagging

Reels shipping domestically shall be lagged with a suitable protective wrap (can be the same thermal protection wrap) and banded with steel straps. This wrap shall cover the cable from flange to flange and provided some mechanical protection to the outer layers of cable as well as weather resistance. Reels shipping for export shall be lagged with wooden boards nailed to each flange and banded with steel straps in addition to the protective wrap around the outer layers of cable.

Figure 4 - Reel Stickers

7.4 Others

7.4.1 Cable Ends

Each end of the cable shall have end seals, either end caps or KELLEMS® pulling grips, in order to prevent moisture ingress into the cable during shipping, storage, or installation.

The top end of the cable shall be securely fastened to the inside of the reel flange to prevent the cable from becoming loose in transit or during handling. The bottom end, "test tail", shall be approximately three meters in length and easily accessible. The end shall be protected within a cable slot and be securely fastened to the outside of the reel flange with wire ties or walkout straps. Staples, nails or yarn attached to the reel during manufacturing shall be removed.

The cable slot can be partially protected to prevent the cable tail from moving outside this, however for export orders the cable slot must be completely sealed by either metallic protection rings, plywood covers, or other.

7.4.2 Cable Length Tolerance

Cables ordered to standard factory lengths shall have an actual length within -0% and +5% of the length ordered unless otherwise specified by the customer.

7.4.3 Certified Test Data

Each cable shall have certified test data securely fastened to the reel in a waterproof wrapping. The certified test data sheet shall include the following information:

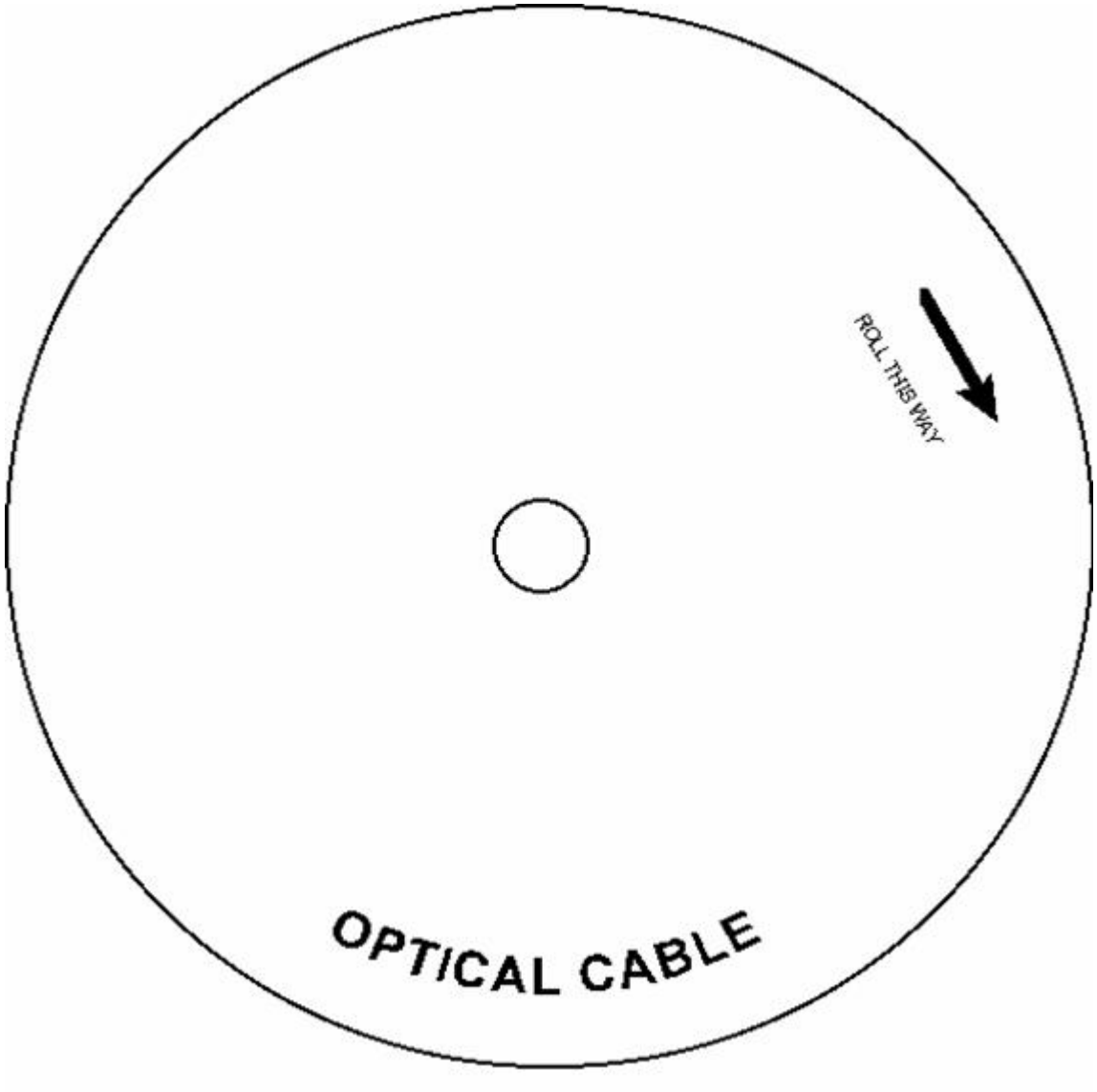
- Cable Number
- Date
- Customer Name
- Ordered Length
- Customer Order Number
- Ship Length
- Customer Cable Code
- Customer Reel Number
- Customer's Attenuation Specification(s)
- Number of Fibers
- Cable Construction
- Fiber Transmission Data
- Bandwidth Data - only applies to Multi-Mode Fibers
- Authorized Signature

7.4.4 Reel Tag

Each cable shall have a reel tag securely fastened to the reel in a waterproof wrapping. The Reel Tag (Cut Length Data Sheet) shall include the following information:

- Cable Number
- Date
- Customer Name
- Ordered Length
- Customer Order Number
- Ship Length
- Customer Cable Code
- Customer Reel Number
- Customer's Attenuation Specification(s)
- Number of Fibers
- Beginning and Ending Sequential Length Markings
- Gross Weight
- Net Weight
- Inspected By Signature

8. Appendix 1. Reel STENCILING



* If company name stenciling is required use lettering height shown below.

Reel	"Company name" Height	"OPTICAL CABLE" Height
ALL SIZES	4	2

All Dimensions in Inches

9. Appendix 2 Fiber Specifications

9.1 Zero Water Peak Singlemode Fiber Specifications

Parameter	Zero Water Peak Singlemode fiber
Attenuation at 1310 nm (dB/km)	≤ 0.35 dB/km
Attenuation at 1385 nm (dB/km)	≤ 0.31 dB/km
Attenuation at 1490 nm (dB/km)	≤ 0.27 dB/km
Attenuation at 1550 nm (dB/km)	≤ 0.25 dB/km
Attenuation at 1625 nm (dB/km)	≤ 0.27 dB/km
Attenuation difference from 1550 nm value at any wavelength between 1525-1575 nm (dB.km)	≤ 0.02 dB/km
Attenuation difference from 1550 nm value at any wavelength between 1550-1625 nm (dB.km)	≤ 0.04 dB/km
Point Discontinuity at 1310 and 1550 (dB0	0.05 dB Max
Cladding Diameter (um)	125.0 ± 0.7 um
Cladding non-circularity	≤ 0.70%
Core-clad concentricity error (um)	≤ 0.5 um
Coating outer diameter (um)	241 ± 5 um
Coating concentricity error (um)	≤ 12 um
Mode Field Diameter, 1550 nm (um)	10.4+0.5 um
Dispersion [ps/(nm/km)]: C-band, 1530-1565 nm L-band, 1565-1625 nm	 Max Dispersion 18 ps/nm2-km @1550nm 22 ps/nm2-km @ 1625 nm
Zero Dispersion wavelength (nm)	1312 nm
Dispersion Slope at 1550 nm [ps-nmsq.km)]	≤ 0.090 ps/nm2-km
Macrobend Attenuation: 1 Turn-32 mm Diameter, (dB at 1550 nm) (dB at 1625 nm)	 ≤ 0.05 dB @ 1550/1625 nm
100 Turn-60 mm Diameter (dB at 1550 nm) (dB at 1625 nm)	 ≤ 0.05 dB @ 1550/1625 nm
Polarization Mode Dispersion Fiber Link Design Value (ps/km 1/2) Max. Individual Fiber (ps/km 1/2) Cable Link Design Value (ps/km 1/2)	 Fiber Link Design Value ≤ 0.06 ps/(km 1/2) Max. Individual Fiber ≤ 0.1ps/(km 1/2) Cable Link Design Value ≤ 0.1 ps/(km 1/2)
Cable Cutoff Wavelength (nm)	≤ 1260 nm
Proof Test (kpsi)	100 kpsi
Fiber Curl (radius of curvature) (m)	≥ 4 m
Coating Strip Force (N)	≥1.3 N (0.3 lbf.) and ≤ 8.9 N (2.0 lbf.)
Temp. Dependence of Attenuation Induced Attenuation -60 degrees C to +85 degrees C at 1319 nm (dB/km) at 1550 nm (dB/km)	 ≤ 0.05 dB/km @ 1310/1550
Temperature-Humidity Cycling up to 95% RH Induced Attenuation -10 degrees C to + 85 degrees C at 1310 nm (dB/km) at 1550 nm (dB/km)	 ≤ 0.05 dB/km @ 1310/1550

Accelerated Aging (Temperature) Induced Attenuation due to Temperature Aging at 85+2 degrees C at 1310 nm (dB/km) at 1550 nm (dB/km)	≤ 0.05 dB/km @ 1310/1550
Water Immersion Induced Attenuation due to Water Immersion at 23+2 degrees C at 1310 nm (dB/km) at 1550 nm (dB/km)	≤ 0.05 dB/km @ 1310/1550

9.2 62.5 um Multimode Fiber Specifications

Parameter	62.5 um Multimode Fiber
Attenuation at 850 nm (dB/km)	≤ 3.4 dB/km
Attenuation at 1300 nm (dB/km)	≤ 1.0 dB/km
Bandwidth at 850 nm (dB/km)	≤ 200 MHz*km
Bandwidth at 1300 nm (dB/km)	≤ 500 MHz*km
1 Gb Ethernet distance 850 nm 1000BASE-SX (m)	275 m
1 Gb Ethernet distance 1300 nm 1000BASE-LX (m)	550 m
10 Gb Ethernet distance 850 nm 10GBASE-S (m)	33 m
10 Gb Ethernet distance 1300 nm	No Standards
Point Discontinuity at 850 nm and 1300 nm (dB)	0.08 dB Max
Cladding Diameter (um)	125.0 ± 1.0 um
Cladding non-circularity	≤ 1%
Core-clad concentricity error (um)	≤ 1.5 um
Coating outer diameter (um)	245 ± 10 um
Coating concentricity error (um)	≤ 6 um
Zero Dispersion wavelength (nm)	1320-1365 nm
Dispersion Slope [ps-nmsq.km)]	≤ 0.97 ps/nm2-km
100 Turn-75 mm	≤ 0.5 dB
Proof Test (kpsi)	100 kpsi
Coating Strip Force (N)	≥2.2 N (0.5 lbf.) and ≤ 4.4 N (1.0 lbf.)
Temp. Dependence of Attenuation Induced Attenuation -60 degrees C to +85 degrees	≤ 0.1 dB/km @ 1310/1550
Temperature-Humidity Cycling up to 94% RH Induced Attenuation -10 degrees C to + 85 degrees C	≤ 0.1 dB/km @ 1310/1550
Accelerated Aging (Temperature) Induced Attenuation due to Temperature Aging at 85+2 degrees C	≤ 0.2 dB/km @ 1310/1550
Water Immersion Induced Attenuation due to Water Immersion at 23+2 degrees C	≤ 0.2 dB/km @ 1310/1550