THAI FIBER OPTICS CO., LTD.

SPECIFICATION

OF

SINGLE MODE OPTICAL FIBER (ITU-T G.652.D)

ANTI-RODENT SELF-SUPPORTING (ARSS), SINGLE JACKET, SINGLE ARMOR,

DRY CORE LOOSE TUBE FIBER OPTIC CABLE

Specification No. TFS-1413-00

Issued Date : August 25, 2016

(URAPHONG JUNSEM)

TECHNICAL SECTION MANAGER

(PORNSAWAN BOONTARAWA)

DEPUTY FACTORY MANAGER

(MASAYUKI SHIBATA)

FACTORY MANAGER

Certificate: No. 157515

Certificate: No. 196777

DIRECTOR & GM : _____ DOC. No. _____

MARKETING DEPARTMENT DISTRIBUTED DATE _____

1. General

1.1 Scope

This specification covers the construction and properties of anti-rodent self-supporting (ARSS), single jacket, single armor, dry core loose tube fiber optic cable for aerial application. The optical fibers are in compliance with ITU-T Rec. G.652. D

1.2 Quality Assurance

Thai Fiber Optics Co., Ltd. takes pride in being an industry leader recognized for producing a quality product. To ensure a continuing level of quality in production cables, a consistent quality system with ISO 9001 “Quality Management System” and ISO 14001 “Environment Management System” are provided for all optical fiber and fiber optic cables.

The adequacy of all materials is assured through incoming inspection, source inspection, or vendor certified data. Fiber is measured and classified before being placed into inventory, and then selected from inventory to satisfy customer order requirements. Inspection of cable construction characteristics is the responsibility of the employees producing the product. All cables are tested for compliance to customer specified transmission requirements in Final Test. Adequacy of this quality control system is assured through product and process audits conducted by the internal quality improvement organization.

TFOC is supported by standards such as
- Electronic Industries Association (EIA)
- Telecommunications Industry Association (TIA)
- International Telecommunications Union (ITU)
- International Electrotechnical Commission (IEC)
- American Society for Testing and Materials (ASTM)
- TIS 2166-2548 (2005) Optical fiber cables Part 3-20 : Outdoor cables- Family specification for optical self-supporting aerial telecommunication cables

All of optical fiber cable element should comply with RoHS Directive 2002/95/EC and its amendment directives with the Laboratory that fully comply with the requirements of ISO/IEC 17025-05, The Basic Rules, IECEE 01: 2008-11 and Rules of Procedure IECEE 02: 2008-10, and the relevant IECEE CB-Scheme Operational Documents.

1.3 General Fiber Optic Cable Characteristics

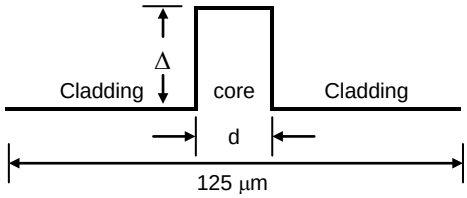
High quality optical fibers made with pure silica-based glass have very low loss for infrared wavelengths and can be used to carry large amounts of information for very long distances in optical communication systems. High fiber strength is obtained by protecting the surface of the glass fiber with thin coating layers of polymeric materials.

The coated Fibers are then placed in cable structures having additional layers to protect the fiber during the rigors of outside plant installation and to provide long term reliable operation in the outside plant environment. The design philosophy in meeting these objectives is to provide high quality, rugged, well-tested fiber optic cables, which are compact and have a high strength-to-weight ratio. Compact fiber optic cables are easier to handle and install in the field and provide longer length for field installation.

2. Optical Fiber Requirements

TFOC Zero Water Peak (ZWP) Single Mode Optical Fiber consists of a germanium doped core and a silica cladding. The fiber is fully compatible with other commercially available matched cladding fibers. TFOC ZWP Single Mode Optical Fiber is the industry's first fiber designed for use with transmission systems operating in entire wavelength region from 1280 to 1625 nm. Current systems operate in either the 2nd window (1280-1325 nm) or the 3rd window (1530-1565 nm). The 5th window from 1350 to 1450 nm has not been available because of higher attenuation (up to 1 dB/km) over much of the region. TFOC ZWP fiber enables usage over this much wider range because of a new manufacturing process, which practically eliminates the incorporation of OH ions (water) into the fiber. A concentration of several parts per billion (ppb) of OH ions in a conventional single mode fiber core cause the attenuation in the region around 1385 nm (the "water" peak) to be up to 300% higher than in the 1310 nm region. With TFOC ZWP fiber, the attenuation in the 5th window is always less than that in the 2nd window.

TFOC fibers feature a dual UV curable acrylate coating system, which provides unparalleled performance in a wide range of environmental conditions. The advantages of this coating structure are excellent resistance to micro-bending induced losses, superior hydrolytic stability and long term preservations of color code integrity. The coating is easily strippable using mechanical methods.



(d = core diameter)

Fig.1 Refractive index profile, Dispersion Unshifted Single Mode Fiber

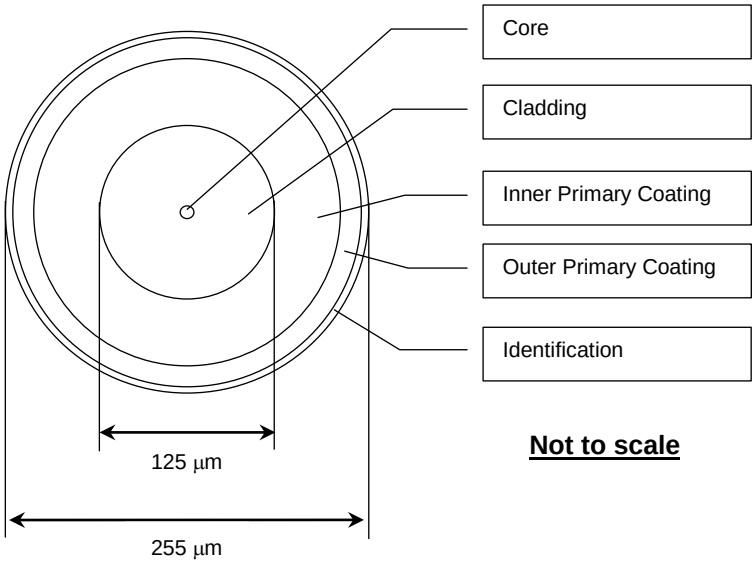


Fig. 2 Cross Section View of Dispersion Unshifted Single Mode Fiber

Table 1. Single Mode Fiber Requirements, Dispersion-Unshifted Fiber (ITU-T Rec. G.652.D)

Fiber attributes		
Item		**Description**
Manufacturing Method		VAD (vapor axial deposition method)
Refractive Index Profile		Step Index, Matched Cladding
Core		Germanium (GeO_2) doped Silica (SiO_2)
Core Diameter		8.3 μm
Cladding		Silica (SiO_2)
Primary Coating		2 layers of UV curable resin
Refractive index for core		1.452 @ 1310 nm 1.450 @ 1550 nm
Refractive index for cladding		1.447 @ 1310 nm 1.445 @ 1550 nm
Index of refraction Difference		0.35%
Group refractive index *		1.469 @ 1310 nm and 1550 nm
Cladding Diameter		125 ± 1 μm
Cladding Non-Circularity		≤ 1 %
Core/Cladding Concentricity error		≤ 0.5 μm
Coating Diameter (uncolored)		245 ± 5 μm
Coating/Cladding Concentricity error		≤ 12 μm
Colored Fiber Diameter		255 ± 10 μm
Mode Field Diameter		9.2 ± 0.4 μm @ 1310 nm 10.4 ± 0.5 μm @ 1550 nm
Proof test stress		The entire length of fiber is subjected to tensile stress greater than 0.69 GPa. (100 kpsi), Ref. EIA-455-31B or IEC 60793-1-30
Attenuation with Bending	100 turns, 30 mm radius	≤ 0.05 dB @ 1310 nm ≤ 0.10 dB @ 1550 nm
	1 turns, 16 mm radius	≤ 0.5 dB @ 1550 nm
Zero-Dispersion Wavelength (λ_0)		$1300 \le \lambda_0 \le 1324$ nm
Max. Zero-Dispersion Slope (S_{0max}) at λ_0		≤ 0.092 ps/(nm^2.km)
Chromatic dispersion coefficient, D(λ)		$D(\lambda) = \lambda S_{0max} / 4 \bullet [1 - \{\lambda_0/\lambda\}^4]$ ps/(nm•km) (λ = Operating Wavelength) ≤ 3.5 ps/(nm.km) @ 1288 ~ 1339 nm ≤ 18 ps/(nm.km) @ 1550 nm ≤ 22 ps/(nm.km) @ 1625 nm
Coating Strip Force (@ 0 °C to +45 °C)		1.3 N (0.3 lbf) ≤ F ≤ 8.9 N (2.0 lbf)
Cable attributes		
Item		**Description**
Attenuation coefficient		≤ 0.35 dB/km @ 1310 nm ≤ 0.35 dB/km @ 1383 nm ≤ 0.24 dB/km @ 1490 nm ≤ 0.21 dB/km @ 1550 nm ≤ 0.23 dB/km @ 1625 nm
Attenuation Coefficient @ 1285~1330 nm		≤ Measured attenuation at 1310 nm + 0.03 dB/km
Attenuation Coefficient @ 1525~1575 nm		≤ Measured attenuation at 1550 nm + 0.02 dB/km
Cabled Cut-off Wavelength (λ_{cc})		≤ 1260 nm (Ref. EIA/TIA-455-170)
Polarization mode dispersion (PMD) (Link Design Value)		≤ 0.20 ps/√km

* Optical time domain reflectometers (OTDRs) require the setting of the fiber's group refractive index in order to calculate and display distance. The above is a group refractive index values for OTDR settings.

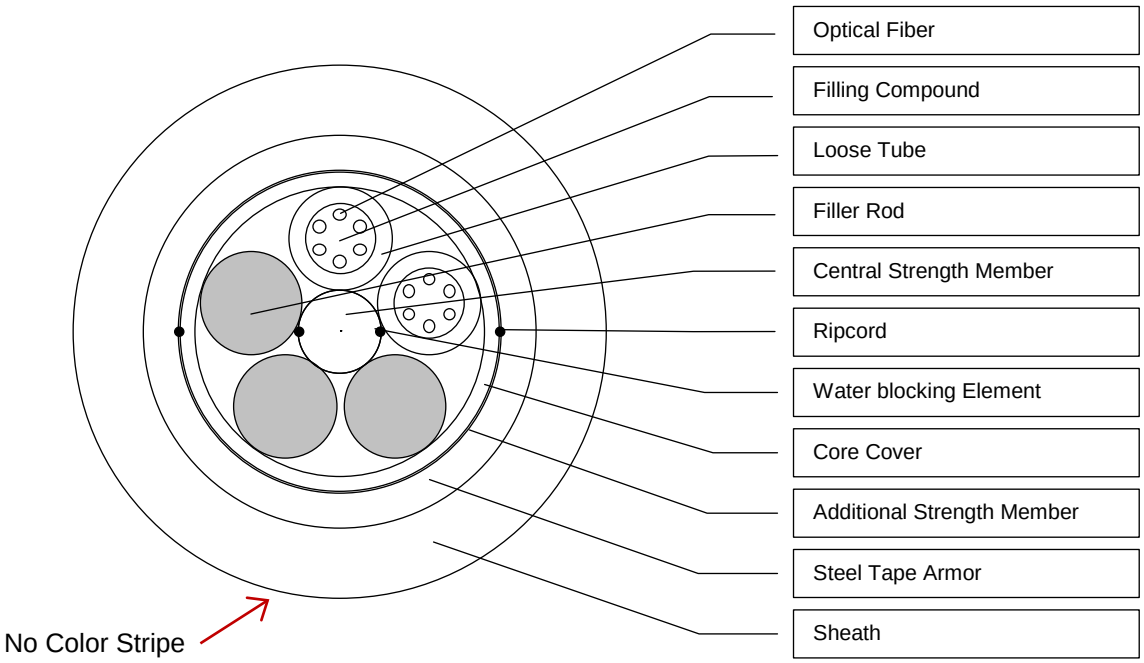
3. Cable Core / Cable Characteristics and Construction
These core/cable combinations are described in detail below.

Table 2. Constructions of anti-rodent self-supporting (ARSS), single jacket, single armor, dry core loose tube fiber optic cable.

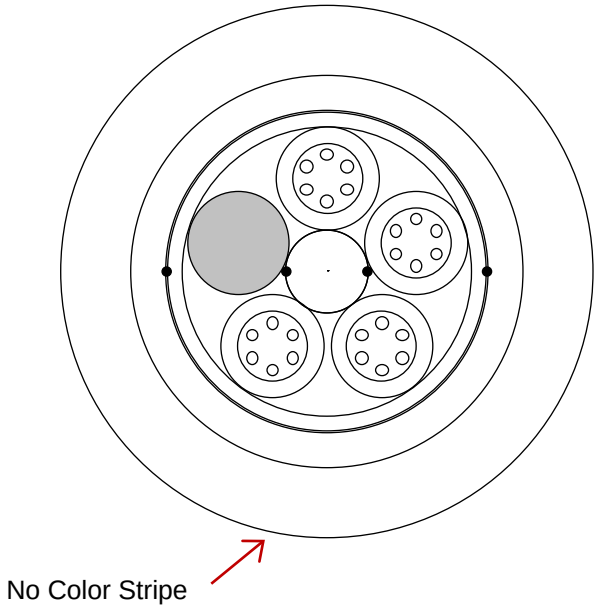
Item		Description
		Up to 30 Fibers
Optical Fiber	Construction	Table 1
Filling Compound	Material	Thixotropic Jelly Compound
Loose Tube	Material	(PBT) Polybutylene Terephthalate with color code
	Fiber per Tube	Max. 6
	Number	1 – 5
	Assembly	Fibers are brought together with the filling compound and placed in the extruded tube
Filler Rod	Material	Polyethylene, natural color
	Number	0 – 4
Stranding	Method	Reverse oscillating lay (ROL) technique (SZ Direction)
Central Strength Member	Material	FRP (Fiberglass Reinforce with Plastic)
Water Blocking Element	Material	Suitable Water Swellable Materials (Dry-Core Technology)
Core Covering	Material	Water Blocking tape
	Assembly	The tape shall be wrapped longitudinally over the cable core
Additional Strength Member	Material	Aramid yarns (If necessary)
	Number	The quantity of additional strength member shall be selected to minimize cable cost while meeting the performance requirement of the cable applications
*Ripcord	Material	Aramid cords
	Number	2
Armoring	Material	Corrugated steel tape coated with polymer
	Thickness	Steel Tape : 0.15 +/- 10% mm Polymer : Not less than 0.05 mm
	Overlap	Not less than 3 mm
Sheath	Material	UV-Proof Black High Density Polyethylene
	Thickness	Minimum 1.5 mm
Cable Diameter (Maximum) mm.		12.0
Cable Weight (Approx.) kg/km		110
Structure		Fig. 3

Note:
- The thickness of the thinnest point shall not be measured at the groove of the ripcord.
- *Each ripcord shall have sufficient strength to be capable of slitting the sheath for a continuous length of 1(one) meter.
- Manufacturer may use additional/deduction suitable tape(s), water blocking elements, thread(s) or dielectric elements into suitable place in the cable for manufacturer's reason.

12 Fibers



24 Fibers



Not to scale

Fig. 3 Cross-section view for anti-rodent self-supporting (ARSS), single jacket, single armor, dry core loose tube fiber optic cable.

Table 3. TIA/EIA-598-A Color Code for Fiber and Loose tube Identification

No.	Fibers Identification	Loose Tube Identification
1	Blue	Blue
2	Orange	Orange
3	Green	Green
4	Brown	Brown
5	Slate	Slate
6	White	-

Note: - All fibers and tube used in our cables are color code to facilitate individual identification. Unless otherwise specified, all cables employ the standard industry color code system in accordance with the Munsell color shades as specified in EIA/TIA-359 and EIA/TIA-598A (Rose and Aqua color recommended standard TIA/EIA-598-B), Color Coding of Fiber Optic Cables. Anyway, the color code can be changed by customer's request.
- Unless otherwise requested by the customer, all cable jackets are black.

Table 4. Mechanical Specification of the cable

Item		**Specification**
Maximum Span Length		40 m
Minimum installation Sag		0.5% of Maximum Span Length
Worst case loading condition (Short-term)	Wind Velocity	126 km/hr
	Temperature	25 °C
Relative humidity		Up to 90%, no frost
Temperature Range	Installation	32 °C
		0 to 60 °C
	Operation	-10 to 70 °C
	Storage/Shipping	-20 to 70 °C
Maximum allowable pulling tension		1,800 N
Minimum bending Radius	During Installation Or handling	20 x External Diameter of Cable
	During Service Or fixed	15 x External Diameter of Cable

Note: At the maximum allowable pulling tension, fiber will not be subjected to a tension to get the strain higher than 0.33% or 1/3 of fiber proof test.

4. Cable Marking and Shipping Requirements

4.1 Sheath marking

The sheath marking is available upon customer's request. The Sheath marking shall be printed (Hot Stamp) on the outer sheath of the cable with white color in one-meter intervals.

4.2 Reels

4.2.1 The cable will be delivered at the required length on a wooden reel. The reels are designed to prevent damage to the cable during shipment and installation.

4.2.2 The cable shall be delivered on wooden reel in standard manufacturing length of 4,000 m. (Special length is available upon request, but the cost may be increased.)

4.2.3 The diameter of the barrel shall be not less than 30 times of the outer diameter of the cable.

4.2.4 Circumference shall be completely enclosed with wooden battens, these battens shall be secured by nails to each flange. There are metallic bands are strapped about the wooden batten to help secure the battens to the reel.

4.2.5 To provide access for testing, the inner end of the cable protrudes through the inside of the reel. The end is securely kept on the side of the flange to protect it during transport and storage. The length of the inner end is typically 1 meter. The cable ends are securely fastened so as not to protrude beyond any portion of the reel in an unprotected manner and to prevent the cable from becoming loose in transport.

4.3 Sealing and Cable Termination

The both end of the cable shall be sealed with a suitable rubber cap or heat shrinkable cap to prevent ingress of moisture.

4.4 Information Accompanying the Reel

The following information is securely attached to the reel.

- Manufacturer's Name
- Customer's Name
- Customer Order Number
- Customer Part Number (if Applicable)
- Kind & Size (Cable Description)
- Order Length
- Outside sequential
- Inside sequential
- Drum No.
- Reel ID.
- Ship Length
- Gross Weight
- Net Weight
- Date

Appendix A
The Calculation of Single Mode Optical Fiber Life-time

The calculated life time, according to the failure frequency technique, is as follows

Formula;

$$F = 1 - \exp\left(-N_p L \times \left(\left[1 + \left(t_s/t_p\right) \times \left(k \times \delta_s/\delta_p \right)^n \right]^{m/(n-2)} - 1 \right) \right)$$

Where

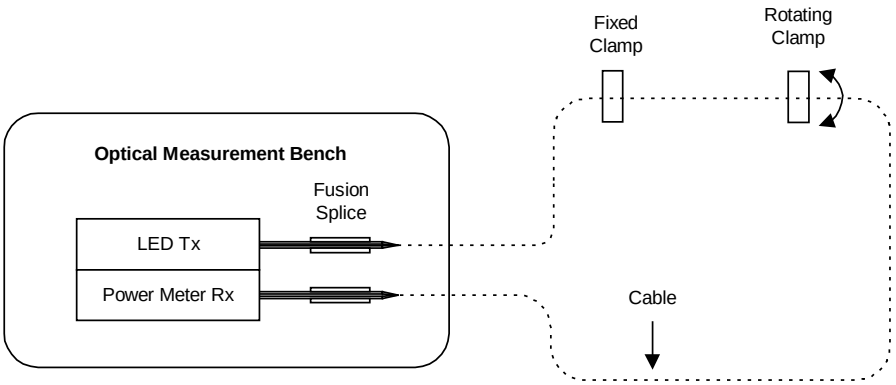
F	=	Failure probability (%)	
N_p	=	Failure probability at the proof test (times/km)	: 0.02
L	=	Fiber length (km)	: 100
t_s	=	Life time (Sec.)	: 7.88×10^8 (25 Years)
t_p	=	Duration of proof test (Sec.)	: 1
δ_s	=	Strain in life time (%)	: 0.2
δ_p	=	Strain of Proof test (%)	: 1
n	=	Stress corrosion factor	: 21
m	=	Weibull slope in low strength region	: 2
k	=	Safety factor at minimum proof strain	: 1

Failure probability (F) for fiber with length 100 km for 25 years is 0.000035 %

Appendix B
Properties of Cable Sheath

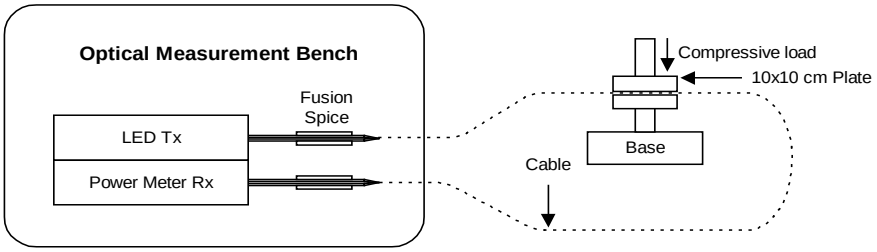
Parameter	Specification	Method
1. Carbon Black	2.6 ± 0.25 %	ASTM D1603
2. Minimum Tensile Strength	168 kg/cm^2	ASTM D470
3. Minimum Elongation	300 %	ASTM D470
4. Environment Stress Cracking : Max. Failure From 10 Specimens	2	ASTM D1693
5. Max. Shrinkback	5%	Slab specimens 50x13 mm in the oven at 115±1ºC for 4 hours

Appendix C
Mechanical Test



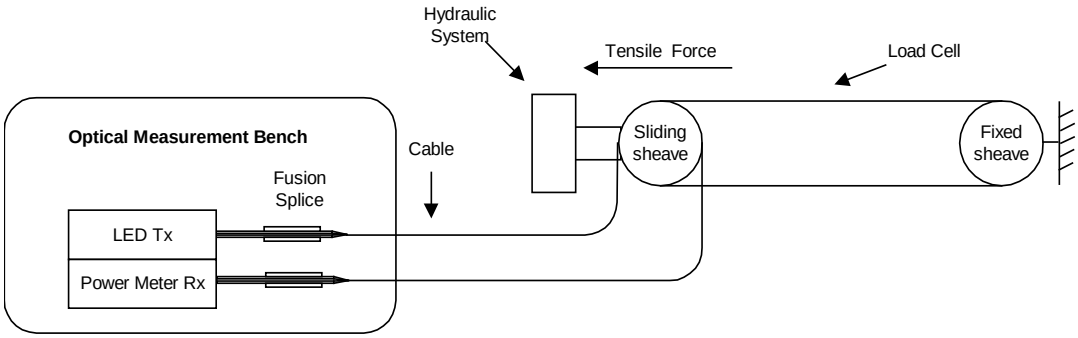
Method EIA-455-85A or IEC 60794-1-2-E7 Twist Test

Length Test:	1 m
Load	per Table2, TIA/EIA-455-85A
Rotation:	±180° , 10 cycles
Requirements:	- Maximum attenuation change < 0.1 dB at 1550 ± 10 nm. - No fiber break and no cable damage.



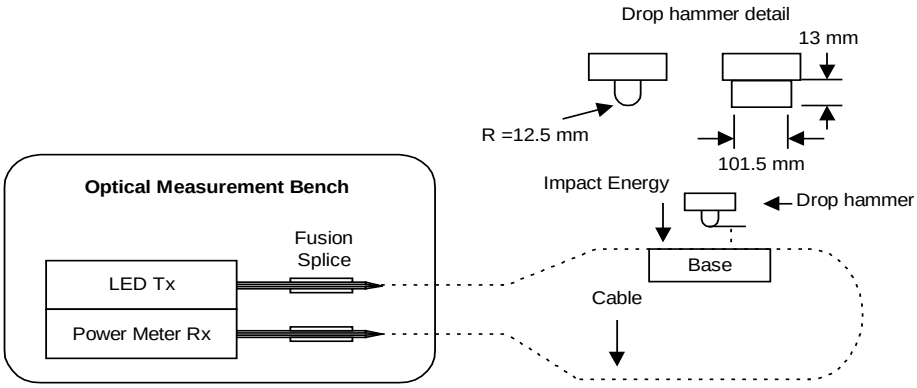
Method EIA-455-41A or IEC 60794-1-2-E3 Compression Test

Load:	$\geq$ 2,200 N (220N/cm)
Duration:	$\geq$ 10 minutes (one point and one time)
Length of Sample:	Approximately 20 m
Requirements:	- Maximum attenuation change < 0.1 dB at 1550 $\pm$ 10 nm. - No fiber break and no cable damage.



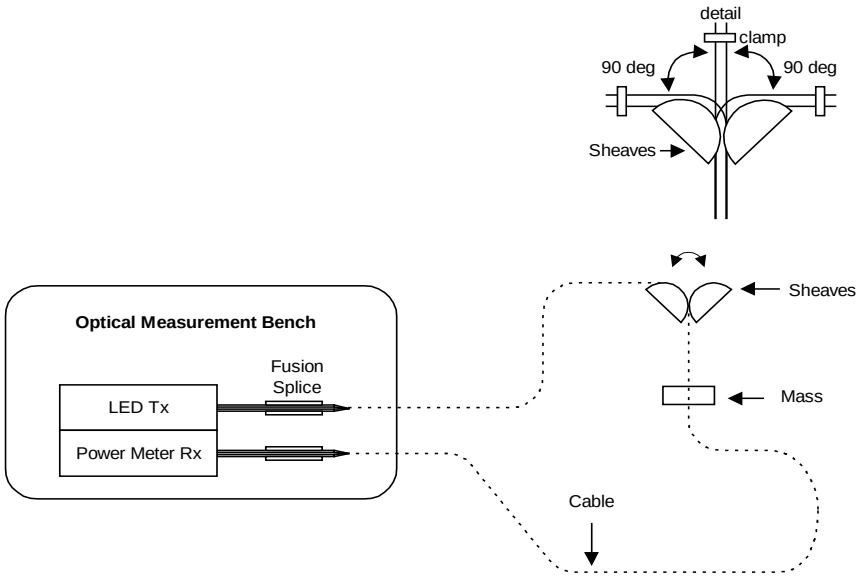
Method IEC-60794-1-2-E1 and EIA-455-33A Tensile Performance Test

Length of Cable under Load:	Min. 25 m
Sheave Diameter:	30 x outside diameter of the cable
Load cable:	1,800 N , 1 hour
Requirements:	- Maximum attenuation change ≤ 0.05 dB at 1550 ± 10 nm. The fiber strain shall not be greater than 0.33% or the 1/3 of the fiber proof test. - No fiber break and no cable damage.



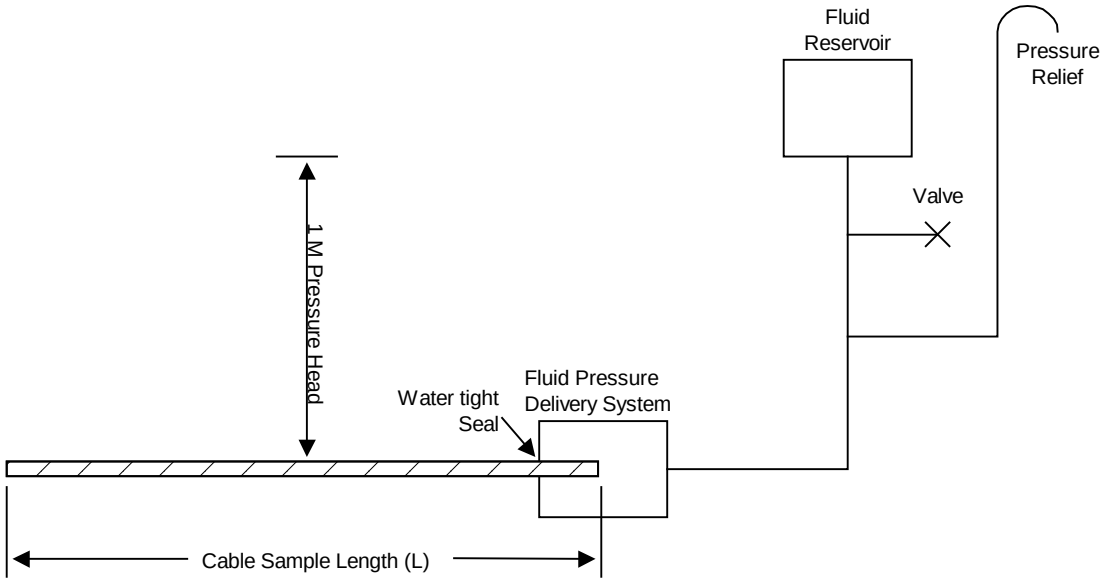
Method EIA/TIA-455-25C or IEC 60794-1-2-E4 Impact Test

Starting Energy:	Dependent on Cable Diameter, per Table 1, EIA/TIA-455-25C
Number Impact:	20 Cycles
Radius of hammer head:	12.5 $\pm$ 0.1 mm.
Impact rate:	$\leq$ 2 sec/cycle
Requirements:	- Maximum attenuation change < 0.1 dB at 1550 $\pm$ 10 nm. - No fiber break and no cable damage.



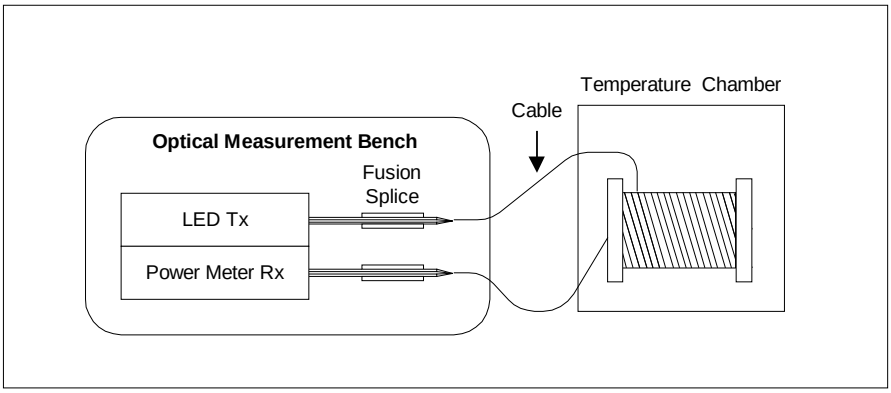
Method EIA/TIA-455-104A or IEC 60794-1-2-E6 Repeated Bending Test

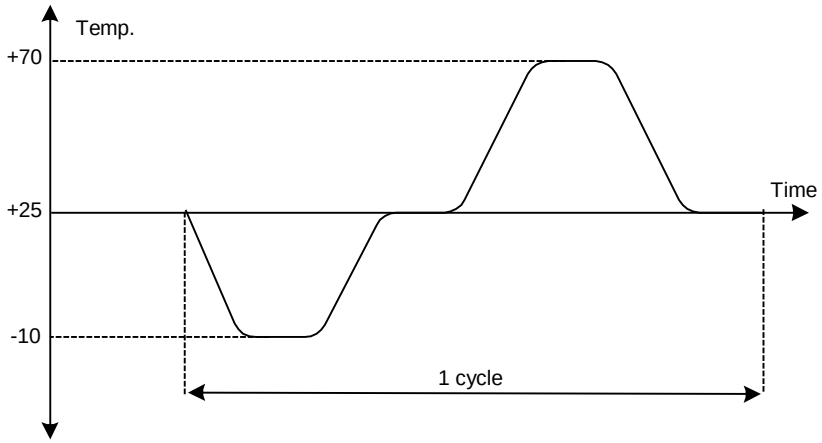
Sheave Diameter:	20 x diameter of cable
Number Cycles:	≥ 25 cycles
Load:	per Table 2, EIATIA-455-104A
Flexing rate:	≤ 2 sec./cycle
Length of sample:	Approximately 20 m
Requirements:	- Maximum attenuation change < 0.1 dB at 1550 ± 10 nm. - No fiber break and no cable damage.



Method EIA-455-82A or IEC 60794-1-2-F5B Water Penetration Test

Fluid Pressure:	1 m static head or equivalent pressure
Sample Length:	3 m.
Duration:	1 hour
Requirements:	No fluid leakage through the open cable end after 1 hour.





Method EIA/TIA-455-3A IEC 60794-1-2-F1 Temperature Cycling Test

Time at Temperature:	At least 14 hr. each Temp.
Temperature Range:	-10°C (± 2°C) Minimum +70°C (± 2°C) Maximum
Number of Cycles:	2 cycles
Soak time:	per Table A, Minimum Soak Times for a Given Sample Mass of EIA/TIA-455-3A
Requirements:	- Maximum attenuation change < 0.1dB/km at 1550 ± 10 nm. - No fiber break and no cable damage.

Cable Bending Test

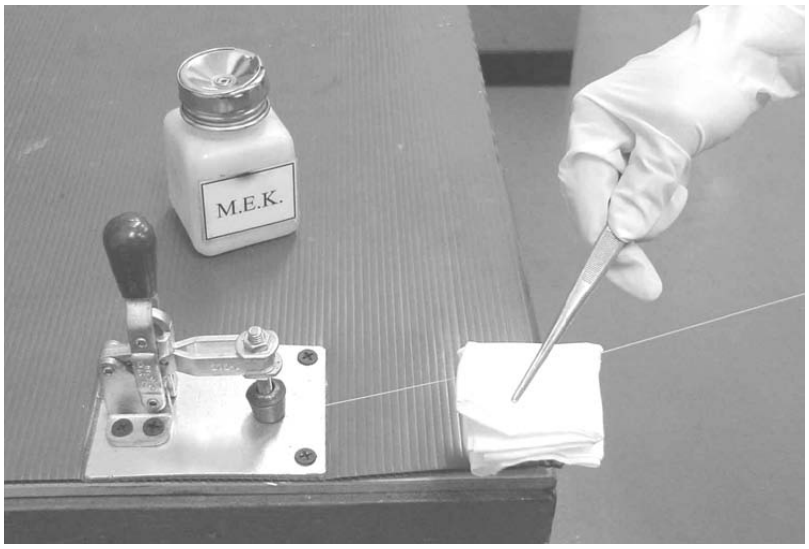
Test standard:	IEC 60794-1-2-E11B
Diameter of mandrel:	20 x diameter of cable
Number of cycles:	1
Wave length:	1550 ± 10 nm
Test result:	Attenuation changes < 0.1 dB and no fiber break and no cable damage

Cable Sheath Test

Carbon Black:	The procedure for carbon black testing shall conform to ASTM D1603 Standard Test Method for Carbon Black in Olefin Plastics.
Tensile strength and elongation:	Specimens of polyethylene material die cut from the sheaths shall be tested in accordance with ASTM D470-latest issue, except that the speed of jaw separation shall be 50 cm. (20 in.) per minute for inner sheath and 5 cm. (2 in.) per minute for outer sheath.
Environmental stress cracking:	Test specimens shall be die cut in the transverse direction from the cable sheath having an outside diameter of 2.8 cm. (1.1 in.) and larger. These specimens shall be prepared and subjected to an environmental stress cracking test as described in ASTM D1693 latest issue, except that the conditioning requirements is waived, the depth of the controlled imperfection shall be proportional to the sheath thickness, and the stress cracking reagent shall be a 10 percent solution (By volume) of "Igepal" CO-630.
Shrinkback:	Slab specimens shall be cut from the cable sheaths 5 cm. (2 in.) long, 13 mm. (1/2 in.) wide, and the same thickness as the cable sheath. The slab specimens shall be placed in a convection type circulating air oven operating at a temperature of 100 ± 1°C for a 4- hour period for inner sheath and 115 ± 1°C for outer sheath.

Fiber Rub Test

Sample:	50 cm length of the single colored fiber.
Materials:	1. Absorbent materials in white color such as cleaning tissue or soft cotton cloth. 2. Pincers 3. MEK Solution, grade: MEK FOR ANALYSIS, Code: 462703, Carlo Erba Reagents Co.,Ltd, Local supplier: Vidhaya-som Co.,ltd. etc. 4. Tool for fixing one end of the colored fiber 5. Rubber gloves 6. Mask
Procedure:	The test shall be prepared and performed according to below figure. The 5 ml (5 milliliters) of MEK solution shall be dripped at the middle point of absorbent material. After the absorbent material is soaked by the MEK solution then the MEK soaked cloth or tissue shall be wiped on the single colored fiber core with uniform backward and forward motion (15 cm wiping span , one time of backward and forward motion = 1 cycle = 30 cm wiping length) requiring total 75 cycles. Observe the sample.
Test result:	- no color of fiber peel off until could see the surface of bare fiber by visual check.



- END OF SPECIFICATION -

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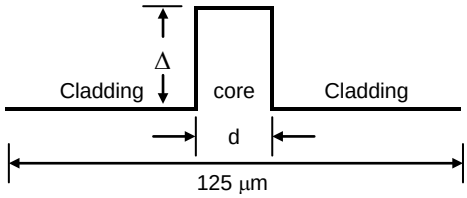
The coated Fibers are then placed in cable structures having additional layers to protect the fiber during the rigors of outside plant installation and to provide long term reliable operation in the outside plant environment. The design philosophy in meeting these objectives is to provide high quality, rugged, well-tested fiber optic cables, which are compact and have a high strength-to-weight ratio. Compact fiber optic cables are easier to handle and install in the field and provide longer length for field installation.

2. Optical Fiber Requirements

TFOC Zero Water Peak (ZWP) Single Mode Optical Fiber consists of a germanium doped core and a silica cladding. The fiber is fully compatible with other commercially available matched cladding fibers. TFOC ZWP Single Mode Optical Fiber is the industry's first fiber designed for use with transmission systems operating in entire wavelength region from 1280 to 1625 nm. Current systems operate in either the 2nd window (1280-1325 nm) or the 3rd window (1530-1565 nm). The 5th window from 1350 to 1450 nm has not been available because of higher attenuation (up to 1 dB/km) over much of the region. TFOC ZWP fiber enables usage over this much wider range because of a new manufacturing process, which practically eliminates the incorporation of OH ions (water) into the fiber. A concentration of several parts per billion (ppb) of OH ions in a conventional single mode fiber core cause the attenuation in the region around 1385 nm (the "water" peak) to be up to 300% higher than in the 1310 nm region. With TFOC ZWP fiber, the attenuation in the 5th window is always less than that in the 2nd window.

TFOC fibers feature a dual UV curable acrylate coating system, which provides unparalleled performance in a wide range of environmental conditions. The advantages of this coating structure are excellent resistance to micro-bending induced losses, superior hydrolytic stability and long term preservations of color code integrity. The coating is easily strippable using mechanical methods.



(d = core diameter)

Fig.1 Refractive index profile, Dispersion Unshifted Single Mode Fiber

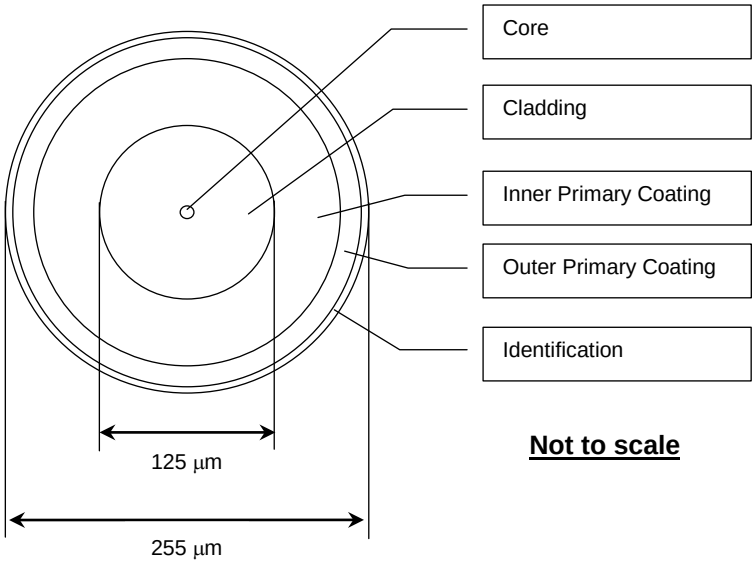


Fig. 2 Cross Section View of Dispersion Unshifted Single Mode Fiber

Table 1. Single Mode Fiber Requirements, Dispersion-Unshifted Fiber (ITU-T Rec. G.652.D)

Fiber attributes		
Item		**Description**
Manufacturing Method		VAD (vapor axial deposition method)
Refractive Index Profile		Step Index, Matched Cladding
Core		Germanium (GeO_2) doped Silica (SiO_2)
Core Diameter		8.3 μm
Cladding		Silica (SiO_2)
Primary Coating		2 layers of UV curable resin
Refractive index for core		1.452 @ 1310 nm 1.450 @ 1550 nm
Refractive index for cladding		1.447 @ 1310 nm 1.445 @ 1550 nm
Index of refraction Difference		0.35%
Group refractive index *		1.469 @ 1310 nm and 1550 nm
Cladding Diameter		125 ± 1 μm
Cladding Non-Circularity		≤ 1 %
Core/Cladding Concentricity error		≤ 0.5 μm
Coating Diameter (uncolored)		245 ± 5 μm
Coating/Cladding Concentricity error		≤ 12 μm
Colored Fiber Diameter		255 ± 10 μm
Mode Field Diameter		9.2 ± 0.4 μm @ 1310 nm 10.4 ± 0.5 μm @ 1550 nm
Proof test stress		The entire length of fiber is subjected to tensile stress greater than 0.69 GPa. (100 kpsi), Ref. EIA-455-31B or IEC 60793-1-30
Attenuation with Bending	100 turns, 30 mm radius	≤ 0.05 dB @ 1310 nm ≤ 0.10 dB @ 1550 nm
	1 turns, 16 mm radius	≤ 0.5 dB @ 1550 nm
Zero-Dispersion Wavelength (λ_0)		$1300 \le \lambda_0 \le 1324$ nm
Max. Zero-Dispersion Slope (S_{0max}) at λ_0		≤ 0.092 ps/(nm^2.km)
Chromatic dispersion coefficient, D(λ)		$D(\lambda) = \lambda S_{0max} / 4 \bullet [1 - \{\lambda_0/\lambda\}^4]$ ps/(nm•km) (λ = Operating Wavelength) ≤ 3.5 ps/(nm.km) @ 1288 ~ 1339 nm ≤ 18 ps/(nm.km) @ 1550 nm ≤ 22 ps/(nm.km) @ 1625 nm
Coating Strip Force (@ 0 °C to +45 °C)		1.3 N (0.3 lbf) ≤ F ≤ 8.9 N (2.0 lbf)
Cable attributes		
Item		**Description**
Attenuation coefficient		≤ 0.35 dB/km @ 1310 nm ≤ 0.35 dB/km @ 1383 nm ≤ 0.24 dB/km @ 1490 nm ≤ 0.21 dB/km @ 1550 nm ≤ 0.23 dB/km @ 1625 nm
Attenuation Coefficient @ 1285~1330 nm		≤ Measured attenuation at 1310 nm + 0.03 dB/km
Attenuation Coefficient @ 1525~1575 nm		≤ Measured attenuation at 1550 nm + 0.02 dB/km
Cabled Cut-off Wavelength (λ_{cc})		≤ 1260 nm (Ref. EIA/TIA-455-170)
Polarization mode dispersion (PMD) (Link Design Value)		≤ 0.20 ps/√km

* Optical time domain reflectometers (OTDRs) require the setting of the fiber's group refractive index in order to calculate and display distance. The above is a group refractive index values for OTDR settings.

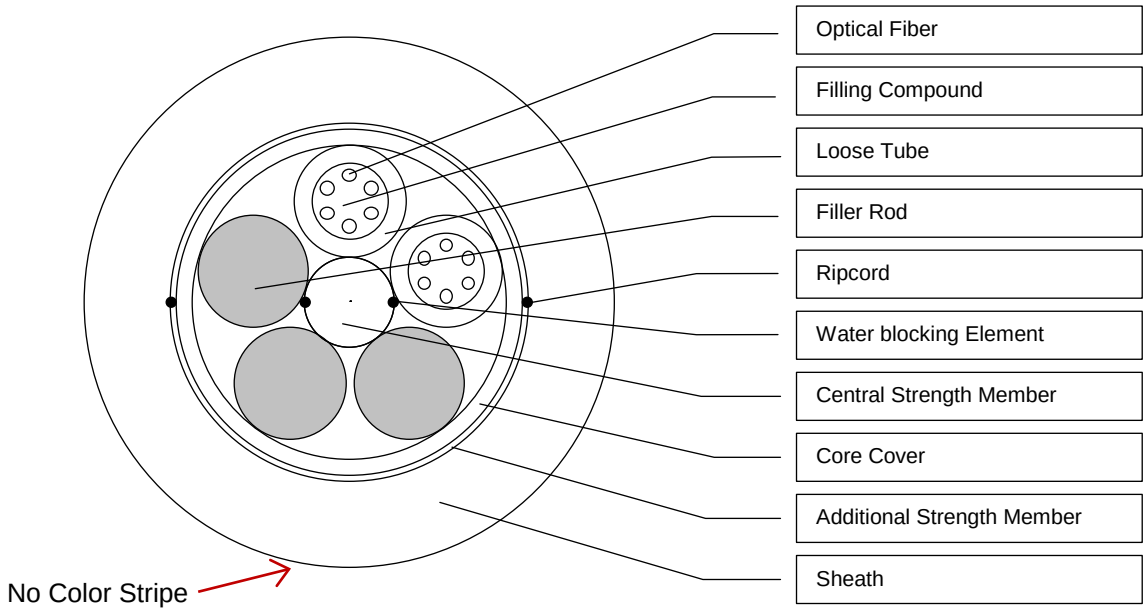
3. Cable Core / Cable Characteristics and Construction
These core/cable combinations are described in detail below.

Table 2. Constructions of all-dielectric self-supporting (ADSS), single jacket, dry core loose tube fiber optic cable.

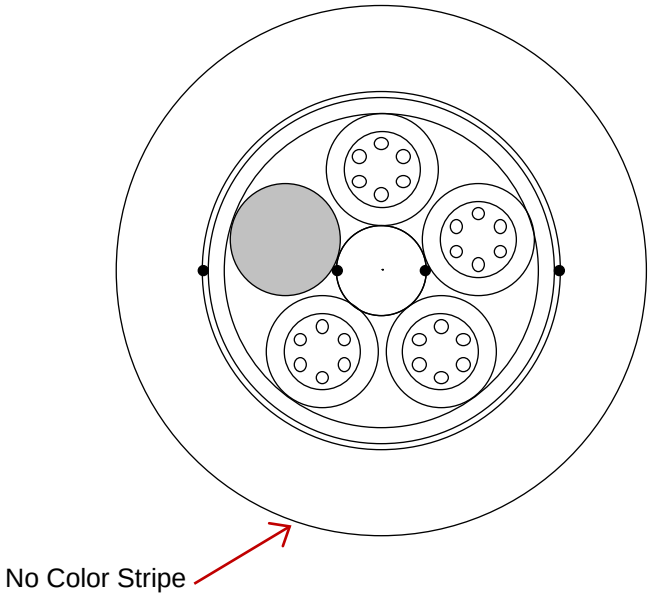
Item		**Description**
		Up to 30 Fibers
Optical Fiber	Construction	Table 1
Filling Compound	Material	Thixotropic Jelly Compound
Loose Tube	Material	(PBT) Polybutylene Terephthalate with color code
	Fiber per Tube	Max. 6
	Number	1 - 5
	Assembly	Fibers are brought together with the filling compound and placed in the extruded tube
Filler Rod	Material	Polyethylene, natural color
	Number	0 - 4
Stranding	Method	Reverse oscillating lay (ROL) technique (SZ Direction)
Central Strength Member	Material	FRP (Fiberglass Reinforce with Plastic)
Water Blocking Element	Material	Suitable Water Swellable Materials (Dry-Core Technology)
Core Covering	Material	Water Blocking tape
	Assembly	The tape shall be wrapped longitudinally over the cable core
Additional Strength Member	Material	Aramid yarns (If necessary)
	Number	The quantity of additional strength member shall be selected to minimize cable cost while meeting the performance requirement of the cable applications
*Ripcord	Material	Polyester cords
	Number	2
Sheath	Material	UV-Proof Black High Density Polyethylene
	Thickness	Minimum 1.5 mm
Cable Diameter (Maximum) mm.		10.5
Cable Weight (Approx.) kg/km		80
Structure		Fig. 3

Note:
- The thickness of the thinnest point shall not be measured at the groove of the ripcord.
- *Each ripcord shall have sufficient strength to be capable of slitting the sheath for a continuous length of 1(one) meter.
- Manufacturer may use additional/deduction suitable tape(s), water blocking elements, thread(s) or dielectric elements into suitable place in the cable for manufacturer's reason.

12 Fibers



24 Fibers



Not to scale

Fig. 3-1 Cross-section view for all-dielectric self-supporting (ADSS), single jacket, dry core loose tube fiber optic cable.

Table 3. TIA/EIA-598-A Color Code for Fiber and Loose tube Identification

No.	Fibers Identification	Loose Tube Identification
1	Blue	Blue
2	Orange	Orange
3	Green	Green
4	Brown	Brown
5	Slate	Slate
6	White	-

Note: - All fibers and tube used in our cables are color code to facilitate individual identification. Unless otherwise specified, all cables employ the standard industry color code system in accordance with the Munsell color shades as specified in EIA/TIA-359 and EIA/TIA-598A (Rose and Aqua color recommended standard TIA/EIA-598-B), Color Coding of Fiber Optic Cables. Anyway, the color code can be changed by customer's request.
- Unless otherwise requested by the customer, all cable jackets are black.

Table 4. Mechanical Specification of the cable

Item		**Specification**
Maximum Span Length		40 m
Minimum installation Sag		0.5% of Maximum Span Length
Worst case loading condition (Short-term)	Wind Velocity	126 km/hr
	Temperature	25 °C
Relative humidity		Up to 90%, no frost
Temperature Range	Installation	32 °C
		0 to 60 °C
	Operation	-10 to 70 °C
	Storage/Shipping	-20 to 70 °C
Maximum allowable pulling tension		1,800 N
Minimum bending Radius	During Installation Or handling	20 x External Diameter of Cable
	During Service Or fixed	15 x External Diameter of Cable

Note: At the maximum allowable pulling tension, fiber will not be subjected to a tension to get the strain higher than 0.33% or 1/3 of fiber proof test.

4. Cable Marking and Shipping Requirements

4.1 Sheath marking

The sheath marking is available upon customer's request. The Sheath marking shall be printed (Hot Stamp) on the outer sheath of the cable with white color in one-meter intervals.

4.2 Reels

4.2.1 The cable will be delivered at the required length on a wooden reel. The reels are designed to prevent damage to the cable during shipment and installation.

4.2.2 The cable shall be delivered on wooden reel in standard manufacturing length of 4,000 m. (Special length is available upon request, but the cost may be increased.)

4.2.3 The diameter of the barrel shall be not less than 30 times of the outer diameter of the cable.

4.2.4 Circumference shall be completely enclosed with wooden battens, these battens shall be secured by nails to each flange. There are metallic bands are strapped about the wooden batten to help secure the battens to the reel.

4.2.5 To provide access for testing, the inner end of the cable protrudes through the inside of the reel. The end is securely kept on the side of the flange to protect it during transport and storage. The length of the inner end is typically 1 meter. The cable ends are securely fastened so as not to protrude beyond any portion of the reel in an unprotected manner and to prevent the cable from becoming loose in transport.

4.3 Sealing and Cable Termination

The both end of the cable shall be sealed with a suitable rubber cap or heat shrinkable cap to prevent ingress of moisture.

4.4 Information Accompanying the Reel

The following information is securely attached to the reel.

- Manufacturer's Name
- Customer's Name
- Customer Order Number
- Customer Part Number (if Applicable)
- Kind & Size (Cable Description)
- Order Length
- Outside sequential
- Inside sequential
- Drum No.
- Reel ID.
- Ship Length
- Gross Weight
- Net Weight
- Date

Appendix A
The Calculation of Single Mode Optical Fiber Life-time

The calculated life time, according to the failure frequency technique, is as follows

Formula;

$$F = 1 - \exp\left(-N_p L \times \left(\left[1 + \left(t_s/t_p\right) \times \left(k \times \delta_s/\delta_p \right)^n \right]^{m/(n-2)} - 1 \right) \right)$$

Where

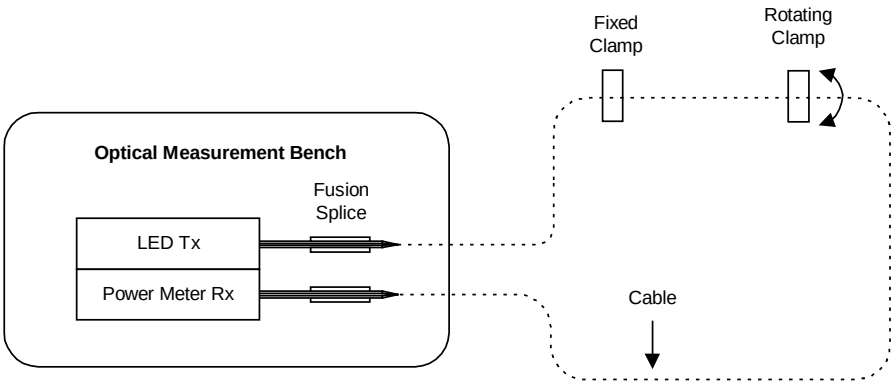
F	=	Failure probability (%)	
N_p	=	Failure probability at the proof test (times/km)	: 0.02
L	=	Fiber length (km)	: 100
t_s	=	Life time (Sec.)	: 7.88×10^8 (25 Years)
t_p	=	Duration of proof test (Sec.)	: 1
δ_s	=	Strain in life time (%)	: 0.2
δ_p	=	Strain of Proof test (%)	: 1
n	=	Stress corrosion factor	: 21
m	=	Weibull slope in low strength region	: 2
k	=	Safety factor at minimum proof strain	: 1

Failure probability (F) for fiber with length 100 km for 25 years is 0.000035 %

Appendix B
Properties of Cable Sheath

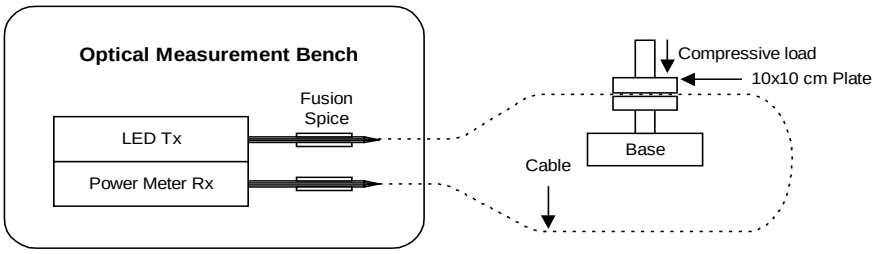
Parameter	Specification	Method
1. Carbon Black	2.6 ± 0.25 %	ASTM D1603
2. Minimum Tensile Strength	168 kg/cm^2	ASTM D470
3. Minimum Elongation	300 %	ASTM D470
4. Environment Stress Cracking : Max. Failure From 10 Specimens	2	ASTM D1693
5. Max. Shrinkback	5%	Slab specimens 50x13 mm in the oven at 115±1ºC for 4 hours

Appendix C
Mechanical Test



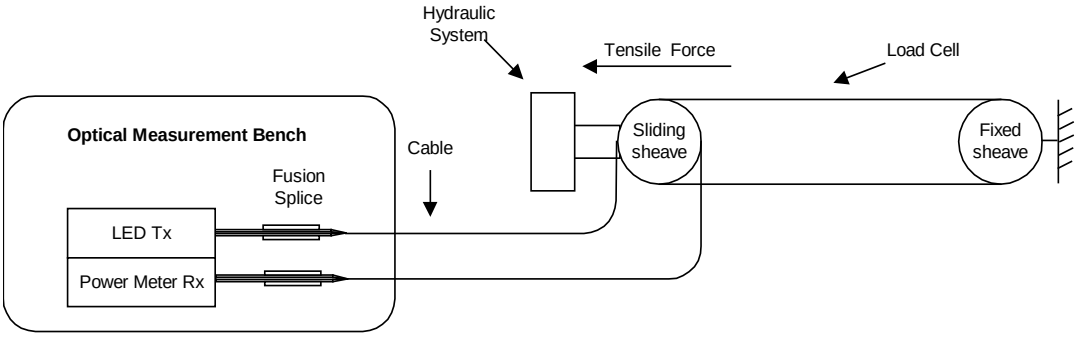
Method EIA-455-85A or IEC 60794-1-2-E7 Twist Test

Length Test:	1 m
Load	per Table2, TIA/EIA-455-85A
Rotation:	±180° , 10 cycles
Requirements:	- Maximum attenuation change < 0.1 dB at 1550 ± 10 nm. - No fiber break and no cable damage.



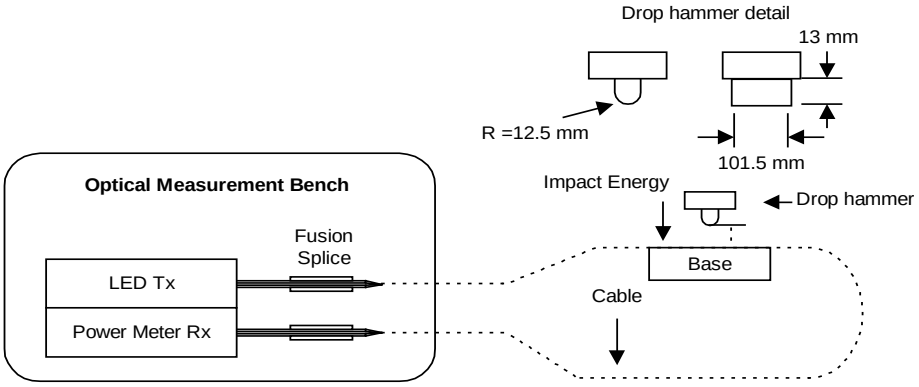
Method EIA-455-41A or IEC 60794-1-2-E3 Compression Test

Load:	$\geq$ 2,200 N (220N/cm)
Duration:	$\geq$ 10 minutes (one point and one time)
Length of Sample:	Approximately 20 m
Requirements:	- Maximum attenuation change < 0.1 dB at 1550 $\pm$ 10 nm. - No fiber break and no cable damage.



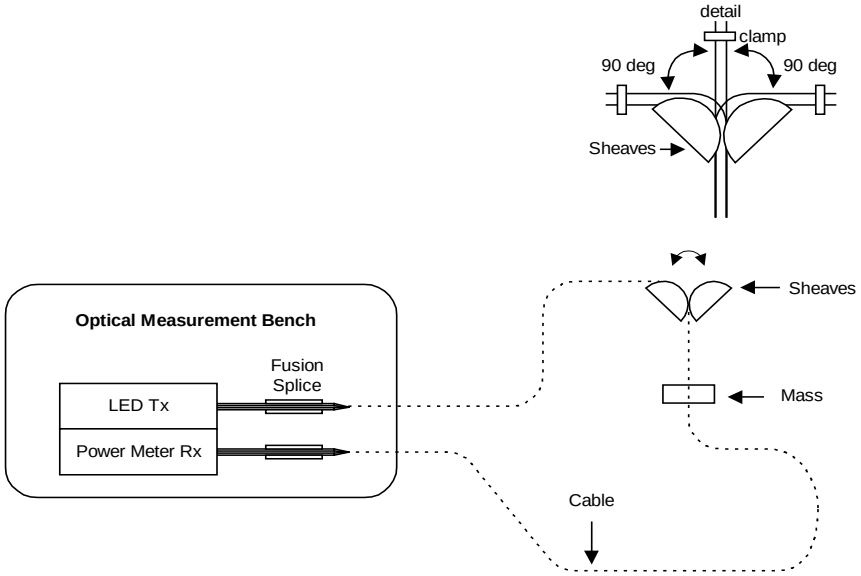
Method IEC-60794-1-2-E1 and EIA-455-33A Tensile Performance Test

Length of Cable under Load:	Min. 25 m
Sheave Diameter:	30 x outside diameter of the cable
Load cable:	1,800 N , 1 hour
Requirements:	- Maximum attenuation change ≤ 0.05 dB at 1550 ± 10 nm. The fiber strain shall not be greater than 0.33% or the 1/3 of the fiber proof test. - No fiber break and no cable damage.



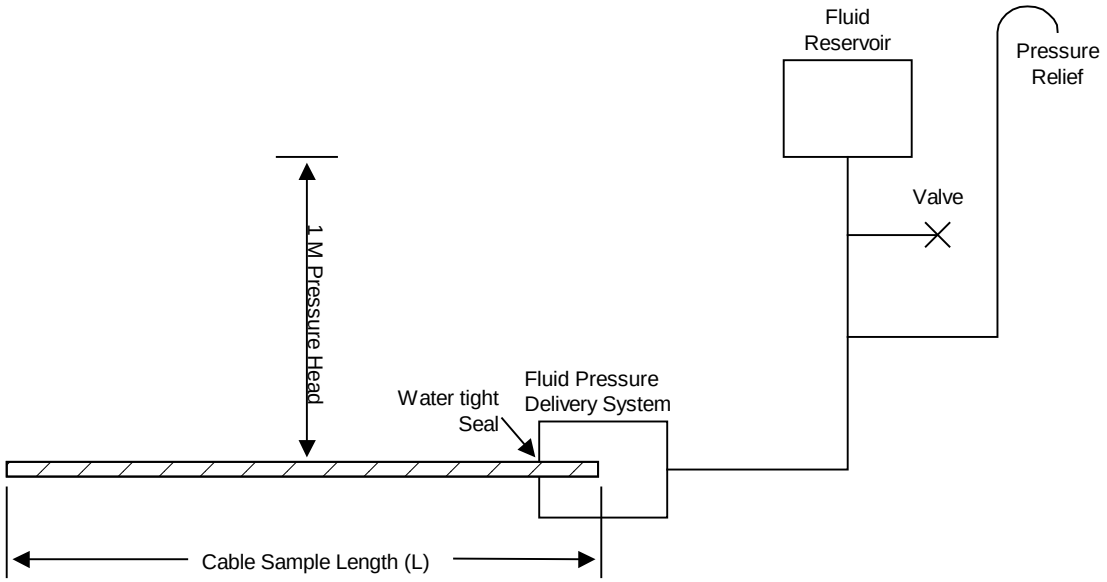
Method EIA/TIA-455-25C or IEC 60794-1-2-E4 Impact Test

Starting Energy:	Dependent on Cable Diameter, per Table 1, EIA/TIA-455-25C
Number Impact:	20 Cycles
Radius of hammer head:	12.5 $\pm$ 0.1 mm.
Impact rate:	$\leq$ 2 sec/cycle
Requirements:	- Maximum attenuation change < 0.1 dB at 1550 $\pm$ 10 nm. - No fiber break and no cable damage.



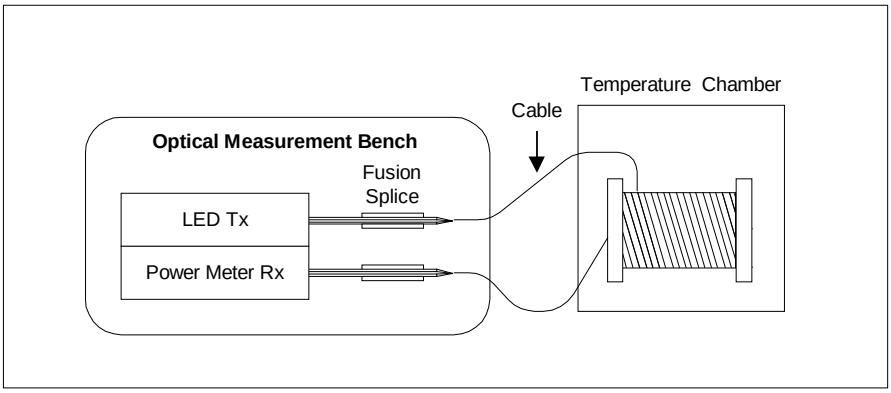
Method EIA/TIA-455-104A or IEC 60794-1-2-E6 Repeated Bending Test

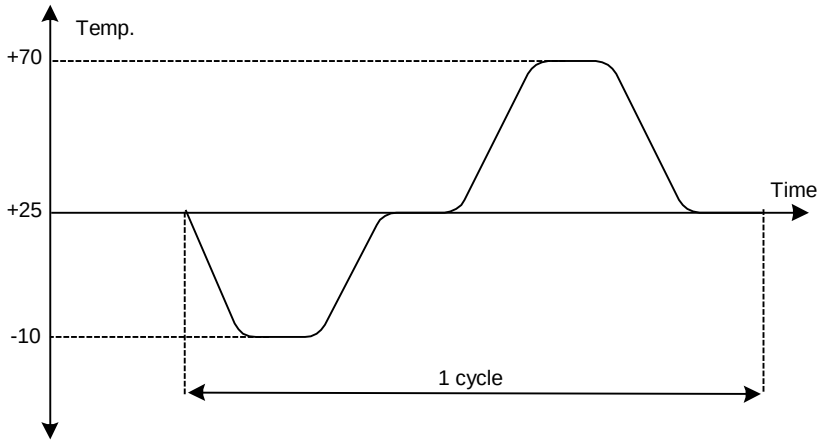
Sheave Diameter:	20 x diameter of cable
Number Cycles:	≥ 25 cycles
Load:	per Table 2, EIATIA-455-104A
Flexing rate:	≤ 2 sec./cycle
Length of sample:	Approximately 20 m
Requirements:	- Maximum attenuation change < 0.1 dB at 1550 ± 10 nm. - No fiber break and no cable damage.



Method EIA-455-82A or IEC 60794-1-2-F5B Water Penetration Test

Fluid Pressure:	1 m static head or equivalent pressure
Sample Length:	3 m.
Duration:	1 hour
Requirements:	No fluid leakage through the open cable end after 1 hour.





Method EIA/TIA-455-3A IEC 60794-1-2-F1 Temperature Cycling Test

Time at Temperature:	At least 14 hr. each Temp.
Temperature Range:	-10°C (± 2°C) Minimum +70°C (± 2°C) Maximum
Number of Cycles:	2 cycles
Soak time:	per Table A, Minimum Soak Times for a Given Sample Mass of EIA/TIA-455-3A
Requirements:	- Maximum attenuation change < 0.1dB/km at 1550 ± 10 nm. - No fiber break and no cable damage.

Cable Bending Test

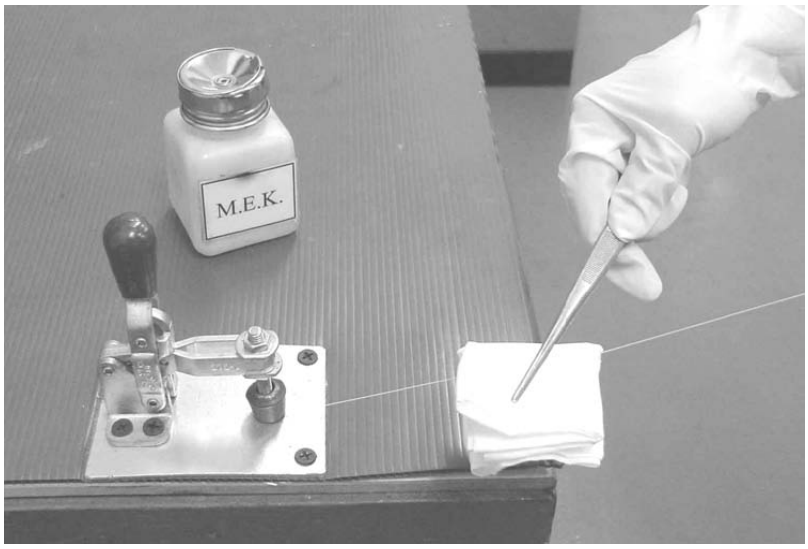
Test standard:	IEC 60794-1-2-E11B
Diameter of mandrel:	20 x diameter of cable
Number of cycles:	1
Wave length:	1550 ± 10 nm
Test result:	Attenuation changes < 0.1 dB and no fiber break and no cable damage

Cable Sheath Test

Carbon Black:	The procedure for carbon black testing shall conform to ASTM D1603 Standard Test Method for Carbon Black in Olefin Plastics.
Tensile strength and elongation:	Specimens of polyethylene material die cut from the sheaths shall be tested in accordance with ASTM D470-latest issue, except that the speed of jaw separation shall be 50 cm. (20 in.) per minute for inner sheath and 5 cm. (2 in.) per minute for outer sheath.
Environmental stress cracking:	Test specimens shall be die cut in the transverse direction from the cable sheath having an outside diameter of 2.8 cm. (1.1 in.) and larger. These specimens shall be prepared and subjected to an environmental stress cracking test as described in ASTM D1693 latest issue, except that the conditioning requirements is waived, the depth of the controlled imperfection shall be proportional to the sheath thickness, and the stress cracking reagent shall be a 10 percent solution (By volume) of "Igepal" CO-630.
Shrinkback:	Slab specimens shall be cut from the cable sheaths 5 cm. (2 in.) long, 13 mm. (1/2 in.) wide, and the same thickness as the cable sheath. The slab specimens shall be placed in a convection type circulating air oven operating at a temperature of 100 ± 1°C for a 4- hour period for inner sheath and 115 ± 1°C for outer sheath.

Fiber Rub Test

Sample:	50 cm length of the single colored fiber.
Materials:	1. Absorbent materials in white color such as cleaning tissue or soft cotton cloth. 2. Pincers 3. MEK Solution, grade: MEK FOR ANALYSIS, Code: 462703, Carlo Erba Reagents Co.,Ltd, Local supplier: Vidhaya-som Co.,ltd. etc. 4. Tool for fixing one end of the colored fiber 5. Rubber gloves 6. Mask
Procedure:	The test shall be prepared and performed according to below figure. The 5 ml (5 milliliters) of MEK solution shall be dripped at the middle point of absorbent material. After the absorbent material is soaked by the MEK solution then the MEK soaked cloth or tissue shall be wiped on the single colored fiber core with uniform backward and forward motion (15 cm wiping span , one time of backward and forward motion = 1 cycle = 30 cm wiping length) requiring total 75 cycles. Observe the sample.
Test result:	- no color of fiber peel off until could see the surface of bare fiber by visual check.



- END OF SPECIFICATION -

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THAI FIBER OPTICS CO., LTD.

SPECIFICATION

OF

SINGLE MODE OPTICAL FIBER (ITU-T G.657.A1)

OPTICAL FIBER DROP CABLE (ROUND TYPE),

(OPTICAL DROP WIRE FOR FTTX (ROUND TYPE-2F))

Specification No. TFS-1415-00

Issued Date : August 25, 2016

(URAPHONG JUNSEM)

TECHNICAL SECTION MANAGER

(PORNSAWAN BOONTARAWA)

DEPUTY FACTORY MANAGER

(MASAYUKI SHIBATA)

FACTORY MANAGER

Certificate: No. 157515

Certificate: No. 196777

DIRECTOR & GM : _____

DOC. No. _____

MARKETING DEPARTMENT

DISTRIBUTED DATE _____

1. General

1.1 Scope

This specification describes the construction and properties of Optical Fiber Drop Cable (round type) which is applied to aerial use. The optical fiber shall be covered with tight buffer to prevent the optical fiber movement along the cable after installation. The Optical Fiber used in this cable is allowed small bending radius in comparison with conventional optical fiber and in compliance with fiber attributes of ITU-T G657.A1.

1.2 Quality Assurance

Thai Fiber Optics Co., Ltd. takes pride in being an industry leader recognized for producing a quality product. To ensure a continuing level of quality in production cables, a consistent quality system with ISO 9001 “Quality Management System” and ISO 14001 “Environment Management System” are provided for all optical fiber and fiber optic cables.

The adequacy of all materials is assured through incoming inspection, source inspection, or vendor certified data. Fiber is measured and classified before being placed into inventory, and then selected from inventory to satisfy customer order requirements. Inspection of cable construction characteristics is the responsibility of the employees producing the product. All cables are tested for compliance to customer specified transmission requirements in Final Test. Adequacy of this quality control system is assured through product and process audits conducted by the internal quality improvement organization.

TFOC is supported by standards such as
- Electronic Industries Association (EIA)
- Telecommunications Industry Association (TIA)
- International Telecommunications Union (ITU)
- International Electrotechnical Commission (IEC)
- American Society for Testing and Materials (ASTM)

1.3 General Fiber Optic Cable Characteristics

High quality optical fibers made with pure silica-based glass have very low loss for infrared wavelengths and can be used to carry large amounts of information for very long distances in optical communication systems. High fiber strength is obtained by protecting the surface of the glass fiber with thin coating layers of polymeric materials.

The coated Fibers are then placed in cable structures having additional layers to protect the fiber during the rigors of outside plant installation and to provide long term reliable operation in the outside plant environment. The design philosophy in meeting these objectives is to provide high quality, rugged, well-tested fiber optic cables, which are compact and have a high strength-to-weight ratio. Compact fiber optic cables are easier to handle and install in the field and provide longer length for field installation.

2. Optical Fiber Requirements

Allwave Bend-insensitive ZWP Fiber maintains very low bending loss across the full spectrum of wavelengths from 1260 to 1625 nm, while ensuring long-term fiber strength and reliability. It can be coiled into a 10 mm radius loop with ≤ 1.0 dB incurred loss at 1625 nm and ≤ 0.5 dB incurred loss at 1550 nm – five times better bend performance than convention single-mode and leading Low Water Peak (LWP) fibers.

TFOC fibers feature a dual UV curable acrylate coating system, which provides unparalleled performance in a wide range of environmental conditions. The advantages of this coating structure are excellent resistance to micro-bending induced losses, superior hydrolytic stability and long term preservations of color code integrity. The coating is easily strippable using mechanical methods.

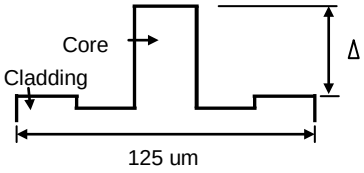

Fig.1 Refractive Index Profile

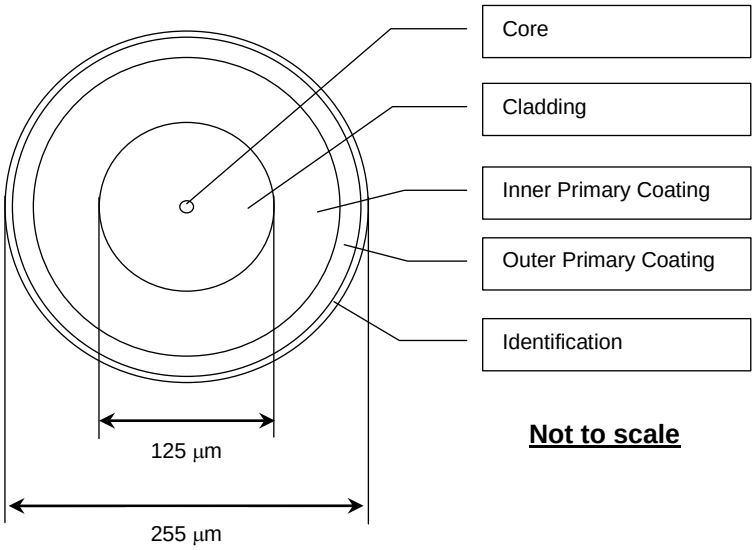

Fig. 2 Cross Section View of AllWave Ben-insensitive ZWP, Single Mode Fiber

Table 1. AllWave Bend-insensitive ZWP, Single Mode Fiber Requirements (ITU-T Rec. G.657.A1)

Fiber attributes		
Item		**Description**
Manufacturing Method		VAD (vapor axial deposition method)
Refractive Index Profile		Step Index, Matched Clad type, Single Mode Optical Fiber
Group refractive index (Typical)		1.467 @ 1310 and 1383 nm 1.468 @ 1490 and 1550 nm 1.472 @ 1625 nm
Core		Germanium (GeO_2) doped Silica (SiO_2)
Core Diameter		8.3 μm
Cladding		Silica (SiO_2)
Primary Coating		2 layers of UV curable resin
Cladding Diameter		125 ± 0.7 μm
Cladding Non-Circularity		≤ 1.0 %
Core/Cladding Concentricity error		≤ 0.5 μm
Coating Diameter (uncolored)		245 ± 5 μm
Coating/Cladding Concentricity error		≤ 12 μm
Colored Fiber Diameter		255 ± 10 μm
Identification		Color coding
Mode Field Diameter		8.6 ± 0.4 μm @ 1310 nm
Proof test stress		The entire length of fiber is subjected to tensile stress greater than 0.69 GPa. (100 kpsi) Ref. EIA-455-31B or IEC 60793-1-30
Attenuation with Bending	10 turns, 15 mm radius	≤ 0.25 dB @ 1550 nm ≤ 0.50 dB @ 1625 nm
	1 turns, 10 mm radius	≤ 0.50 dB @ 1550 nm ≤ 1.00 dB @ 1625 nm
Zero-Dispersion Wavelength (λ_0)		$1300 \le \lambda_0 \le 1324$ nm
Max. Zero-Dispersion Slope (S_{0max}) at λ_0		≤ 0.092 ps/(nm^2.km)
Chromatic dispersion coefficient, D(λ)		$D(\lambda) = \lambda S_{0max} / 4 \bullet [1 - \{\lambda_0/\lambda\}^4]$ ps/(nm•km) (λ = Operating Wavelength) ≤ 3.5 ps/(nm.km) @ 1288~1339 nm ≤ 18 ps/(nm.km) @ 1550 nm ≤ 22 ps/(nm.km) @ 1625 nm
Coating Strip Force (@ 0 °C to +45 °C)		1.3 N (0.3 lbf) ≤ F ≤ 8.9 N (2.0 lbf)
Cable attributes		
Item		**Description**
Attenuation coefficient		≤ 0.38 dB/km @ 1310 nm ≤ 0.35 dB/km @ 1383 nm ≤ 0.30 dB/km @ 1490 nm ≤ 0.28 dB/km @ 1550 nm ≤ 0.30 dB/km @ 1625 nm
Cabled Cut-off Wavelength (λ_{cc})		≤ 1260 nm (Ref. EIA/TIA-455-170)

*In case of shorter length than 1km, measurement error may appear on measured attenuation value. In that case, below specifications are applied.

0.2 ≤ L < 0.5 km, (0.25L + 0.15) dB at 1310nm, (0.15L + 0.12) dB at 1550nm

L ≤ 0.2km, 0.2 dB at 1310nm, 0.15dB at 1550nm

L: Cable length (km)

**Optical time domain reflectometers (OTDRs) require the setting of the fiber's group refractive index in order to calculate and display distance. The above is a group refractive index values for OTDR settings.

3. Cable Core / Cable Characteristics and Construction

These core/cable combinations are described in detail below.

Table 2. Construction of Optical Drop Cable (FTTx Round Type)

Item		Description
		2-Fibers Cable
Tight Buffer	Fiber Spec.	The same as Table 1 (G.657.A1)
	Material	Nylon, PVC or Better materials
	Color	Blue and Orange (Ref. EIA/TIA-598A)
	Dia. of Tight Buffer	600 μm
Additional Strength member	Material	Aramid Yarns
Suspension Unit	Material	Zinc-coated steel wire strand
	Diameter	7/0.40 ± 0.03 mm
Sheath	Material	Flame retardant polyethylene, black color (contain carbon black for UV light protection)
	Thickness	1.0 ± 0.2 mm
Overall Diameter (Approx.) mm		6.5
Cable Dimension (± 0.2) mm		3.5
Cable weight (Approx.) kg/km		30
Structure		Fig. 3

Table 3. Cable sheath specification

Parameters	Specification and Method
1. Carbon Black	2.60 ± 0.25 %, ASTM D1603
2. Minimum Tensile Strength	100 kg/cm^2, ASTM D470
3. Minimum Elongation	160 %, ASTM D470
4. Flame Propagation	See Appendix A

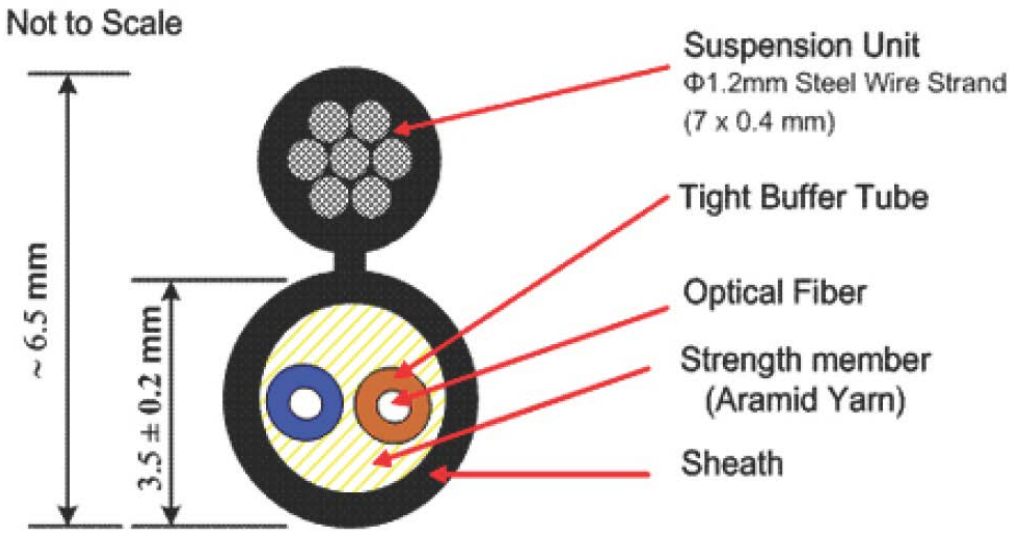

Fig.3 Cross section of 2 Cores (Drop cable (round type))

Table 4. Technical information of the cable

Item		Specification
Maximum pulling tension (Fiber strain ≤ 0.4%)		800N
Maximum pole span length		40 m
Temperature	Installation	32 °C
	Operation	Tropical, -10 °C to 70 °C
Worst case loading condition (short-term)	Wind Velocity	Max. 100 km/hr
	Temperature	25 °C
Initial Sag		0.5% of span length
Relative humidity		Up to 90%, no frost
Temperature range	Installation	0 °C to 60 °C
	Operation	-10 °C to 70 °C
	Storage/Shipping	-10 °C to 70 °C
Minimum Bending Radius	with suspension Unit	130mm (20xD)
	without suspension Unit	35mm (15xD)

4. Mechanical and Environmental Test Requirements.
   This section covers the mechanical and environmental test for the cable.

Table 5. Mechanical and Environmental Test characteristic of the cable

Test	Test Method	Test Conditions	Specification
Tensile Performance Test	IEC-60794-1-2-E1 and EIA-455-33A	Pulling method : Straight pulling Test length : 25m Tension : Maximum pulling tension Duration : 5min.	Maximum attenuation change ≤ 0.1 dB at 1550nm. No fiber break and no sheath damage. A fiber strain shall not be greater than 0.4% during and after testing.
Bending Test	IEC-60794-1-2-E11A	Mandrel radius : 30mm Turns: 10 Cycles: 1 Load : No load	Maximum attenuation change ≤ 0.1 dB at 1550nm after test No fiber break and no sheath damage
Temperature Cycling Test	IEC-60974-1-2-F1 or TIA/EIA 455-3A	Temperature range: -10 to +70 °C Number of cycles: 2	Maximum attenuation change ≤ 0.10 dB/km at 1550nm No fiber break and no sheath damage

5. Sheath printing

The completed optical fiber drop cable shall be permanently and good legibility marked. The color of marking shall preferably by white color and printed on the cable sheath in one meter intervals. The starting number of ordering length for any coil shall begin whit zero meter. The accuracy of the measurement of length marking shall be held within the limits of ± 1%.

Example:
- Name "กระทรวงเทคโนโลยีสารสนเทศและการสื่อสาร" or MICT
- Manufacturer's name
- Year of manufacture
- Type (e.g., OFC/SM/DW-R/FRPE-2F), and etc.

6. Packing and Marking

6.1 The cable shall be packed into a standard length of 1,000 meters per reel or as specified on order with tolerance of – 0, + 5 %.

6.2 The cable wound on the reel shall be wrapped with plastic tape or other suitable material to protect the cable during shipping and handling. Both ends of the cable shall be fitted with a suitable cap and firmly secured.

6.3 Each reel shall be packed in the cardboard box and shall have a label showing the description such as Optic Dropwire for FTTX, SM/OFC/DW-R/FRPE, the number of fiber, TOT contract, the reel Number, Cable length in meters, weight(Kg) per reel, year of manufacture and name of the supplier.

Appendix A
Properties of Cable Sheath Test

Carbon Black:	The procedure for carbon black testing shall conform to ASTM D1603 Standard Test Method for Carbon Black in Olefin Plastics.
Tensile strength and elongation:	The procedure for carbon black testing shall conform to ASTM D1603 and ASTM D470 Standard Test Method for Carbon Black in Olefin Plastics.
Flame Propagation:	The procedure for flame propagation testing shall be tested in accordance with IEC 60332-1. The charred or affected portion shall not have reached within 50 mm of the lower edge of the top clamp.

END OF SPECIFICATION

For more information please contact
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