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GR-1435: Ensuring a Reliable Multi-Fiber Optical Connector

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GR-1435: Ensuring a Reliable Multi-Fiber Optical Connector

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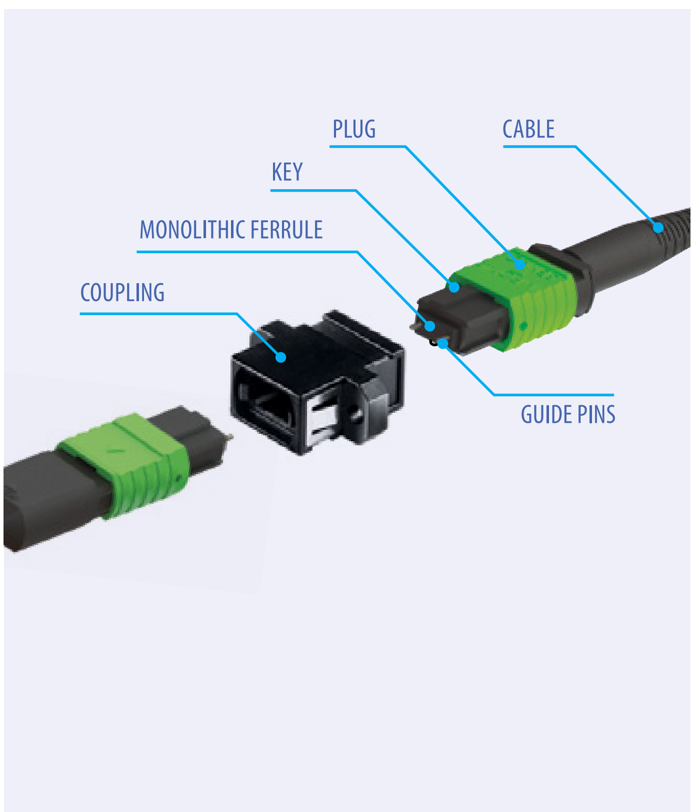
Introduction

In 1985, Nippon Telegraph and Telephone (NTT) introduced MT ferrule technology as a way to improve mass fiber connectivity and efficiency. Multi-fiber Push-On, abbreviated MPO, is an MT ferrule-based fiber optic connector that was developed in the 1990's as a way for mechanical connectorization. The early adoption of MPO connectors was very slow due to high costs and low optical performance.

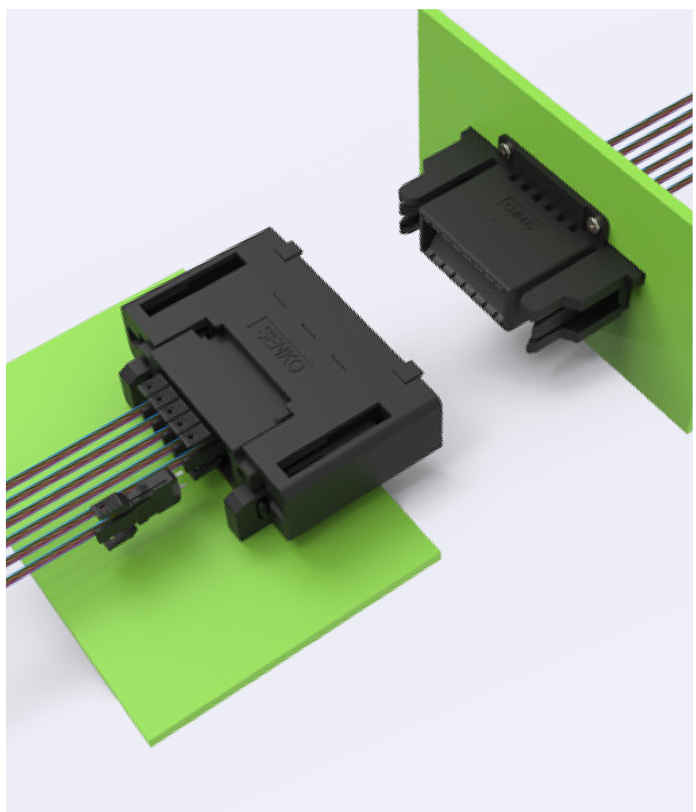
In recent years with the ever-increasing demand for more bandwidth, multi-fiber connectors have become one of the most important components in optical network connectivity. As 100G/400G/800G transceiver technologies continue to gain popularity, more multi-fiber connectors will be deployed to increase network density. However, as history has shown, multi-fiber connectors are not without their own challenges when compared to single fiber connectors. The mechanical alignment of 12, 16, 24, 32, 48, and even 72 fibers between two pins as wide as 5.3 mm is no small engineering feat.

The most widely deployed multi-fiber connector in the market is the MPO connector which features multiple fibers housed within a monolithic ferrule. With so many suppliers in the market offering optical connectors, how does one ensure that the connector that they are selling can perform well during deployment and throughout its life cycle? The quality, reliability, and performance of multi-fiber connectors are assured not only by selecting superior components, but also by following a repeatable refined termination procedure, followed by a refined polishing process, and extensive testing with top-of-the-line equipment.

MONOLITHIC Multi-Fiber Connector



MULTI-FERRULE Multi-Fiber Connector

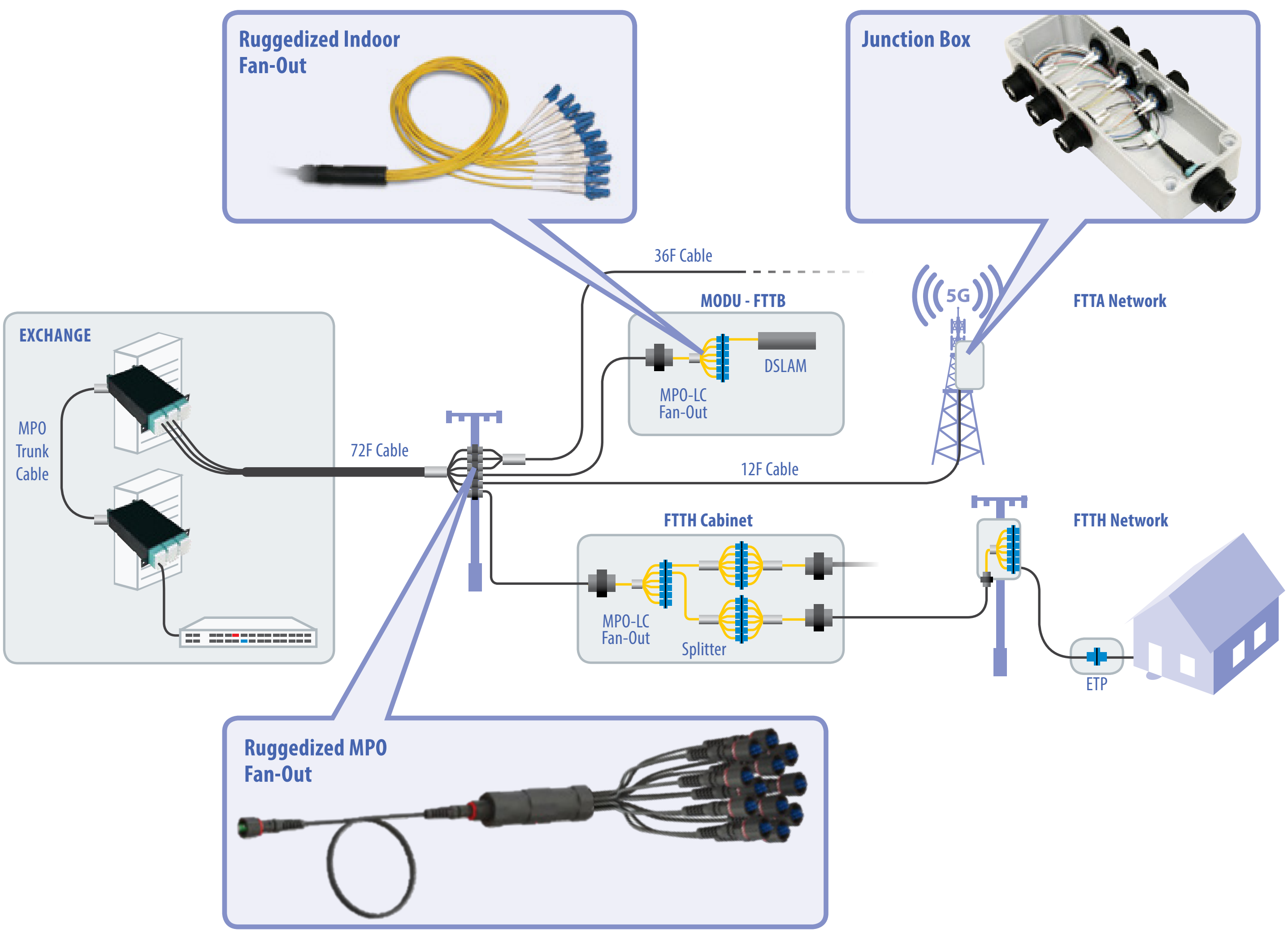


Why is there a need for GR-1435?

It is a very high hurdle to achieve GR-1435 certification. Does this mean that certified connectors will be more expensive? Why would someone spend about twice as much on a connector just because it is certified?

The connector is just one small component in an intricate optical network. However, the connector has a significant impact on overall network performance. Using non-certified components may save on capital expenditures upfront, but from a Total Cost of Ownership perspective, it will be a much higher cost with all the maintenance expenditures in the future. Unlike a single fiber connector where any failure will only affect a single transmission, the potential disruption from a multi-fiber is much more severe.

Let's use a 24-fiber MPO connector as an example, if deployed in a 400 Gbps parallel network, the connector failure would cause a catastrophic failure. The damage would not only be limited to network failure, but also cause a loss in revenue, result in Service Level Agreement (SLA) penalties, and reduce customer confidence.



Introducing GR-1435

The GR-1435-CORE standard outlines the requirements, features, performance criteria, and characteristics of single-mode multi-fiber optical connectors. The standard outlines qualification testing in two phases: 1) initial product qualification/certification, 2) periodic verification to ensure that the product performs within established parameters.

The GR-1435 standard outlines three different fiber/cable media types for providing optical multi-fiber pathways. These three media types vary in connector assembly robustness for diverse applications, such as in back-plane connections or in an outside plant environment. The three media types are:

- **Type I Media: bare ribbon fiber**
- **Type II Media: jacketed ribbon fiber**
- **Type III Media: unreinforced single fiber with a buffer or coating of approximately 0.9mm**

Type I Media
Bare Ribbon Fiber

Type II
Reinforced Jacket

Type III Media
Unreinforced Single Fiber

GR-1435 is designed to test a connector's lifetime performance and reliability through a series of service life performance tests, which include environmental and mechanical tests. These tests are designed to simulate stressors that a connector may experience during its lifetime from manufacturing, storage, transport, operation, handling, and aging. Furthermore, the GR-1435 standard outlines an extended service life test to determine the long-term reliability of the connector assembly. These tests are in addition to the standard service life performance tests and are meant to identify possible weaknesses in the connector assembly, design or materials.

The tests are usually performed on a set of 15 samples from the manufacturer to establish a statistically valid sample size. To achieve GR-1435 compliance certification, testing and reporting is performed by an accredited 3rd party test laboratory, which is part of the requirement for any manufacturer.

GR-1435 Test Criteria and Measurements

Before the multi-fiber connector assembly is put through rigorous testing conditions, we need to establish the initial condition and what changes (if any) are considered acceptable. The GR-1435 standard takes the grade of the connectors into consideration, which are divided into Standard, High-Performance, and Ultra-Performance categories. The connector insertion loss and reflectance are measured at 4 phases throughout the lifetime of the samples, these include as a new product, during testing not under load, during testing under load, and at the end of the test.

Test	Maximum Insertion Loss (dB)			Maximum Insertion Loss Change (dB)	
	Standard (R)	High Performance (CR)	Ultra Performance (CR)	Standard & High Performance (R)	Ultra Performance (0)
New Product	0.70	0.50	0.35	-	-
During Testing, Not Under Load	0.80	0.60	0.45	0.30	0.20
During Testing, Under Load	-	-	-	0.50	0.30
End of Test	0.80	0.60	0.45	-	-

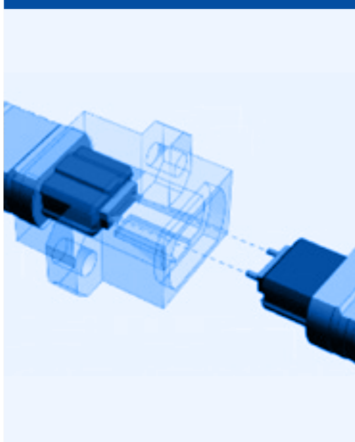
Test	Reflectance (dB)		
	Standard (R)	High Performance (CR)	Ultra Performance (CR)
New Product	-55	-60	-65
During Testing, Not Under Load	-50	-55	-60
During Testing, Under Load	-50	-55	-60
End of Test	-50	-55	-60

(R) - Requirement
(CR) - Conditional Requirement
(0) - Objective

GR-1435 General Requirements

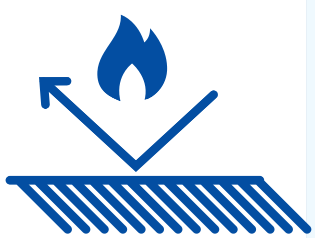
There are basic requirements that the multi-fiber connector assembly must satisfy for it to be considered for the service life performance tests. The three main requirements are connector intermateability, fire-resistance, and fungal resistance.

Basic Requirements



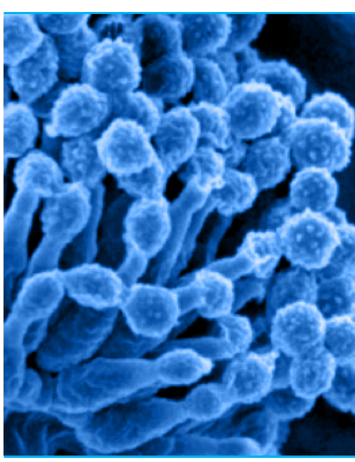
Intermateability

The connector must meet a set of defined physical attributes with couplings and plugs to ensure that connectors supplied from one supplier can be mated with connectors from a different supplier. An example is the most common multi-fiber connector, the MPO connector, needing to be compliant with the EIA/TIA-604-5 Fiber Optic Connector Intermateability Standards (FOCIS-5) standard and the IEC 61754-7 standard.



Fire-resistance

There is a range of flammability tests, such as the ANSI T1.307 and UL94, that must be passed depending on the type of material used. The main reason for this requirement is the possibility of the multi-fiber connector assembly being used in an indoor environment, especially in FTTP and data centers. Flammable materials or materials that emit too much smoke can damage surrounding equipment. Corrosive chemicals in the smoke may also cause acidic condensation, which corrodes equipment over time.

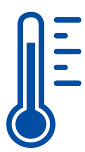
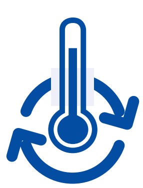
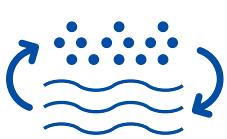
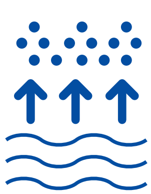


Fungal resistance

Many additives such as lubricants, stabilizers, and plasticizers may be used in the manufacture of the connector. These materials may promote fungal growth, which digests these additives and secretes acids as a by-product. These acids can then breakdown the resins to cause more damage. Polymeric materials used for multi-fiber optical connectors must be resistant to fungal growth. Fungal resistance is tested based on the methodology outlined in the ASTM G21 standard.

GR-1435 Test Criteria

The following table is a description of the Uncontrolled Environmental Tests performed on the connectors during the GR-1435 testing:

Uncontrolled Environment		
	**Thermal Aging**	Connectors are subjected to high temperature of 85°C with uncontrolled humidity for a duration of 168 hours. This test is the least severe of all the environmental tests and simulates and accelerated the processes that may occur during product shipping.
	**Humidity Aging**	Connectors are subjected to high temperature and humidity of 95% relative humidity at 75°C for 168 hours. This test simulates the connector's condition in the second half of its service life with wear and tear,
	**Thermal Cycling**	The thermal cycling test is performed to simulate conditions that the connector assemblies may be exposed to in the outside plant environment after a period of aging. This test is performed with cycles between -40°C to 75°C, as optical connectors may be installed in areas with temperatures at both environmental extremes. This test is run for 168 hours as well.
	**Humidity/ Condensation Cycling**	This test is performed to simulate worst-case condensation conditions that may occur in outside plant environments, such as in enclosures or cabinets. Since enclosures will usually warm up faster, the connector assemblies remain below the dew point of the atmosphere within the enclosure, thus causing condensation to deposit on the connectors. This test is designed to exploit any physical imperfections, such as minor cracks, that would allow water to enter , eventually causing the crack to expand when the water freezes. The samples are exposed to 14 cycles over 168hrs with temperatures going from -10°C to 65°C with 90-100% relative humidity.
	**Dry-out**	The dry-out step is performed to dry the connector assembly before being subjected to subsequent tests. The dry out step is 24 hours at 75°C.

The following table is a description of the Controlled Environmental Tests & Mechanical Tests performed on the connectors during the GR-1435 testing:

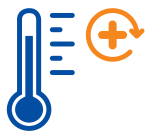
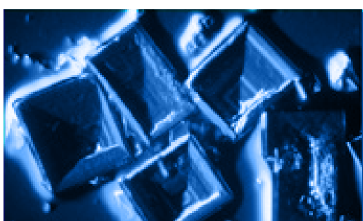
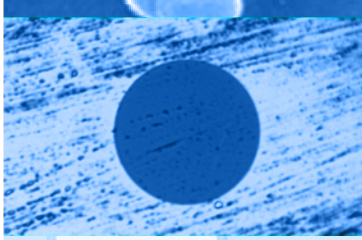
Controlled Environment

Thermal Aging	The controlled thermal aging test is performed to generate wear on the connector assembly by simulating the conditions in the second half of its service life. The connector assembly is subjected to a high temperature at 60°C for 96 hours.
Humidity Aging	This test is designed to simulate the conditions in the second half of the connector assembly's service life with wear and tear. The connector assembly is exposed to a temperature of 40°C at 95% humidity for 96 hours.
Thermal Cycling	The thermal cycle test simulates the exposure of an aged connector assembly to normal operating environments. The connector assembly is subjected to five temperature cycles from -10°C to 60°C.
Dry-out	The dry-out step is performed to dry the connector assembly before being subjected to subsequent tests. The dry out step is 24 hours at 60°C.

Mechanical Testing

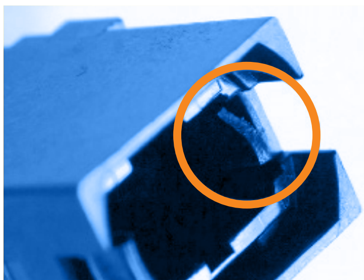
Vibration	The vibration test is designed to expose the connector assembly to environmental vibrations, such as those from passing traffic or the wind. The connector is vibrated on all three main axes to simulate various connector mounting positions.
Cable tension	Cable tension tests are designed to simulate the potential stressors that connector assemblies may be subjected to during normal operation. Connector assemblies may be pulled, flexed, or twisted while under operation. Test conditions vary depending on the media type.
Impact	The impact tests are designed to simulate the connector assembly use in a controlled environment, as well as in an outdoor plant. This test assesses the condition of the connector assembly after stressors experienced from prolonged handling by technicians. It also tests the integrity of non-metallic components by ensuring that the material maintains its non-brittle behavior throughout the operating temperature range.
Durability	The durability test simulates the connector assembly mating and de-mating. As connectors are intended to enable quick changes in network termination, they are expected to be disconnected and reconnected multiple times over their lifetime.

Following the service life tests, one last end of service life test is performed as a confirmation of the connector assembly performance. This test is performed to quantify the cumulative effect of all service life tests that were performed on the connector assembly. The following table is a description of the Extended Service Life Tests performed on the connectors during the GR-1435 testing:

Extended Service Tests		
	**Extended Thermal Aging**	This test is similar to the service life thermal aging test, but is performed for a much longer duration to simulate long term storage.
	**Extended Humidity Aging**	This test is similar to the service life humidity aging test, but is performed for a much longer duration to simulate the operational service lifetime
	**Extended Thermal Cycling**	This test is similar to the service life thermal aging test, but is performed for a much longer duration to simulate the operational service lifetime.
	**Salt Spray**	This test is intended to simulate the installation of the connector assembly in a harsh environment with high salinity, such as by the seaside. This test also determines the rust resistance of the connector assembly's metallic components
	**Airborne Contaminants**	This test simulates the installation of the connector assembly in an environment with a high concentration of contaminants and chemical exposure
	**Dust**	This test simulates the installation of the connector assembly in a dusty environment, such as sandy beaches or deserts
	**Ground Water Immersion**	This test simulates connector assembly deployment in an underground enclosure where it may be potentially exposed to ground water or if improperly installed.

What Failure Looks Like

The GR-1435 standard is one of the most stringent tests for multi-fiber connector assemblies, so it is expected that not all manufacturers can pass all the tests. Some of the common defects observed are:

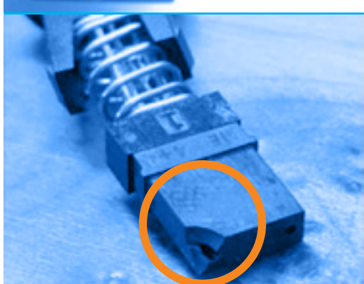


Dimension Defect - Adapter

Connector dimensional non-compliance can result in mating and de-mating force issues. In the worst-case scenario, the latches on the connector or adapter can break.
This image shows the latches broken off. This problem does not only pose a risk to damaging patch panels, but can also damage the connector on high-cost test equipment.

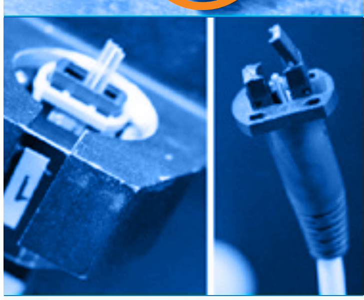
Dimension Defect - Connector

Another example of a connector dimensional non-compliance results in the weakest section of the connector breaking off.
This image shows the side of an MPO connector broken off. This can be caused by misaligned pins and misaligned latches. Stress from repeated mating and de-mating can cause such failures.



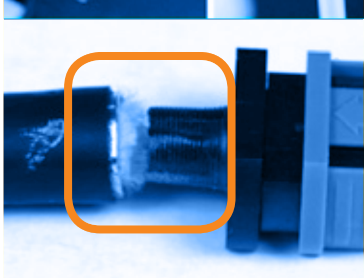
Material Defect

Use of substandard materials can result in distortions, discoloration, and even mechanical failure (such as cracking) when put through a series of environmental tests.
This image shows a cracked MT ferrule that can no longer be used.



Material Defect

Another example of the use of substandard materials results in the inability of connectors to withstand stresses from normal operation.
This image shows an MPO connector that was subjected to a twist test. The strain on the connector body caused it to break off at the base.



Manufacturing Defect

On top of good quality components, proper manufacturing procedures and quality control are crucial to producing high quality connectors.
This image shows the failure of crimping the boot of the connector onto the body, which resulted in it being pulled off when longitudinal stresses were applied to it.

Summary

Network performance reliability relies heavily on the use of high-quality connector assemblies. Multi-fiber connector assemblies that are GR-1435 compliant provide an assurance of the quality of connector components, as well as its manufacturing processes and equipment, by adhering to a strict quality assurance program. When deploying and operating a high-speed transmission networks with 100G, 400G, or even beyond, service providers and installers need a reliable connector assembly from a trusted certified supplier.

References

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2. *International Electrotechnical Commission, IEC 61754-7-1: Fibre optic interconnecting devices and passive components - Fibre optic connector interfaces - Part 7-1: Type MPO connector family - One fibre row, Sep 2014.*
3. *International Electrotechnical Commission, IEC 61754-7-2: Fibre optic interconnecting devices and passive components - Fibre optic connector interfaces - Part 7-1: Type MPO connector family - Two fibre rows, Dec 2017.*
4. *Underwriters Laboratories, UL 94: Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, March 2013.*

Biography

Dr. Bernard HL Lee is currently the Director of Technology & Innovation at SENKO Advanced Components. He started his career in optical communications when he was a Senior Research Office for the European Union IST project known as DAVID in 2000. In 2003, he joined Telekom Malaysia R&D where he has held various technical and management positions there including the Head of Photonic Network Research and also Head of Innovation and Communications. Bernard then joined the parent company, Telekom Malaysia (TM) in 2010 as the Assistant General Manager at the Group Business Strategy Division. Bernard is also an Expert at the International Electrotechnical Commission (IEC), a Chartered Engineer (CEng) accredited by the Engineering Council of UK, a Professional Engineer (PEng) registered with the Board of Engineers Malaysia and also a BICSI Registered Communications Distribution Designer (RCDD).

Andrei Vankov is an Application Engineer at SENKO Advanced Components. He received his BS from Thomas Edison State College and his MSEE from Pennsylvania State University. He began his career in 1993 at Sumitomo Electric Lightwave Corp as a Fiber Optic Manufacturing Engineer where he worked on active and passive components using Kaizen methods in Yokohama, Japan. As a Senior Optical Design Engineer in Franklin, MA (founded as Advanced Interconnect) Andrei Vankov developed various passive optical components and packaging integration to meet Telcordia industry standards. He designed optical interconnects, including optical backplanes (MTP, HBMT, PHD, OGI), and a fiber optic SMPTE compatible Broadcast Connector for HD applications. In 2013-2020 Andrei worked at Nokia division Radio Frequency Systems (RFS) where he provided leadership for a LTE RAN launch project team. He was responsible for engineering, design and cost estimating of fiber optic builds for microwave and cell tower projects, defining design criteria and completing initial planning and cost estimates of fiber optic projects in North America. Andrei holds a number of US and European Patents in fiber optics interconnect technology.

Emmanuel Kolczynski is an Application Engineering Manager at SENKO Advanced Components. He is from Ottawa, Canada where he attended Carleton University and completed his Bachelor of Engineering, with a focus in Electrical. He began his fiber optic career with JGR Optics Inc. in 2013 as an Application Engineer, helping companies globally with production processes and various testing needs. He eventually became a Product Line Manager to help guide the company business direction by making strategic decisions based on market trends and planning a future road map. At SENKO, Emmanuel applies his fiber optic knowledge and expertise to help with the design, testing, and release of critical interconnect technology for use in a constantly evolving market. He is currently a member of the Telecommunications Industry Association (TIA) to follow the latest in industry standardizations and developments. Emmanuel has a passion for technology and being able to reach the fullest potential through constant innovation and developments.

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