Development of Indoor/Outdoor Cables with Robust Structure

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Summary

The demand for high-fiber count cables for data centers (DC) has increased exponentially in recent years. The construction of DC requires inside plant (ISP) cables that are placed inside the building and outside plant (OSP) cables that are placed outside to connect between the buildings to each other. These two types of cables are required to have different characteristics, so it was necessary to deploy both these cables and joint them at the connection point. However, due to the development of I/O cables that satisfy both characteristics, the demand for I/O cables has been increasing as it allows for a reduction in fusion splicing costs. We have already developed I/O cables from 144 to 6912 fibers [1], but they are less strong than OSP cables, for which only pulling installation method was used due to the concern of overloading the I/O cables. Therefore, by developing a Robust I/O (RIO) cable structure that enables jetting installation as well using a caterpillar, we can achieve faster installation compared to pulling installation.

Keywords: fiber optic cable; spider web ribbon; wrapping tube cable; high flame retardant, low smoke emission; high-density, robust structure, jetting installation

1. Introduction

1.1 Data Center Cable

Figure 1 shows a wiring diagram for a hyperscale DC. There are several types of cables that can be attached to cable trays or installation spaces. First, high fiber count OSP cables are used for entry cabling between buildings. These cables should be small diameter and high fiber count for economical high-density wiring. Flame retardant, high fiber count ISP cables are used for distribution cabling between patch panels. These cables need a small diameter and flexible structure as they are laid in narrow spaces.

If we use separate cables for OSP and ISP applications, the OSP and ISP cables must be connected at the entrance of the DC buildings. In addition, if we use high fiber count cables, the connection will take more time and cost. By using high fiber count I/O cables that are compatible with both OSP and ISP applications, we can reduce the time and cost involved in installation and connectivity.

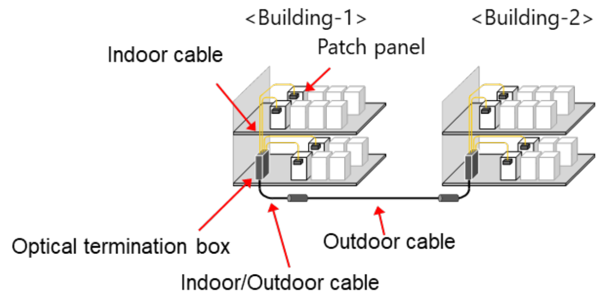

Figure 1: Data Center Wiring Diagram

1.2 How to Lay the Cable

Two typical methods for laying high fiber count cables are shown in Figure 2 and Figure 3. The pulling installation shown in Figure 2 involves connecting the cable to a pre-installed pulling rope in underground ducts and then winding it at the destination. This method is suitable for I/O cables, which tend to reduce components for improved flame retardancy, as it avoids subjecting the cable to overload. The jetting installation shown in Figure 3 involves pushing the cable into underground ducts using a caterpillar while applying pressure. This method does not need pre-installed pulling ropes, which helps save time and cost. However, it applies pressure and sharp bends to the cable, requiring a robust and flexible structure.

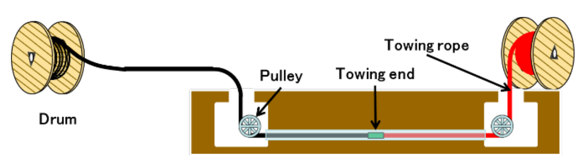

Figure 2. Pulling Installation

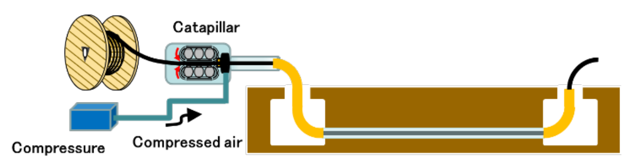

Figure 3. Jetting Installation

2. Cable Design

2.1 High Flame Retardancy and Robustness

To achieve a RIO cable structure that can withstand the jetting installation, we selected the most suitable material and designed the structure. A comparison of jacket materials is shown in Table 1. We compared jacket materials in terms of low smoke zero halogen (LSZH), mechanical properties, UV resistance, and flexibility with advantages as DC I/O cables. The jacket material conventionally used in I/O structures has performance that satisfies the I/O standard ICEA S-104-696-2019[2], but it does not have the robustness to be used for jetting installation. Therefore, new jacket material C has been adopted, and a cable structure that satisfies LSZH, robustness, UV resistance characteristics, and flexibility has been realized.

Table 1. Comparison of Jacket Materials

	Current materials	A	B	C
Flame retardancy	✓	-	✓	✓
Mechanical characteristics	-	✓	-	✓
UV resistance characteristics	✓	✓	-	✓
Flexibility	✓	-	✓	✓
Comprehensive judgement	Bad	Bad	Bad	**Good**

The simulation results are shown in Figure.4. The graph shows the deformation rate of the I/O cable relative to the deformation rate of the OSP cable at a certain load. I/O cable is more prone to collapse than OSP cable in simulations, and the deformation rate has been reached where the jacket can be destroyed under the expected load in the jetting installation. On the other hand, RIO cable have a structure that is less prone to deformation than OSP cable, so it is assumed that it can withstand jetting installation.

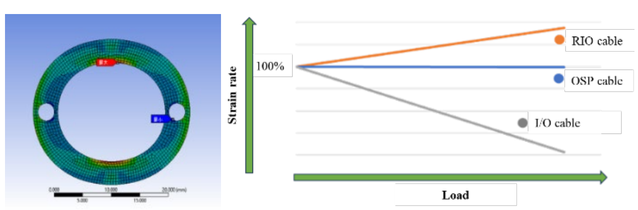

Figure 4. Simulation Result of Mechanical Strength

2.2 Features of SWR and WTC

As shown in Figures 5 and 6, the structure of WTC (Wrapping Tube Cable®) is designed to achieve the smallest diameter using SWR (Spider Web Ribbon®), SZ bundle units, wrapping tape, and peripheral strength members. This design minimizes the use of combustible components, resulting in excellent flame retardancy. In addition, the components of the WTC structure provide the desired features such as light weight, easy identification, fusion splice ability, easy cable preparation and fiber accessibility.

Since the single filament, bonding part, and adjacent fibers of SWR are intermittently fixed, it is possible to flexibly change the shape of a bundled fiber unit. The stripe ring markings are printed with a line along the width of the ribbon so that each ribbon number and each fiber can be easily identified, even after the ribbon is split into single fibers. In addition, 12 and 16 fiber SWR are available. SWR is selectable for the number of fibers in mass fusion splicing. In addition, SWR can be manufactured with fiber pitches of 200 µm or 250 µm, and WTC is designed for the installation environment.

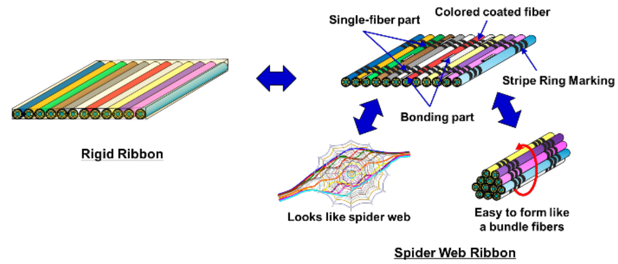

Figure 5. Ribbon Structure for SWR

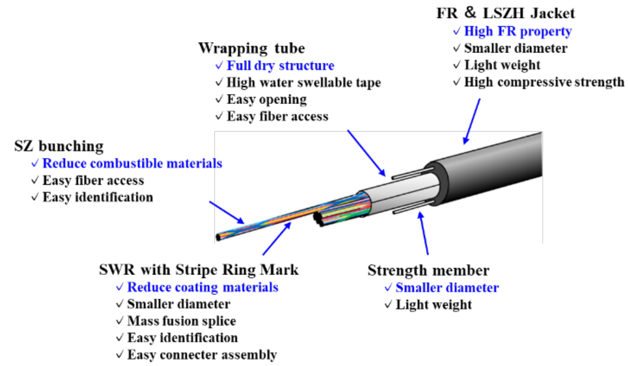

Figure 6. Cable Structure for RIO WTC

3. Cable Performance

Flame retardant requirements and tests vary by country or region. There are two main types of flammability tests performed: Fiber Optic Non-Conductive Risers (OFNR) and Construction Products Regulations (CPR)) [3][4]. Table 2 shows the flame retardancy test results of the representative lineup of RIO WTC. These cables showed sufficient flame-retardant performance.

Table 2. Flame Retardant Test Results

	Flame Retardant Test	
	UL1666	CPR
144F-WTC	Pass	B2ca-s1a, d0
288F-WTC	Pass	Cca-s1a, d0
432F-WTC	Pass	B2ca-s1a, d0
864F-WTC	Pass	B2ca-s1b, d0
1728F-WTC	Pass	Cca-s1b, d1
3456F-WTC	Pass	Cca-s1, d0
6912F-WTC	Pass	Cca-s1, d0

The mechanical properties of this cable are shown in Table 3. The test method complies with the I/O standard ICEA S-104-696-2019 [2]. The measured wavelength for mechanical testing is 1550 nm. In addition, these cables also meet the more stringent ICEA S-83-596-2016[5] requirements for ISP cables. This cable showed satisfactory mechanical performance.

Table 3. Mechanical Test Results According to I/O Cable Specifications

Item	Condition	Result
Low-high Temperature Bend (*1)	Bending radius: 10D（D:Cable Diameter） Temperature: -10, +60 degree C Turns: 4, Cycle: 3	Pass
Cable Cyclic Flexing	Bending radius: 20D（D:Cable Diameter） Cycle: 25	Pass
Impact	Striking surface: 12.5 mm Impact energy: 4.4 N･m Striking count: twice at the same place	Pass
Tensile Strength	Load: 2700 N 1 h（Short Term）	Pass
	Load: 810 N（Long Term）	Pass
Compressive Strength	110 N/cm 10 minutes after 220 N/cm 1minute	Pass
Cable Twist (*1)	Sample length: 1 m Test angle: ±180 degrees, Cycle: 10	Pass

*1 : Tested by ICEA S-83-596-2016 for indoor because it is a stricter test condition.

Table 4 shows the environmental test results of the RIO WTC. The test method complies with the I/O standard ICEA S-104-696-2019 [2]. The results of the temperature cycling test were measured between -40°C and +70°C for two cycles. The variation of transmission loss within this specified temperature range was less than 0.4 dB/km at 1550 nm, showing good temperature cycling characteristics. It has also passed water penetration tests, weathering tests, and aging, and showed sufficient environmental characteristics even when used in an OSP environment.

Table 4. Environmental Test Results

Item	Condition	Result
Temperature Cycling	-40 to +70 degree C Cycle : 2	Pass
Water Penetration	Height of water : 1 m Sample length : 40 m	Pass
Weathering Test	Exposure Time : 720h	Pass
Cable Aging Test	Temperature : 85 degree C Aging Time : 720h	Pass

Figure 7 shows the path of the jetting installation test. Table 5 shows the jetting installation test results for the 864F and 1728F in the lineup. Both have been successfully tested for jetting installation more than 3,000 feet and have shown sufficient performance to withstand practical use, as they have no jacket damage when passing through the caterpillar and have the flexibility to bend along the duct even at nearly right angles.

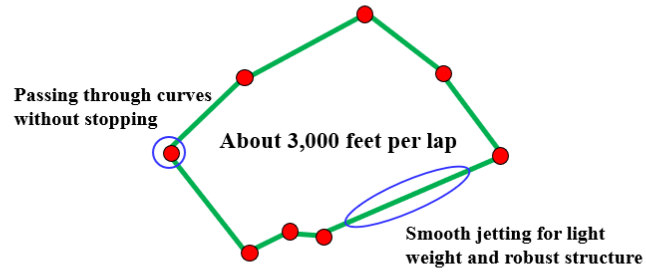

Figure 7. Jetting Installation Test Site

Table 5. Jetting Installation Test Results

Item	Property	Result
864F-WTC	Duct size : 1.25 inch	3,322 feet
1728F-WTC	Duct size : 1.50 inch	3,700 feet

4. Comparison of Cable Structures

Figure 8 shows the lineup of new developed RIO WTC. RIO WTC has the same outer diameter as the existing OSP WTC while being highly flame retardant.

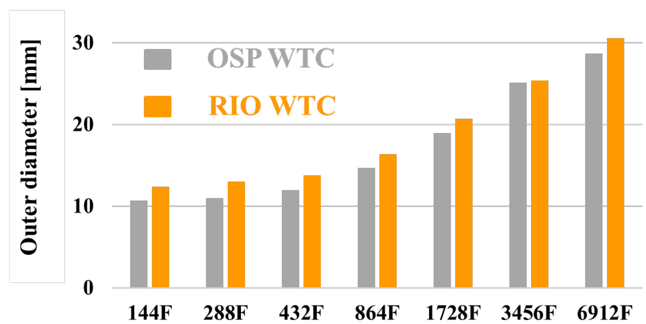

Figure 8. RIO WTC Lineup for Comparison

5. Conclusion

By optimizing the cable design, we have achieved Robust I/O cable that combines high flame retardancy and low smoke emission characteristics. Due to the optimization of materials and structure, these cables exhibit excellent flame retardancy and a smaller diameter compared to other I/O cables, as shown in Table 6. In addition, this developed product, which has a more robustness and flexibility than the I/O cable, also supports jetting installation, so it can be laid more efficiently. As a result, this development will make a significant contribution to the cost-effective construction of DC around the world.

Table 6. Comparison of I/O Cables

6912F I/O cable characteristic	**RIO**	A	B	C
Outer diameter	**31mm**	31mm	34mm	38mm
Flame retardancy(CPR)	**Pass**	-	Pass	Pass
Flame retardancy(OFNR)	**Pass**	Pass	Pass	Pass
Flexibility	**Good**	Bad	Bad	Bad
Fiber accessibility	**Good**	Good	Good	Bad

6. Reference

[1] S. Kaneko, et al., " Development of Indoor / Outdoor cables with high-flame retardant ", Proceedings of IWCS 70, 2021, pp.354-358 (2021).

[2] ICEA S-104-696-2019, "Standard for Indoor-Outdoor Fiber Optic Cables" (2019)

[3] UL 1666, "Safety Standard: Test for Flame Propagation Height of Electrical and Fiber Optic Cables Insulated Perpendicular to the Shaft (Ed. 5)", (2007)

[4] BS EN 50399: 2011+A1: 2016, "General test methods for cables under fire conditions – Heat emission and smoke formation measurements of cables during flame propagation tests – Test apparatus, procedures and results", (2016)

[5] ICEA S-83-596-2016, "Standard for Indoor Fiber Optic Cables", (2016)

7. Pictures of Authors

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