Qualification of Loose Tube fiber Optic Cables with Reduced Weight and Diameter

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Abstract

The telecom industry has expanded into multiple new applications and revenue generating opportunities that require, or would benefit from, low diameter optical cables. Not to mention that smaller cables are generally easier to handle and afford lower bending diameters for confined spaces. One such scenario where cable diameter is of primary consideration is duct applications where duct space is leased to the user. It is important to these customers to secure fiber optic cables with small diameters in an effort to reduce installation and ongoing system costs. The features of this novel construction are very attractive to the customer. Lower cable bend diameters allow more flexibility in cable slack storage locations and longer continuous lengths help reduce the number of splice locations within a route.

This presentation will cover the following qualification data:

- Qualification results showing compliance to Telcordia GR-20
- Qualification results showing compliance to RUS PE-90
- Qualification results showing performance of a field trial

The cable diameters have been reduced by 8 to 24% depending on cable construction. Graphs showing cable diameter and weight reductions will be presented.

Keywords

Telcordia GR-20, RUS PE-90, reduced diameter

1. Introduction

Reduced diameter cables are very attractive in many applications, especially in the local access, metro and trunk networks. Additionally, the possibility of using existing Rights of Way is also an important issue where lower diameter cables are especially attractive. For these, and other, applications, the cable must be highly robust and maintain environmental and mechanical performance levels suitable for outside plant use. For these reasons, the cable designs being introduced/discussed here have two primary design inputs for the North American Region:

- Reduced Diameter and Weight
- Telcordia GR-20 mechanical and environmental performance

Section 2 presents the characteristics and parameters that must be considered when designing a reduced diameter loose tube optical cable. Section 3 presents the configurations available in the reduced diameter loose tube cable. This section will illustrate the diameter and weight reductions when compared with traditionally designed and commercially available loose tube cables. Qualification test data per Telcordia GR-20 and RUS PE-90 will be presented in section 4 to illustrate full compliance to the NAR accepted industry standards. Section 5 presents information regarding a field trial installation in California. Section 6 discusses on going work and finally, section 7 presents our conclusions.

2. Design Considerations

The loose tube optical cable design is comprised of individual fibers that are contained within buffer tubes that are ROL stranded about a central strength element to form the core of the cable. Typically, sheath strength elements in the form of aramid or fiberglass yarns are helically applied about the core to provide additional tensile strength. Multiple sheathing configurations can then be applied to produce Single Jacket, Armored, LAP, etc. constructions. Generally speaking, sheath treatment parameters and dimensions have previously been minimized. For example, as process capabilities have improved, cable jacket thickness has been consistently reduced over the years to minimize material usage thus saving costs and reducing cable overall diameters. Additionally, corrugated steel armoring and LAP (Laminated Aluminum) dimensions have been minimized in an effort to reduce costs and cable diameters while maintaining functionality.

Essentially, the core of a loose tube cable is one of the primary sub-elements that can be manipulated to further reduce cable diameters. However, the core of the cable contains the optical fibers and great care must be taken when considering dimensional changes and/or material changes. The buffer tubes in traditional loose tube optical cables for the North American Region measure at either 2.5mm or 3.0mm outer diameter depending on the number of fibers that are contained therein. Material stability under mechanical and environmental influences is of utmost importance as the buffer tubes provide the first line of protection for the optical fibers.

The central strength element is also a consideration for dimensional reduction. The diameter of the central strength member is defined by the geometry of the buffer tubes, and the number of, stranded about it. Care must be taken in this area to ensure that the central strength member is of sufficient size to maintain anti-buckling performance at low temperature extremes. The combination of reduced tube and central strength element dimensions must be carefully evaluated for mechanical stability. This has been achieved and a reduced diameter loose tube product line has been released that maintains GR-20 levels of mechanical and environmental performance.

3. Design Options

Currently, the reduced diameter loose tube cable is available in the following configurations to support duct, direct buried and self-supporting applications:

- All Dielectric Single Jacket
- Light Armored (Single Jacket, Single Armored)
- Armored (Double Jacket, Single Armor)
- ADSS Self-Supporting for short length drop applications

All cable constructions are designed to meet Telcordia GR-20 specifications. This design criteria has been established primarily to support existing NAR requirements. Design inputs for blown applications as well as regions outside the NAR region are currently under consideration for potential new product introductions that take advantage of requirements less stringent than those of GR-20.

The duct and direct buried configurations have also been tested per the RUS PE-90 specification and have subsequently been listed by the RUS.
The ADSS construction is designed for span lengths up to 300 feet under NESC Medium loading conditions. The ADSS cable is designed so that there is no axial fiber strain at the Maximum Rated Cable Load (MRCL) of 460 lbs. The ADSS cable can also be utilized in duct applications or aerial to duct transitions with a 600 lb rated short-term duct installation load. Upon release of the 600 lb load, any increase in attenuation of the fibers returns to zero.

There has been significant reduction of the cable diameter when manipulating the core configuration. The following table shows the diameter and weight reductions, in percentages, when compared to traditional loose tube configurations.

Table 1: Cable Diameter / Weight percent reduction compared to traditional construction.

	5 elements	6 elements
Single Jacket	11 / 18	12 / 24
Light Armor	10 / 12	12 / 19
Armored	8 / 13	10 / 17
ADSS	24 / 42	NA

The significant reduction in cable diameter and cable weight makes for easier handling. The diameter reduction allows longer continuous lengths on smaller reels, a significant advantage for customers. Many customers, or installation teams, have limitations on the size of a reel that can be handled. The large 96” (2.4m) reels are sometimes very difficult to handle and many installations require a considerably smaller reel. It is our experience that a 60” (1.5m) reel size is a maximum reel size required by multiple customers. Based on this reel size limitation, the reduced diameter cables can offer longer continuous lengths per reel. This is a distinct advantage for minimizing splice points in a route. The following table shows the percentage increase in maximum continuous lengths of cables that can be wound on a US standard 60” reel.

Table 2: Percent increase in cable continuous length on 1.5m reel

	5 elements	6 elements
Single Jacket	26%	28%
Light Armor	23%	30%
Armored	19%	22%
ADSS	68%	NA

4. Qualification Results

All cables have been subjected to the mechanical and environmental test procedures and requirements of Telcordia GR-20. The cables designed for duct and direct buried have also be tested per RUS PE-90, the data package submitted, and subsequent official listing by the RUS.

All testing shows excellent performance verifying the robustness of the configurations. The ADSS product has been tested to ensure that there is no fiber strain at the MRCL. The following table summarizes the test results for each configuration.

Table 3. GR-20 & RUS PE-90 Qualification Results

Test Parameter	Requirement	Result
Jacket Adhesion	14.0 N/mm min. between outer jacket and steel armor	25.92 – 58.26 N/mm.
High & Low Temp. Bend	4 hours @ -30°C & +60°C, 20x OD bend	Max. change: 0.04 dB. No damage
Test Parameter	Requirement	Result
Impact Resistance	25 impacts, 30 cycles/min. Impact mass per cable OD	**GR-20**: Max. change: 0.02 dB. **PE-90**: Max change: 0.07 dB. No damage.
Compressive Strength	**Non-Armored:** Incidental load: 220N. Long term load: 110N. **Armored:** Incidental load: 440N. Long term load: 220N.	Max. change: 0.05dB at incidental load.
Tensile Strength	(a) Fiber strain less than 60% of proof strain (0.60%) @ rated install load (600lbs) (b) At load, 360° twist within 3 meters, no armor	(a) Max. fiber strain: 0.098%. (b) Max atten.

	zippering or jacket splitting. (c) At 30% of install load (180lbs), fiber strain < 20% of proof strain and fiber shall not exceed allowable attenuation change.	change: 0.03 dB. (c) Max fiber strain: 0%. Max atten. change: 0.0 dB.
Cable Twist	2 meter max. sample, 10 cycles, 180° CW twist, 360° CCW twist, 180° CW twist.	Max. atten. change: 0.02 dB. No mechanical damage.
Cyclic Flex	25 flex cycles, 20x OD, 30 cycles/min.	Max. atten. change: 0.02 dB. No mechanical damage.
Temp. Cycle	-40°C to +70°C extremes.	Avg: 0.04 dB. Max: 0.13 dB.
Aging	85°C, 168 hrs.	Avg: 0.03 dB. Max: 0.06 dB.
Buffer Tube Shrink-back	RUS PE-90. Shrinkback < 5%	All samples < 5%.
Buffer Tube cold bend	RUS PE-90. –20°C, Mandrel OD < 5x tube OD, 10 wraps	No damage.
Cold Impact	RUS PE-90. 4 N-m impact, -20°C.	No damage.

As the industry develops new lower cost materials and smaller dimensions for fiber optic cable, maintaining GR-20 and RUS PE-90 levels of mechanical and environmental performance becomes more difficult. Our ability to maintain sound compressive performance in the reduced diameter cables can be primarily contributed to the robustness of the PBT buffer tubes. Current alternative materials for buffer tubes, although generally a bit more flexible, experience difficulties maintaining mechanical crush resistance to the levels that can be achieved with PBT.

5. Field Trial

In January, 2002, a 144 fiber Single Jacket low diameter cable was installed in Oakland California. The low diameter cable was necessary to support installation of the cable within conduit measuring a ¾" (19mm) ID. At an 85% fill ratio, the customer required a cable diameter of 0.64" (16.25mm) or less. The product provided has a diameter of 13.4mm, which met the customer requirement and ultimately improved the installation performance by offering a fill ratio of 70%. A typical commercially available 144-fiber loose tube cable has a diameter of 0.74" (18.8mm).

A pulling grip was installed in the field and a 2500 ft (762 m) section of cable was easily installed within the ¾" conduit. The balance of the cable was installed in a 1-¼" conduit. The configuration of the route required considerable handling of the cable whereby the product was placed in a Figure-8 configuration for pulling in multiple sections. This was specifically required based on the pulling/installation configuration and not related to the cable product. The cable's flexibility and ease of handling made this operation user friendly and improved the speed and efficiency of installation. During the entire installation, the tensions measured never exceeded 200 lbs (890N). This can be attributed to the length of cable installation as well as the low fill ratio.

An additional benefit seen by the installation team was the reduction in volume of tube filling compound. There is less filling compound to clean which resulted in a slight improvement to fiber access time.

All fibers were measured optically after the installation with no change relative to the values measured at the factory.

6. On going work

1. These concepts are being applied to all other products within the loose tube portfolio.
2. We expect to expand upon these concepts to introduce application specific products. These application specific products, blown cables for example, will be designed to meet the conditions of the application. Where lower tensile strength cables can be employed or applications for temperature extremes that do not go to –40°C, products with further reduced diameters and weights can be established.
3. With decreased buffer tube sizing comes improved potential for a completely dry loose tube configuration. Work is being done to develop a water blocked buffer tube free of gels. Control of the buffering process and fiber to tube excess length are the primary considerations. The smaller tube design results in a smaller area requiring water blocking super absorbents.

7. Conclusion

A reduced diameter loose tube product has been developed that maintains very high levels of mechanical and environmental performance. The product supports GR-20 and RUS PE-90 requirements while reducing product diameters from 8 to 24 percent depending on configuration. The bending performance of these products is rated at 10 times the cable diameter in static conditions and 15 times the cable diameter in dynamic conditions, producing some of the lowest bend diameters available for loose tube cables. The features of the product, lower diameter, improved flexibility, longer continuous lengths, easier handling, etc. make this product line an attractive solution for many applications. This has been achieved without reducing cable performance, making the product a simple transition for the user.

Continued work is ongoing to transfer this concept into all existing products. There is an effort to develop applications specific products that offer the customer an advantageous solution.

We are pursuing the potential to develop a completely dry loose tube cable in an effort to completely eliminate the need for solvents to clean the compounds. We believe that the reduction in tube diameter, and thus the reduction in free space, will allow the development of this product.

8. Author

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