New Ultra-Density Fiber Cable Technology for FTTx and Access Markets Using New SpiderWeb® Ribbon

Patrick E. Dobbins, Director—Applications Engineering, AFL
Brett Villiger, Cable Engineering—Development Manager, AFL

ABSTRACT

This paper examines the application of a new ultra-density fiber optic cable technology for fiber-to-the-home (FTTH), fiber-to-the-curb (FTTC) and other optical fiber access technology (FTTx) applications. The new ultra-density fiber optic cable technology, called Wrapping Tube Cable (WTC), utilizes a new optical fiber ribbon arrangement technology called SpiderWeb Ribbon (SWR®). This new ribbon and cable technology provides for significant improvement in fiber density and corresponding reduction of overall cable diameters when compared to existing traditional ribbon based cable or loose buffered fiber optic cable.

Technical application methods will be demonstrated for cable installation in both aerial and underground access networks. Fiber optic closure preparation, mass fusion splicing techniques and mid-cable express entry access will also be demonstrated. The significant increase of fiber packaging density and corresponding diameter reduction of the new cable technology will provide a positive impact to future FTTx network builds by lowering the total system cost and present cost savings that will be demonstrated in this paper.

Keywords: SpiderWeb Ribbon (SWR), wrapping tube cable (WTC), fiber-to-the-home (FTTH), fiber-to-the-curb (FTTC), other fiber optic access (FTTx).

1.0 INTRODUCTION

As fiber optic access networks begin to proliferate, more operating companies will begin to deploy optical fiber cable in various configurations to the last mile. Key technology requirements in fiber optic cable designs are being identified to lower the average build cost per subscriber. In fiber-to-the home (FTTH), fiber to the node (FTTN) or any fiber optic access (FTTx) type topologies, the same cost issues are prevalent as in traditional outside plant (OSP) point-to-point builds. Speed of deployment, cost of right-of-way access, logistics cost and turn-up time all have an impact on the overall cost to build an optical fiber network.

Traditional OSP cable designs utilize either a loose buffer core or ribbon core cable design. Limitations of these cable designs are most impacted by the fiber density and core configurations. In most cases, the system designer will use ribbon cables in higher fiber counts above 144 fibers and use loose tube cables in fiber counts below 144 fibers. Fiber optic cable is deployed this way to optimize utilization of the aerial or underground rights-of-way and to get the advantages of splicing efficiency in high-fiber-count, reel-end splicing versus mid-cable access splicing in the distribution or access part of the network. The traditional cable technologies of standard ribbon fiber optic cable and loose tube fiber optic cable have design and application limitations that make them counterproductive when considered for both feeder (F1) and distribution (F2) portions of FTTx networks.

The new Wrapping Tube Cable (WTC) that utilizes SpiderWeb Ribbon (SWR) will be compared to these traditional ribbon and loose tube cable technologies to look at cable performance comparisons to industry standards to demonstrate that WTC cable is consistent with industry requirements and customer handling needs.

It will also be demonstrated in this paper how WTC was developed to address the design and application limitations of traditional loose tube and ribbon fiber optic cables by getting the best attributes of each technology. By having an extremely high fiber density, the WTC diameter and weight is much lower than traditional loose tube or ribbon fiber optic cable. This significantly improves installation speed and efficiency. With its dry core technology and the ability to mass fusion splice or single fiber splice, the WTC cable is more efficient in reel-end splicing time or mid-cable access time. Additional savings are also found in reduced hand-hole sizes, splice closures sizes and logistic cost.

2. WRAPPING TUBE CABLE DESIGN

The new ultra-density fiber optic cable technology, Wrapping Tube Cable, is made possible by the introduction of SpiderWeb Ribbon. SWR allows for significant reduction in cable diameter because the ribbon can be bunched and bundled allowing it to be packed tightly into a high density cable.

2.1 SpiderWeb Ribbon

As mentioned previously, the key technology that allows for this innovative cable design is SpiderWeb Ribbon. SWR, illustrated in *Figure 1—SpiderWeb Ribbon Design and Functionality*, consists of 12 fibers that are connected to each other by an intermittent UV-curable resin. The intermittent nature of the bond allows for the ribbon to be bunched similar to a bundle of loose fibers. The intermittent bond also allows the ribbon to act as either a traditional ribbon for mass fusion splicing or to be broken out into individual fibers. The SpiderWeb Ribbon can also be striped and bundled with other SpiderWeb Ribbons to create a high-density fiber package.

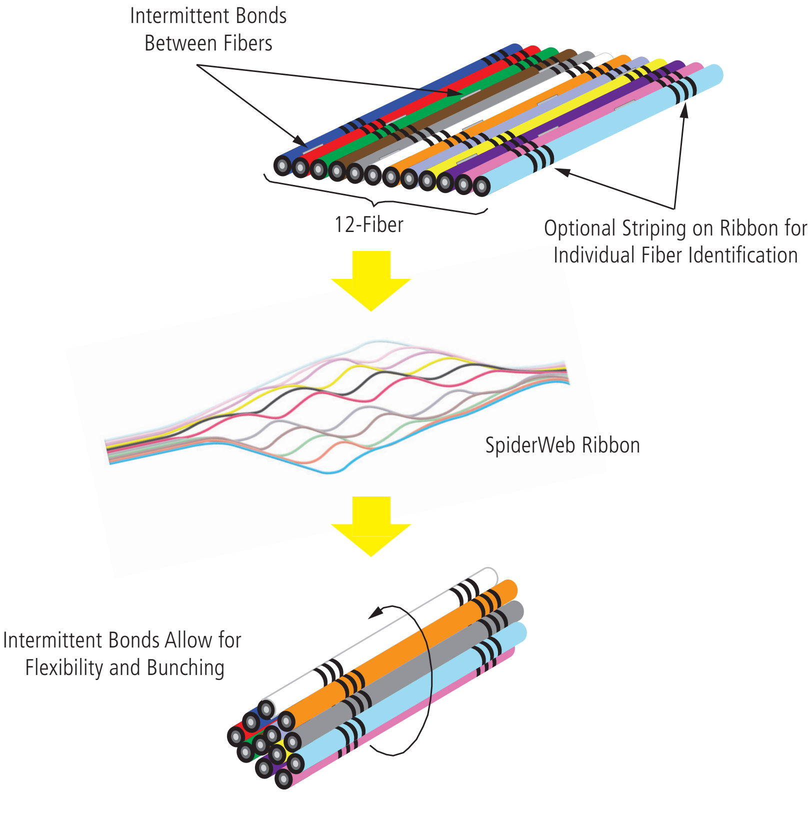


Figure 1—SpiderWeb Ribbon Design and Functionality

2.2 Wrapping Tube Cable Design

The Wrapping Tube Cable design is illustrated with a cross-sectional view as seen in *Figure 2—Wrapping Tube Cable Cross-Sectional View* and a detailed assembly view seen in *Figure 3—Wrapping Tube Cable Detailed Assembly View*. The Wrapping Tube Cable design consists of a core of SpiderWeb Ribbons that can be striped and bundled depending on cable fiber count. The bundles are wrapped with a colored tape for easy identification and separation from other bundles. The fiber core is then covered with a longitudinally-applied water blocking tape that creates the wrapping tube core. The wrapping tube core is then sheathed with FRP strength members embedded within the jacket walls. Standard ripcords are placed 180-degrees apart under the sheath. The ripcord locations are identified with a projection that is extruded into the sheath. The projection allows for the installer to identify ripcord location for safe access to a mid-span access point without damaging the fibers.

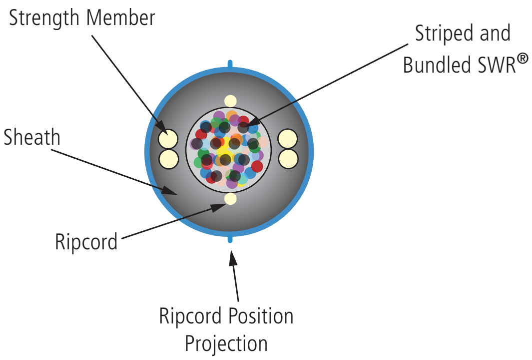


Figure 2—Wrapping Tube Cable Cross-Sectional View

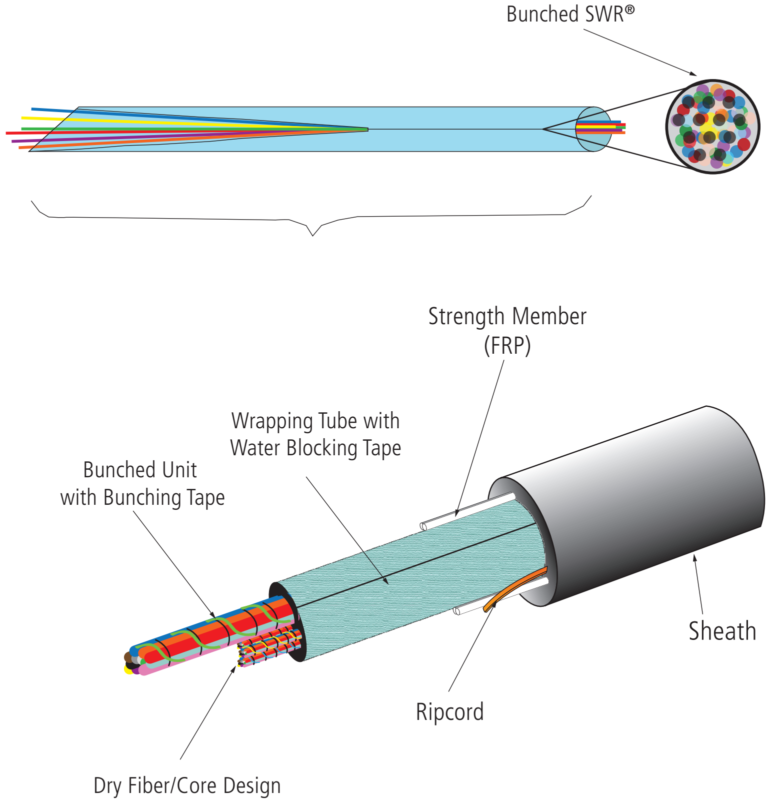


Figure 3—Wrapping Tube Cable Detailed Assembly View

The Wrapping Tube Cable is a completely dry structure allowing for efficient cable splicing and installation. There are no gels or buffer tubes for the installer to deal with, just clean and easily identifiable fiber bundles. The Wrapping Tube Cable is completely scalable depending on fiber count allowing for a standardized design structure.

2.3 Cable Performance

The performance of the Wrapping Tube Cable has been tested and characterized to both IEC 60794-1-2 and Telcordia GR-20-CORE cable standards per customer specific requirements. *Table 1—Test Results of Wrapping Tube Cable* lists the critical and most commonly specified tests.

Table 1—Test Results of Wrapping Tube Cable

TEST	STANDARD	RESULT
Low and High Temperature Cable Bend	IEC60794-1-2, Method E11; GR-20-Core, Issue 4	Pass
Repeated Bending	IEC60794-1-2, Method E6; GR-20-Core, Issue 4	Pass
Compression Strength	IEC60794-1-2, Method E3; GR-20-Core, Issue 4	Pass
Impact Resistance	IEC60794-1-2, Method E4; GR-20-Core, Issue 4	Pass
Cable Twist	IEC60794-1-2, Method E7; GR-20-Core, Issue 4	Pass
Tensile Strength	IEC60794-1-2, Method E1 A&B; GR-20-Core, Issue 4	Pass
Water Penetration	IEC60794-1-2, Method F5B; GR-20-Core, Issue 4	Pass
Temperature Cycling	IEC60794-1-2, Method F1; GR-20-Core, Issue 4	Pass

3.0 WTC SYSTEM COST SAVINGS

3.1 Comparisons of Traditional Cables

For the basis of comparison of traditional ribbon or loose tube cable, some assumptions were made. As previously stated, it is assumed that for fiber counts of 144 fibers and below, the fiber optic cables will be a gel-filled loose tube fiber optic cable. For cable fiber counts above 144 fibers, it is assumed that the cable will be multi-buffer gel-filled ribbon designs. It is also assumed that the cables will be double-jacket single armored cable (PSP) cable designs that are used in both underground and aerial fiber optic networks.

Table 2—Traditional OSP Cable Diameter vs. WTC Cable Diameter Comparison shows and average of 18% reduction in diameter with the uses of WTC cable technology.

Table 2—Traditional OSP Cable Diameter vs. WTC Cable Diameter Comparison

	TRADITIONAL CABLE DIAMETER		WTC/SWR CABLE DIAMETER		PERCENT REDUCTION
	in.	mm	in.	mm	%
24F PSP	0.59	14.9	0.55	14.0	7%
48F PSP	0.59	14.9	0.57	14.5	3%
72F PSP	0.62	15.8	0.57	14.5	8%
96F PSP	0.69	17.5	0.59	15.0	14%
144F PSP	0.83	21.2	0.61	15.5	26%
288F PSP	1.06	27.0	0.69	17.5	35%
432F PSP	1.06	27.0	0.75	19.0	29%
864F SP	1.17	29.8	0.89	22.5	24%
AVERAGE DIAMETER REDUCTION					**18%**

The range of reduction is from 7% for low fiber count cable to 35% for high fiber count cables. It should be noted that the highest percentage of reduction in cable diameter is at the most significant fiber counts where the smaller diameter of the WTC cable will have the largest impact to cost of constructions.

Table 3—Traditional OSP Cable Weight vs. WTC Cable Weight Comparison shows that an average of 28% reduction in weight with the use of WTC cable technology.

Table 3—Traditional OSP Cable Weight vs. WTC Cable Weight Comparison

	TRADITIONAL CABLE WEIGHT		WTC/SWR CABLE WEIGHT		PERCENT REDUCTION
	lbs/kft	kg/km	lbs/kft	kg/km	%
24F PSP	128	190	111	165	13%
48F PSP	128	190	121	180	6%
72F PSP	143	212	124	185	13%
96F PSP	169	252	124	185	26%
144F PSP	234	348	144	215	38%
288F PSP	348	519	175	260	50%
432F PSP	348	519	205	305	41%
864F SP	415	618	279	415	33%
AVERAGE DIAMETER REDUCTION					**28%**

The range of weight reduction with the WTC cable is from 6% on low fiber counts to maximum of 50% on high fiber counts.

With the range and basis of the weight and diameter reduction impact defined we can now continue looking at the specific cost reduction impact of the FTTx builds.

3.2 General Areas of Cost Reduction Impact

Investigating what areas of cost on a FTTx project developed a list of 10 general categories where cost savings were anticipated. This list of items included:

- Logistics—Shipping and Storage
- Scrap Reduction—Residual Losses
- Installation Rate—Aerial and Underground
- Loading on Aerial Messenger
- Fill Ratio and Weight in Underground Duct
- Splice Closure Size Reductions
- Cable Splice Preparation
- Splicing Time Reductions—Network Splices
- Splicing Time Reductions—Access Splices
- Cable Handling and Storage

Each of the categories will be investigated and discussed. In this process the direct and indirect savings will be identified and documented.

3.2.1 Logistics—Shipping and Storage

Shipping cost comparisons were explored and it was determined that limitations for shipping cost were most impacted by the load limits of the truck or container size based on volume, i.e. size and number of reels. Flatbed trucks are limited to the maximum size limits of the reel height versus the actual weight of the shipping reel and associated cable. Shipping containers were similarly impacted by the orientation of the reel, the reel heights and then the associated cribbing of the reels to ensure no movement. Assuming a limit on the reels as being a maximum of 2.13 m high by 0.864 m traverse by 0.889 m drum diameter (84" x 34" x 35"), we are able to ship an average of 69% more cable length with approximately the same total weight of the 432 fiber count cable. This savings varies by fiber count but the most significant impact was on the 288 fiber count cables and higher. The average length increase across all standard fiber counts is approximately 35% increase in length shipments at a slightly lower weight on the same standard reel sizes.

3.2.2 Scrap Reduction—Residual Loss

In reviewing the project scrap impact to using a WTC cable design, we look at using larger master reels for the construction job. Regardless if you are cutting a cable to a required pull length or using a single large master reel, there is a positive impact for keeping the residual scrap (the unusable length at the inside end of the reel) to a minimum. The assumptions were stated that the last 100 meters (328 feet) would be the typical assumption of lost or scrapped cable. This being stated, the impact of residual scrap is based on the starting reel size. Since WTC cables have longer lengths on a single reel, the residual scrap will be less. In comparing traditional cable to WTC cable, the 100 meters of residual loss had an impact of saving of 0.2% to 2.68% with the average being 1.2% savings.

Table 4—Scrap Impact of WTC to Master Lengths

REEL SIZE 1.83 M x 0.86 M x 0.89 M						
FIBER COUNT	SCRAP (M)	WTC (M)	SCRAP (%)	TRADITIONAL (M)	SCRAP (%)	DIFFERENCE (%)
24F PSP	100	8,349	1.2%	7,358	1.4%	0.2%
48F PSP	100	7,776	1.3%	7,358	1.4%	0.1%
72F PSP	100	7,776	1.3%	6,533	1.5%	0.2%
96F PSP	100	7,259	1.4%	5,309	1.9%	0.5%
144F PSP	100	6,792	1.5%	3,593	2.8%	1.3%
288F PSP	100	5,309	1.9%	2,191	4.6%	2.7%
432F PSP	100	4,491	2.2%	2,191	4.6%	2.4%
864F PSP	100	3,182	3.1%	1,789	5.6%	2.5%
AVERAGE CABLE SCRAP REDUCTION						**1.2%**

An average of 1.2% savings on $5M in cable is $60K in savings impact.

3.2.3 Installation Rate—Aerial and Underground

In comparing the installation rate of WTC fiber optic cable, the impact of smaller diameters and lighter weight helped in increasing the installation efficiency in both aerial cable installations and underground installations. Each location is unique and has many variables that can impact installation speed. This posed difficulties in normalizing the comparisons of traditional loose tube and ribbon cables to WTC fiber optic cable.

What was generally noted was that the impact was greatest on underground networks. Savings in time and cost for underground networks were noted in the following:

- Reduced set up time due to significant weight reduction, decreasing cable transport cost, cable drum positioning and cable management time.
- Quicker conduit proving time due to smaller rodding mandrel.
- Quicker installation time, due to less weight over existing cables reducing friction.

Photograph 1—Underground Puller

The time saving on the underground projects that were measured with traditional loose tube and ribbon designs meant the installation crews could typically average 671 meters (2,202 feet) of cable per day. With the WTC cable design, the installation crew was able to average 745 meters (2,444 feet) per day on similar terrain and congestion. This is an 11.0% productivity increase for underground construction using the WTC fiber optic cable.

Aerial network construction is typically twice as fast as underground construction. In using the moving reel method of installation and lashing to existing messengers, the direct speed comparison of traditional cable to WTC cables in not near as dramatic. Savings in time and cost for aerial networks were noted in the following:

- Reduced set up time, more efficient productivity by being able to carry more cable in a single trip.
- Faster cable lashing due to lighter weight and smaller bend radius.
- Faster transitions of expansion loops at each pole.
- Faster assembly of slack storage due to smaller diameter.

Photograph 2—Aerial Moving Reel Lasher

The time savings on measured aerial projects included traditional loose tube and ribbon designs and enabled the installation crews to typically average 1,469 meters (4,820 feet) of cable per day. With the WTC cable design, the installation crew was able to average 1,537 meters (5,042 feet) per day. This is approximately a 4.6% productivity average increase.

As both productivity increases are based on averages, the overall impact to a small project cost appears to be relatively insignificant. As these savings are applied to a large FTTx project they begin to have a significant impact as the installation cost of cable can be a high percentage of the overall cost to build.

3.2.4 Loading of the Aerial Messenger

Messenger loading limits are a function of the composition of all the cable mass on the messenger, the effective cable diameter of all the cable on the messenger and the environmental load of radial ice load with wind conditions that are applied to the effective cable diameter on the messenger. The most significant impact to limits of this load is not the weight addition of the added cable by itself but the diameter and the additional load caused by ice build on the total diameter caused by the composition of all the cables lashed to the messenger.

With the diameter reduction of the WTC cable being most significant in the 144 fiber to 864 fiber counts, this loading impact of the effective cable diameter and loading of ice and wind will be most significant in these cases. The reduction of diameter in 144 fiber to 864 fiber cable ranges from 24 to 35 percent. The direct extrapolation of how this singular diameter reduction would impact the loading a composite loaded messenger would depend on the other cables that were in the cable bundle.

With a single cable on a messenger, it can be concluded that achieving the maximum load limits on an EHS messenger with WTC cable would be significantly slower versus traditional cable diameters. Using the National Electrical Safety Code (NESC) loading criteria for NESC Heavy Loading, 12.0 mm radial ice, 190 Pascal's wind and constant of 4.4 N/m, the load tension builds on the WTC cable at a rate of 15.5% to 25.2% slower depending on the fiber count, as shown in *Table 5—NESC Load of Wind and Ice*.

Table 5—NESC Load of Wind and Ice

WEIGHT OF WIND AND ICE ONLY (kg/m)			
NESC HEAVY LOADING			
FIBER COUNT	TRADITIONAL RIBBON/LOOSE TUBE	WTC	% REDUCTION
144	2.0104	1.6993	15.5%
288	2.4186	1.8084	25.2%
432	2.4186	1.8997	21.5%
864	2.5676	2.1222	17.3%

3.2.5 Fill Ratio and Weight Impact in Underground Duct

When looking at the impact of WTC cable on underground duct systems, both the weight and the cable diameter have an impact. The weight reduction of the WTC cable compared to loose tube fiber cable or ribbon fiber cable will impact when the cable pulling limits are reached and potentially the pulling speeds. The diameter has the most significant impact of fill ratio of the duct or inner duct in the cases when these are used.

Photograph 3—Underground Duct with Two 432F and One 864F WTC Cables

There are a number of industry calculation methods to determine the pulling tension based on the impact of the fiber optic cable weight, the weight correction factor, the coefficient of friction, number of bends and the length of cable to be pulled. These calculations are used as the basis of planning the conduit layout and of the maximum attempted cable pulling lengths. The reality is that current methods in North America use a combination of a breakaway swivel and monitoring of the pulling tension as a means of limiting the installation tension to acceptable strain limits. The WTC, having a 28% lower average weight reduction, will be able to pull longer lengths before exceeding the maximum installation tension. The pulling limits on WTC are truncated into two limit levels based on fiber count, as shown in *Table 6—Wrapping Tube Cable Tension Limits*.

Table 6—Wrapping Tube Cable Tension Limits

FIBER COUNT	24-144F	288-864F
Tension Limits WTC Cable	1,600 N	2,700 N

The fill ratio of the cable in the duct impacts both the pulling tension and the potential for a cable jamb to take place in the conduit during the pull process. As the WTC cable has an 18% average lower cable diameter across range of fiber counts, the subsequent fill ratio will be considerably less in either inner duct or standard underground duct.

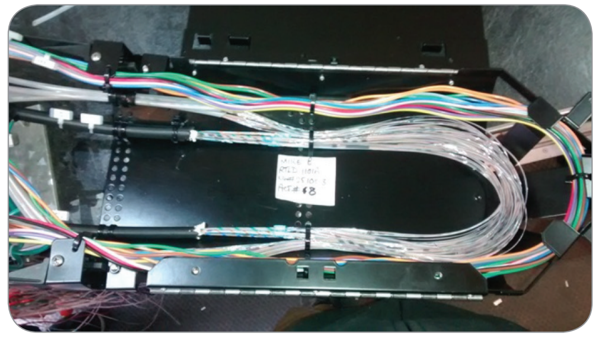
Table 7—Conduit Fill Ratio Comparison

CONDUIT DIAMETER (mm)	CABLE FIBER COUNT	TRADITIONAL CABLE DIAMETER		WTC/SWR CABLE DIAMETER		FILL RATIO GAIN
		mm	FILL	mm	FILL	%
35	24F PSP	14.9	19.53%	14.0	16.97%	13%
35	48F PSP	14.9	19.53%	14.5	18.23%	7%
35	72F PSP	15.8	21.57%	14.5	18.23%	15%
35	96F PSP	17.5	26.71%	15.0	19.53%	27%
35	144F PSP	21.2	38.65%	15.5	20.88%	46%
35	288F PSP	27.0	63.04%	17.5	26.71%	58%
35	432F PSP	27.0	63.04%	19.0	31.56%	50%
35	864F SP	29.8	76.80%	22.5	44.44%	42%
AVERAGE FILL RATIO REDUCTION						32%

Using a 35 mm (1.25 in.) conduit as the reference point we compare the WTC fiber optic cable versus the traditional (loose tube and ribbon) cables as a basis of fill ratio. Industry guidelines suggest that fill ratios for underground installation should never exceed 60% for cables installed using pulling processes. As identified in *Table 7—Conduit Fill Ratio Comparison*, the traditional loose tube and ribbon cables will exceed the industry guidelines above 144 fiber cables while the WTC fiber optic cable is below the industry guidelines all the way through 864 fiber cables. When compared side by side the WTC cable on average has a 32% lower fill ratio.

3.2.6 Splice Closure Size Reductions

Splice closure sizing is dictated by the cable diameter range of the cable entry ports, the number of cables for the splice point, the organizer/basket size limitation and the maximum number of splice sleeves allowed by the splice manifolds. Another key consideration in the closure selection is the type of splicing. Network splicing and access splicing have significantly different and distinct requirements. Network splicing has higher number of cable entries into the closure, more requirements for buffer or unit storage and many times, connects multiple cable types together from feeder, or F1 segment of the network. Access splicing is typically after the convergence point, or in the F2 segment of the network and is categorized as using express entry techniques where cable is expressed through the closure and only the fibers that are being assigned to the access node are spliced to the terminal access point.



Photograph 4—Network Splice Organizer 432F WTC and 144F Loose Tube Cables

The impact of an overall closure size, either for network or access splicing, cascades to impact on the size of the underground hand holes and the storage method of the closure on a cable support messenger or pole-mount bracket. We have already discussed the average diameter reduction impact of the WTC fiber optic cable at 18% across all fiber counts. Where this becomes the most significant is the impact at the higher fiber counts of 144 fiber to 864 fiber cables. In these fiber counts the diameter range reduction is from 24% to the high of 35%. The splice sleeve storage is a function of the splicing tray with most high density tray using mass fusion splicing of up to 144 fibers in 12 ribbons or 144 single fusion splice trays.

Photograph 5—Network Splice Trays 432F WTC and 144F Loose Tube Cables

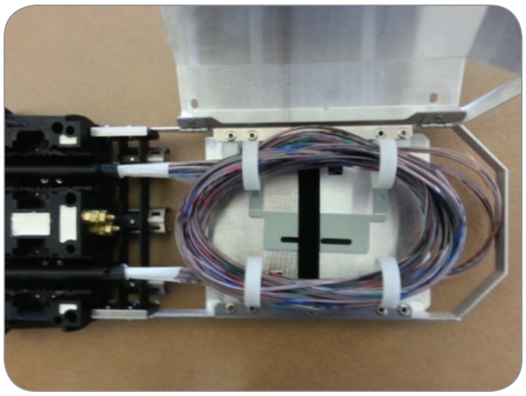
The most significant impact that WTC fiber optic cable has on splice closure selection is in the organizer section of the closure where the units are stored and arranged for the splicing process. The significant differences with WTC fiber optic cable is that it has no buffer tubes for loose fiber or buffer tubes for ribbon fibers. The cable core and sub units are in a wrapping cloth which allows the core to be more flexible and better organized. *Photograph 4—Network Splice Organizer 432F WTC and 144F Loose Tube Cable* shows a network splice location in the F1 segment that has 432F WTC fiber optic cable and 144F loose tube fiber. The picture shows the detail of the organizer basket with the WTC units and the loose tube buffer units. Note that the WTC optical unit binders and core make up approximately half the density of the loose tube buffer units.

This splice point used a traditional sized closure for a 432 fiber backbone splice and it is noted as having significant space available for more density leading to a conclusion that at least one size smaller closure could have been used at this location.

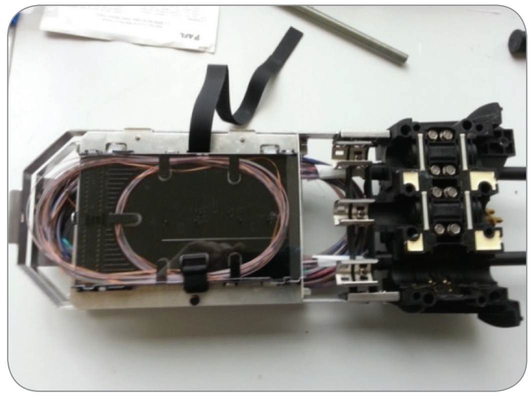
In access splicing there are different considerations for the closure sizing. Part of the consideration is determined by the environment such as is the splice point for underground/hand holes or for aerial access. In underground applications, the closure size is critical as it will determine the hand-hole size and corresponding excavation impact. In mid-cable access splicing, much of the cable is expressed through the organizer and then a small portion of the fiber is used for assigning fiber to a node or access point. This expressing of the fiber is shown in *Photograph 6—Mid-Cable Access Arrangement Sealed Closure of a 576F WTC Fiber Cable.*

Photograph 6—Mid-Cable Access Arrangement Sealed Closure of a 576F WTC Fiber Cable

Photograph 7—WTC 576F Storage in Sealed Access Closure shows the final storage location in an underground sealed closure designed specifically for WTC fiber optic cable with a smaller storage basket. This storage coil of fiber is then separated into expressed fibers versus access fiber that are then 144 fibers are routed to a splice tray for fusion spicing to branch or access cables shown in *Photograph 8—WTC 144F Sealed Access Splice Tray* that will then assign the 6 to 12 fibers for the terminal node and customer drops.



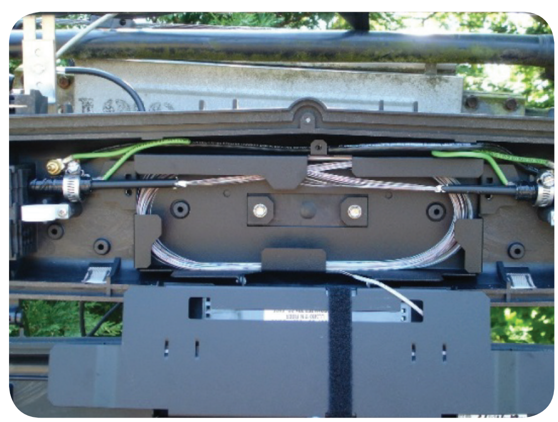
Photograph 7—WTC 576F Storage in Sealed Access Closure



Photograph 8—WTC 144F Sealed Access Splice Tray

In aerial access applications, the WTC fiber optic cable typically utilizes an aerial breathable terminal or access closure. In these cases the cable access is facilitated by leaving a 1.5 meter diameter coil on the messenger strand. *Photograph 9—Aerial 288F WTC Mid-Cable Access Coil* shows this one meter coil.

Photograph 9—Aerial 288F WTC Mid Cable Access Point Coil



Photograph 10—Aerial Breathable Access Closure WTC Storage

The WTC fiber optic cable, in the 1.5 meter access coil, is then prepared in a mid-cable access method and stored in the aerial breathable terminal closure in a similar fashion as the underground seal access closure. This is where optical fiber bundles of the WTC fiber cable are coiled in a storage area of the closure and only the 6 to 12 fibers need for the access node are spliced. This is shown in *Photograph 10—Aerial Breathable Access Closure WTC Storage*.

Savings in splice closures when using the WTC fiber optic cable are quantified in several ways. Network splicing of the F1 segment there is a minimum of downsizing of one standard closure size depending on the total number of splices and the number of cables that enter into the closure. This represents approximately between 33% to as high as 40% savings in the material cost of the closures and splice trays.

Access splicing will also afford a reduction in the closure size and cost based on the express entry method, storage area and splicing of access node for 6 to 12 customers. The estimated savings is approximately 15% to a high of 25% for terminal closure cost depending on the configuration and number of actual customers for the access node point.

3.2.7 Cable Splice Preparation Time

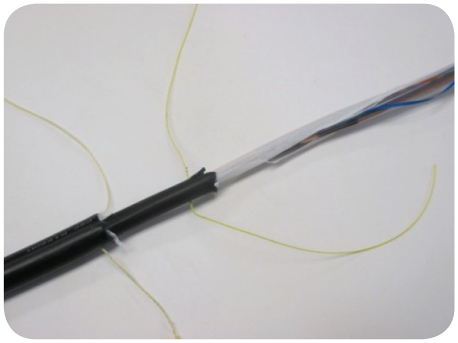
Cable preparation time for network splicing and access splicing is impacted by the following:

- Outer Jacket and Armor Removal
- Inner Jacket Access
- Core Unbinding and Unit Identification
- Gel Removal and Cleaning

Network splicing is typically reel-end splicing and/or branch cable splicing. Network splice methods typically use an end cable preparation of 1.84 m to 2.44 m (72" to 96") of fiber optic cable. The cable preparation time is most impacted by core unbinding, identification of units and any cleaning and gel removal from the fiber or ribbons.

With traditional loose tube, traditional ribbon and WTC fiber optic cable, there are similarities in outer jacket/armor and inner jacket removal. The standard industry tools are applicable for accessing the ripcords and the methods are consistent across all three cable designs. *Photograph 11—Industry Standard Tools for Cable Preparation* identifies the typical tools used for cable entry. WTC fiber optic cable has several unique advantages in sheath entry that facilitates faster sheath stripping of the outer armor and the inner jacket. The outer armor has two ripcords, 180 degrees apart, that are robust enough to rip both the outer cable jacket and armor together and split the outer sheath and armor into two separate segments. The WTC fiber optic cable inner sheath also has unique attributes of ridges on the inner jacket sheath indicating where the two ripcords are located under the inner jacket. This helps in both network splicing and mid-cable access splicing. Core unbinding and identification of the WTC is slightly disadvantaged over traditional loose tube and in that there are more super binders that must be secured for future reference in the network splicing. In gel removal and cleaning for network splicing, the WTC fiber optic cable has an advantage in that there is no gel or special cleaning preparation required. This is a significant savings compared to traditional loose tube or traditional ribbons.

Photograph 11—Industry Standard Tools for Cable Preparation



Photograph 12—WTC Inner and Outer Ripcords

Access splicing cable preparation has the same cost consideration elements as network splicing preparation; however, the access length and technique are different. In access splicing, the most common method is a mid-cable or slack loop splice where the express cable sheath is open in a length of 1 to 2 meters (39" to 78") and all the optical units or buffer tubes are expressed through the closure. The outer sheath/armor removal and inner sheath removal are consistent on either the WTC or the loose tube fiber optic cables. Since this is access splicing, a loose buffer tube cable of 144 fiber or lower is used most of the time. In this case, the WTC fiber optic cable has a significant advantage of being a dry core design with removal of only the binders from the unit bundle being accessed versus the mid-tube access of the loose tube cable design and the cleaning/preparation of the loose buffer tube fibers.

For cable splice preparation time, the WTC fiber optic cable design saves approximately 10 to 20 percent depending on the splicing type, cable type and fiber counts.

3.2.8 Splicing Time Reductions

Network splicing methods for the WTC fiber optic cable that has SWR is similar to traditional ribbon splicing technology. The difference is that the WTC is a dry core cable with no buffering tube or gels. The splice protection sleeve is placed first over one of the two SWR groups that are being spliced together. Then SWR is aligned and arranged into a traditional splice holder by pulling the SWR group through the technicians thumb and forefinger. This aligns the SWR into a ribbon array. The SWR ribbon array is then placed in a traditional fiber holder for a mass fusion splicer. The SWR ribbon in the fiber holder is then placed into a traditional ribbon thermal stripper and the acrylate coating is thermally removed leaving the twelve 125 micron cladded single-mode fibers ready for cleaning with a fiber cleaning solution or regent-grade alcohol.

Photograph 13—SWR Ribbon Aligned into Splicing Fixture

Photograph 14—Thermal Stripping of SWR

After thermal stripping and cleaning of the fibers, the fibers are visually checked for alignment then the fiber holder and fibers are placed into the mass cleaver for the proper end cleave. This requires a precision mass fusion cleaver to provide a three-degree (or less) end cleave.

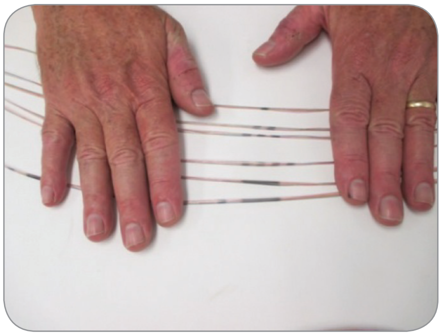
After cleaving, the fibers are placed into a mass fusion splicer and the other SWR ribbons is prepared in a similar fashion. At this point the fibers are mass fused and carefully removed from the splice holder on the side where the splice protector sleeve was previously positioned. While maintaining a slight tension to prevent buckling of the splice, the splice protector sleeve is slid over the mass fusion splice and then positioned into a splice sleeve heater for curing. After the splice has been heated, shrunk and cooled, the mass fusion splice sleeve is properly placed into the splice storage tray of the splice closure.

Photograph 15—Mass Fusion Splicing of SWR

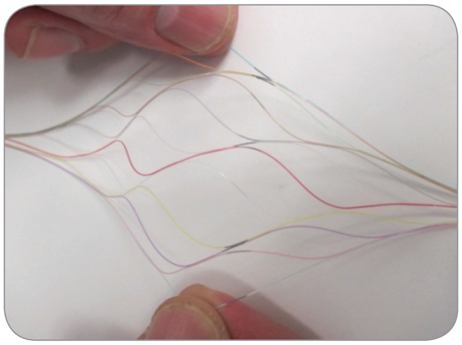
Photograph 16—Finished Mass Fusion Splice of SWR

Access slicing methods of WTC fiber optic cable with SWR is functionally the same as single fusion splicing. One significant advantage with the SpiderWeb Ribbon is that it can be de-ribbonized very quickly without special tools. This is due to the construction of the SWR. The SWR ribbons are arranged into 72 fiber (six groups of 12) binder groups. Each binder group is identified with a color coded binder unit. Inside each of the six ribbons are marked with a black stripe key of one through six.

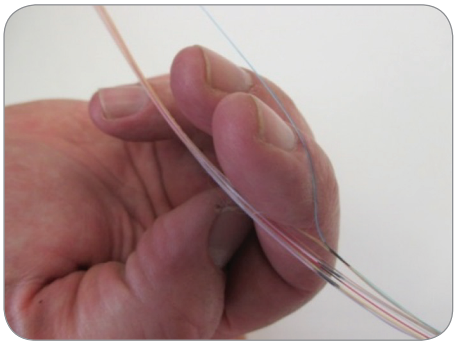
Each of the individual SWR ribbons are identified with their unique color code. The key to access an individual fiber is that the SWR can be separated to pull an individual fiber from the group very easily. By pulling on opposite edges of the ribbon, the individual fiber will fan out.



Photograph 17—SWR Ribbon Identification Stripes



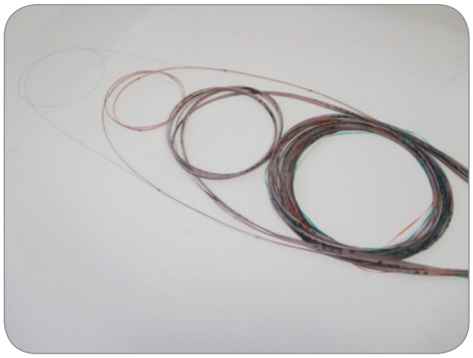
Photograph 18—SWR Ribbon Fan Out



Photograph 19—Single Fiber Extraction from SWR

Once the fiber has been fanned out, the technician can insert this fiber between the fiber web to break the edge bond of the fiber to be separated for access splicing.

The ease of the access splice is demonstrated by the segregation of the various SWR groups in the splice closure. The express fiber is stored in the closure organizer and the SWR ribbon that is to be accessed is stored in the splice tray in the closure with the express fibers coiled into the tray. The fibers to be accessed are separated from the SWR and then cut to facilitate splicing to the access connectors, terminal enclosure tail or directly to the customer drop cables.



Photograph 20—SWR Access Coils Arrangement

Splicing time comparisons are still in process of evaluation at the time of this paper. Preliminary indications are that the SWR splicing time is approximately 50 to 70 percent faster than splicing with traditional loose tube fiber counts up to 144 fiber cables. Splicing time comparisons with traditional high fiber count ribbon cables are near the same. The WTC cable is faster on organizing in the splice tray and does not require the extensive cleaning to remove gels. However, arrangement in the fiber splice holder, cleaning, cleaving and fusion splicing is slightly longer with SWR than conventional ribbons cables.

3.2.9 Cable Handling and Storage

The final area of potential cost savings that was analyzed was the benefits of WTC fiber optic cable when looking at cable handling and storage. Part of this savings is associated with the prospect of faster coiling and storage. The second part of savings is associated with impact on hand holes and fiber storage brackets. With the WTC fiber optic cable being an average of 18 percent smaller in diameter than traditional cables, it can be coiled into significantly smaller diameters than the traditional cable with similar fiber counts. This is most significant in the high fiber counts above 144 fiber counts where this diameter difference is between 25 to 35 percent in smaller cable diameters. As the cable diameter is a direct function of the minimum static bend radius, this has an impact on the requirements of size in hand holes, access coils and aerial cable storage devices.

Photograph 21—WTC 432F PSP Cable Storage Coil

4.0 SUMMARY AND CONCLUSION

This paper has investigated cost saving areas in the use of the new ultra-density fiber optic cable called Wrapping Tube Cable that uses a new ribbon technology called SpiderWeb Ribbon. The cable was developed specifically for access fiber networks such as fiber-to-the-home, fiber-to-the-node and broadband access networks. Various savings areas are identified and summarized in *Table 8—WTC Network Cost Savings Averages*.

Table 8—WTC Network Cost Savings Averages

NO.	ITEM	PERCENT IMPROVEMENT
1	Shipping Cost	35%
2	Scrap Reduction	1.2%
3	Faster Installation	4.6-11%
4	Load on Aerial Messenger	15.5-25.2%
5	Fit in Smaller Available Duct	32%
6	Smaller Splice Closures	15-40%
7	Mid-Cable Access Splice Prep	10-20%
8	End Splice Cable Splice Prep	5%
9	Fusion Splicing Process	0-50%
10	Cable Storage	25-30%

5.0 REFERENCES

1. Mizuki Isaji, Shota Yagi, Yuto Takahashi, Ken Osato, Masayoshi Yamanaka, Naoki Okada, "Ultra-High Density Wrapping Tube Optical Fiber Cable with 12-Fiber SpiderWeb® Ribbon," Proceedings of the 62nd International Wire and Cable Symposium, 2013 pp. 605-609.
2. IEEE-ANSI Standard C2-2012 "National Electrical Safety Code," Institute of Electrical and Electronics Engineers (IEEE), 14 April, 2011. American National Standards Institute (ANSI), 3 June 2011.

6.0 AUTHORS

Patrick Dobbins is currently the Director – Application Engineering for AFL. He joined AFL in 1992 after 13 years as a network design engineer at a major telephone operating company and in a fiber optic cable startup company acquired by AFL. He received his Bachelor of Science in electrical engineering from Georgia Southern University in 1980 and currently holds three U.S. patents in fiber optic technology.

Brett Villiger is currently the Cable Engineering–Development Manager for AFL. He started in 1998 with AFL as a process engineer and has held additional roles as manufacturing engineer and development engineer. He received his Bachelor of Science Degree in Mechanical Engineering from Clemson University in 1995 and a Master's in Business Administration from Clemson University in 2006.