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“Fiber Cable Design Considerations for the Pending RUS PE-90 Spec Revision”

Association of Communication Engineers School

Memphis, Tennessee

May 5, 2008



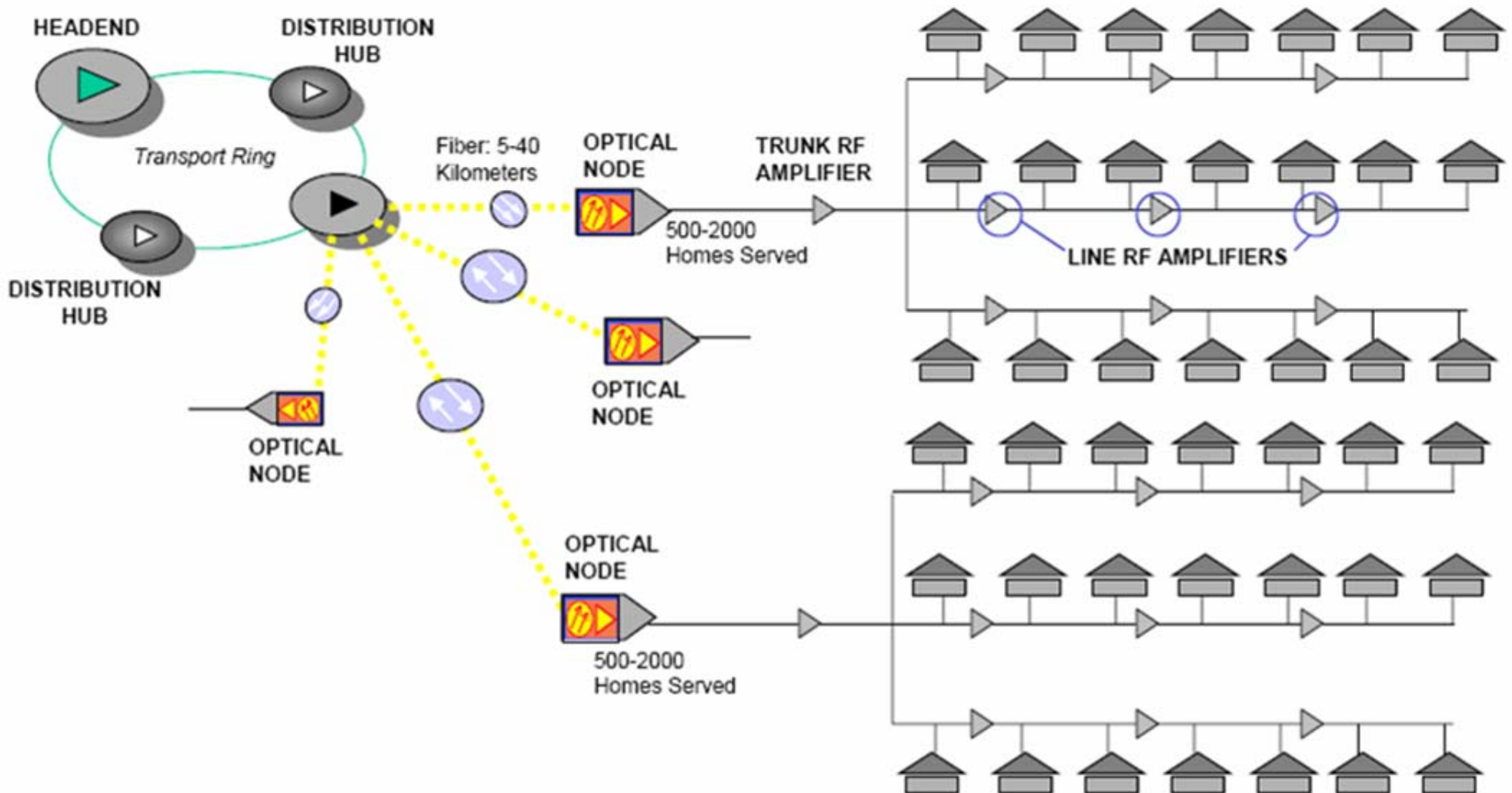
- **The Evolution in Fiber Cable Applications**
 - Changes in deployment since the last RUS specification release
- **New RUS Specifications to address current Fiber Cable/Closure Applications**
- **Cable Mid-Span Access vs. Fundamentals of Fiber Optic Cable Design**
 - Mid-span buffer tube lengths/performance
 - Proper Cable Termination at mid-span points
 - New requirements/test methods in RUS Specifications
- **Crystal Ball – What's the next evolution in Fiber Cables?**



- **Telephone service (POTS)/ business data were the primary uses**
 - Trunk and feeder networks primarily
 - Limited use in distribution networks, fiber to the Remote Terminal
- **CATV providers were using fiber in Hybrid Fiber Coax**
 - Fiber Cable from the Headend to the node, converting back to Coax
- **Network Architecture – Cables began to be accessed at mid-span locations as part of the network design**
 - **Several cable handling/access improvements were made in the industry**
 - *Dry Core cables eliminated core filling compounds*
 - *Flexible polyolefin buffer tubes eliminated furcation tubes*
 - *New buffer tube access tools for reliable fiber access mid-span*
 - **Closures were designed for typically 4-8 ft of expressed buffer tubes at mid-span access points**
 - **Mid-Span access allowed efficiency improvements in trunk and feeder networks**
- **Fiber To The Home was being conceived with limited trials**
 - **Deployment costs vs. Value proposition for content**
- **Internet was in its infancy**



Example: Hybrid Fiber Coax Network





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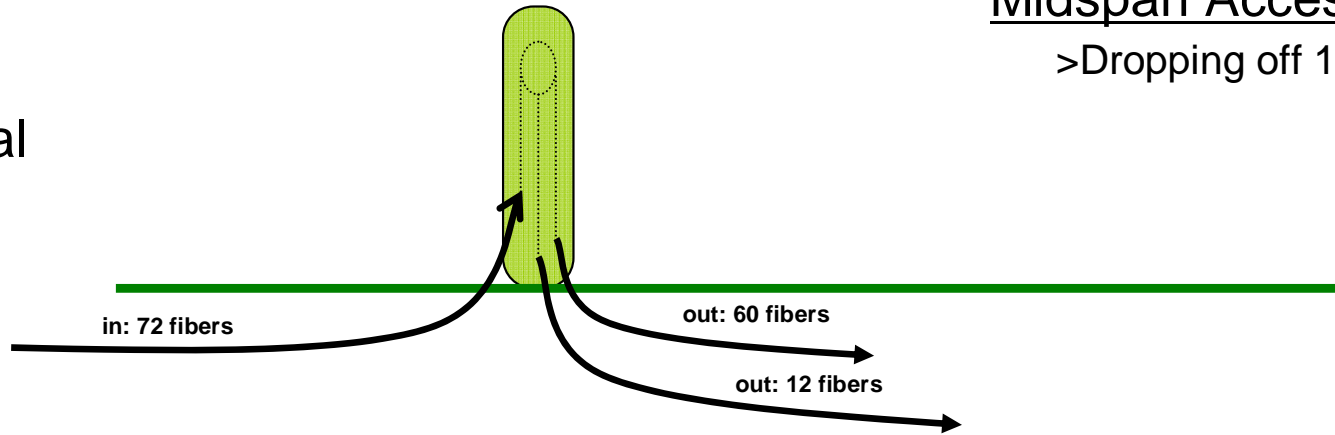


- **FTTx and Broadband are a reality**
 - Bundled services are being offered
 - CATV/HDTV, Internet, telephony, Video On Demand
- **Large bandwidth needed at the subscriber**
 - Internet with streaming video is a large percentage of traffic and bandwidth requirements
- **Fiber is being deployed deep in the network to achieve bandwidth needed**
 - Fiber to the Curb, Fiber to the Prem, Fiber to the Home
- **Architecture**
 - PON (GPON) is the most popular architecture for broadband deployment
- **Mid-Span access of cables is used to drop fibers off to subscribers**
- **Ribbon cables widely used, taking advantage of mass union splicing benefits**
- **New Hardware (closures/pedestals/splitter cabinets) designed for access points, some of which recommend storage of long lengths of expressed buffer tubes**
 - Long buffer tube lengths allow splice trays to be moved into splicing vans
 - Alternative to slack cable coils

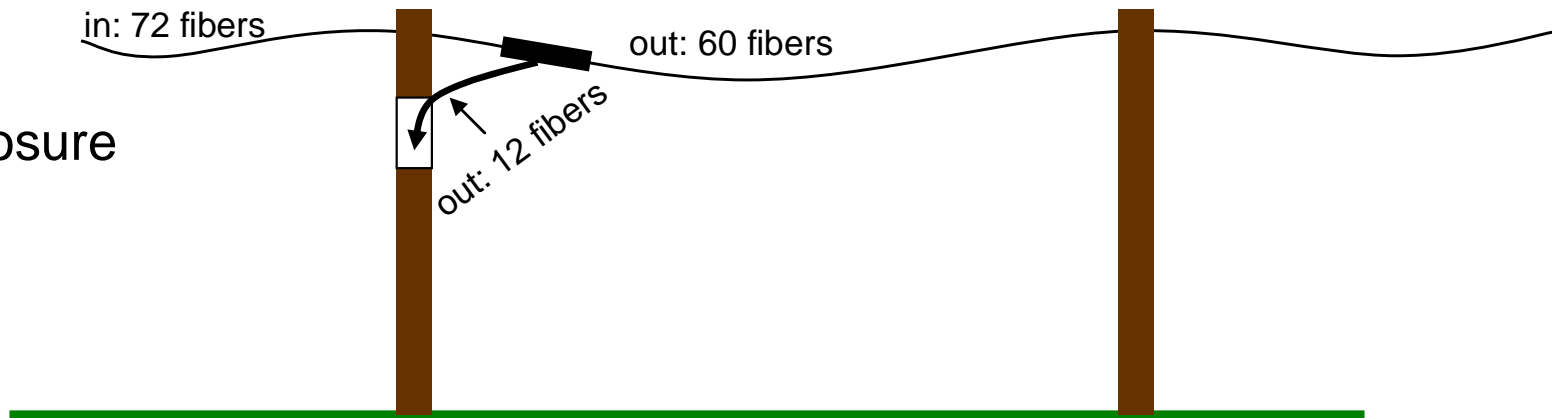
Midspan Access: Typical Scenarios

> Dropping off 12 fibers in Midspan access

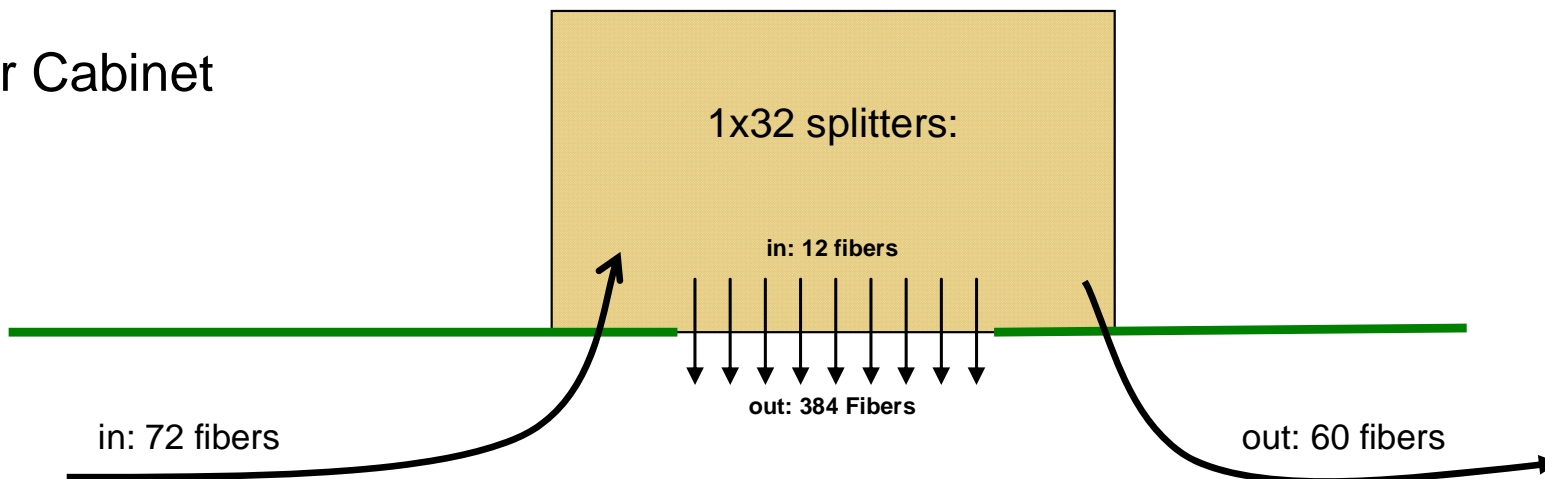
• Pedestal



• Aerial Closure



• Splitter Cabinet





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- **New Revision of the RUS PE 90 Specification for Fiber Optic Cables being released this year**
 - Last specification update was 1994
 - Revisions were needed based upon expanding use of fiber cable
- **The New Revision addresses**
 - New mid-span test method and performance requirements for today's Fiber Cable Deployment
 - Addition of Tensile rating and Fiber Strain requirements
 - Other new requirements (drop cables, new fiber types, PMD, etc)
- **New revision of the RUS PE 91 Specification for Fiber Optic Closures/Pedestals in development**
 - Expected to address test method and performance criteria to ensure closures/pedestals will properly secure terminated cable ends for long term reliability



- **What are the concerns when a cable is mid-span accessed and long lengths of buffer tubes are stored in closures/pedestals?**
- **Why is it important to terminate the jacket and central member at mid-span access points in a properly designed closure?**



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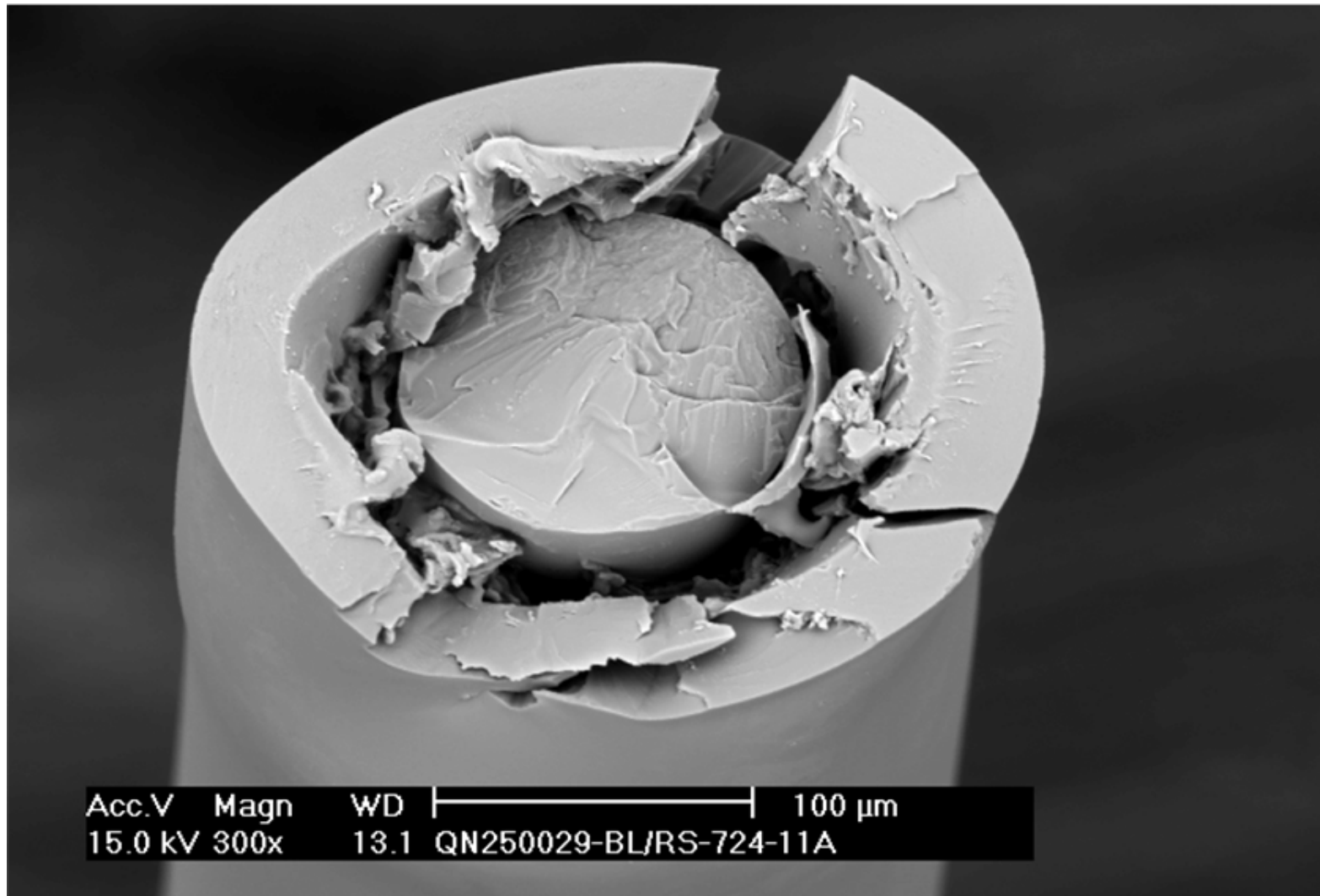
- **Cable designs are “engineered packages” designed to protect the optical fiber during installation and over a long (20+ year) operating life**
- **The “Cable Package” is designed to minimize the stress imposed on the optical fiber to avoid attenuation increases (power loss) and fiber breaks**
- **There are 2 basic ways to break a fiber**
 - Very high stress ($> 100,000$ psi) which can cause an immediate break
 - Moderate stress ($< 100,000$ psi) which causes fatigue and a break to occur over time
- **There are 2 basic ways to cause power loss (attenuation)**
 - Lateral stress (pressure) on the fiber causing microbending
 - Small bend radius on the fiber causing macrobending



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High Stress Break Scanning Electron Microscopy

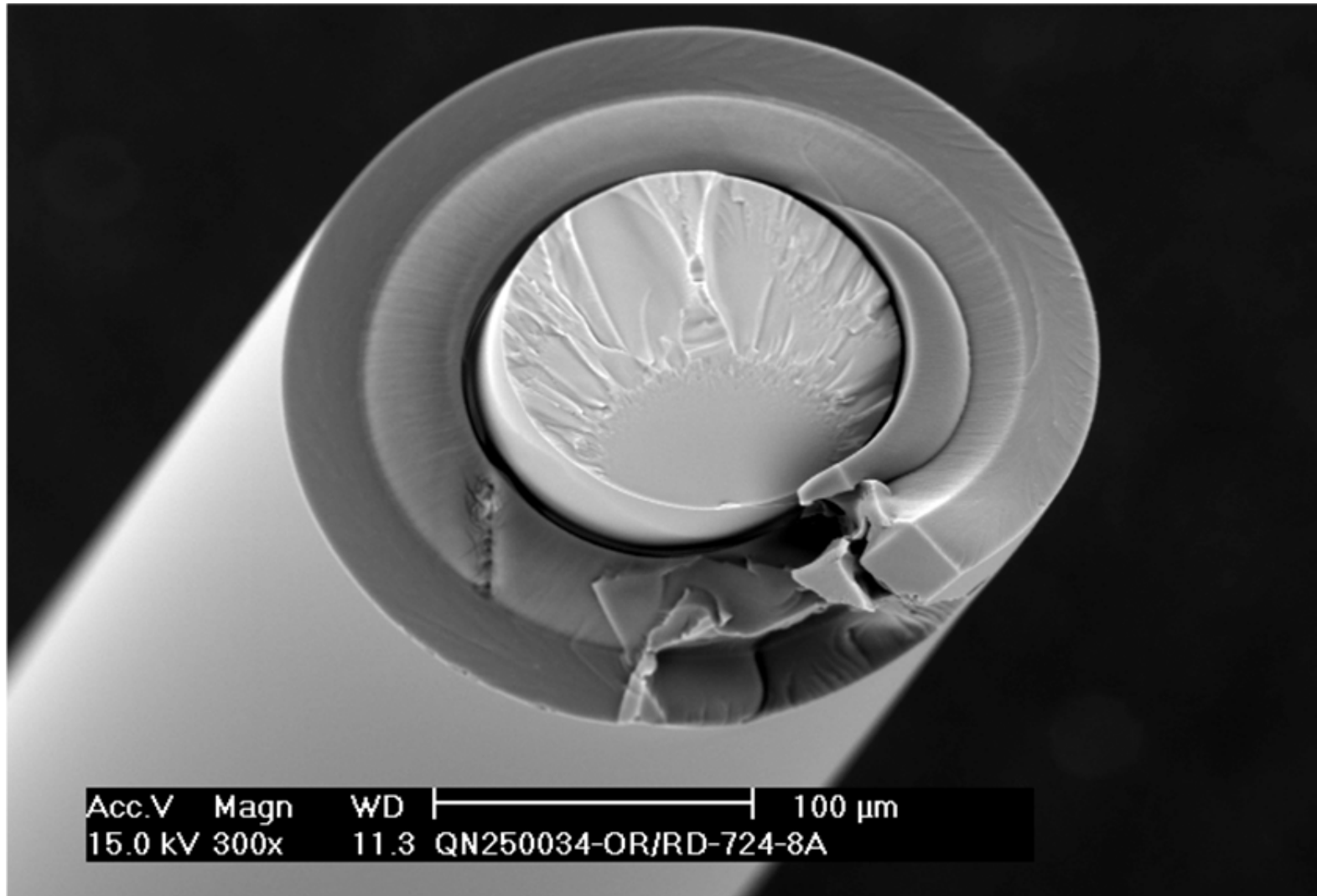




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Low Stress Break Scanning Electron Microscopy



Cabling for the real world.

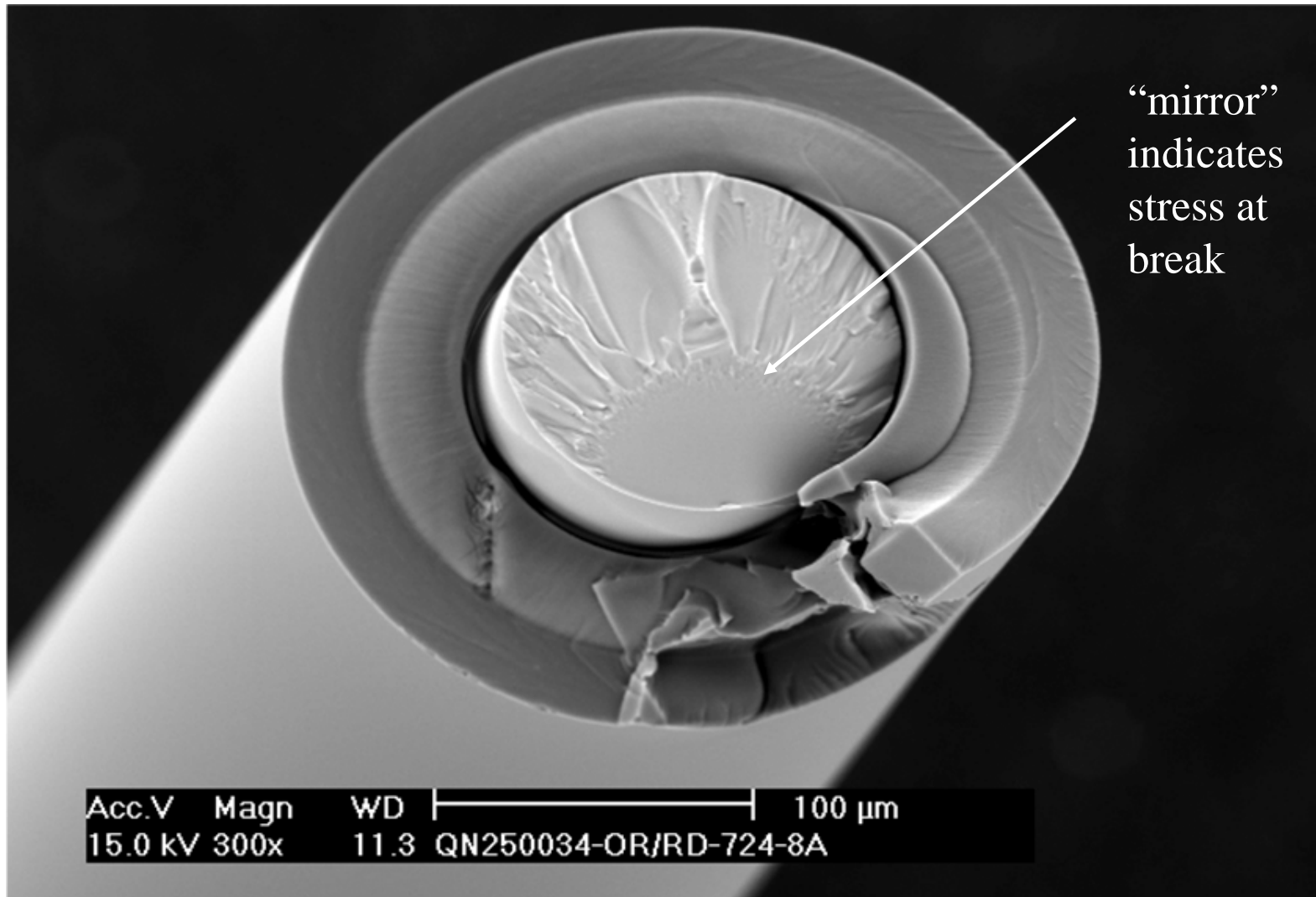
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Low Stress Break Scanning Electron Microscopy





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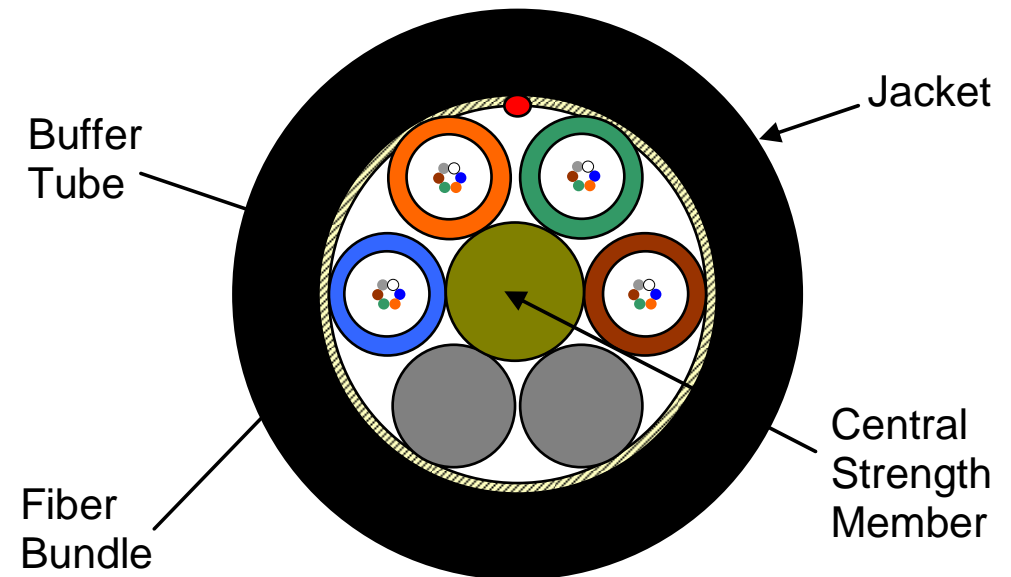


- **An effective Cable Design must minimize stresses during**
 - Installation loads
 - External loads during operating life (ie. Crush, ice loading, wind galloping, etc)
 - Large temperature changes (-40C to +70C)
- **Effective cable designs limit fiber stress/strain for long term reliability (no breaks/no added loss)**
 - Short term fiber stress is normally limited to < 0.60 % strain (100 kpsi fiber)
 - Long term fiber stress is normally limited to < 0.20 % strain (100 kpsi fiber)
 - Minimal lateral pressure on the optical fiber to avoid power loss microbending (fibers “float” inside of buffer tubes)
 - Bend radius > 40 mm to avoid power loss due to macrobending



Loose Tube Cable Designs

- Buffer tubes are used to group the fibers and provide protection
- Buffer tubes are stranded around a central strength member and coupled with binder threads
- Strength yarns, corrugated armor tape (optional) and a tough Polyethylene jacket are added for additional strength and protection
- Typical loose tube cables are designed for
 - *600 lb tensile loads during installation*
 - *180 lb operating load over lifetime*
 - *Operating temperature -40C to + 70C*
 - *Very small power loss over lifetime of 20 years*





How are Loose Tube Cables Designed to meet these requirements?

- **Two main objectives**
 - Select strength materials to **minimize the cable strain** during installation and operating loads
 - **Create a “Fiber Freedom Window”** with tube/stranding dimensions so cable strain does not create fiber strain

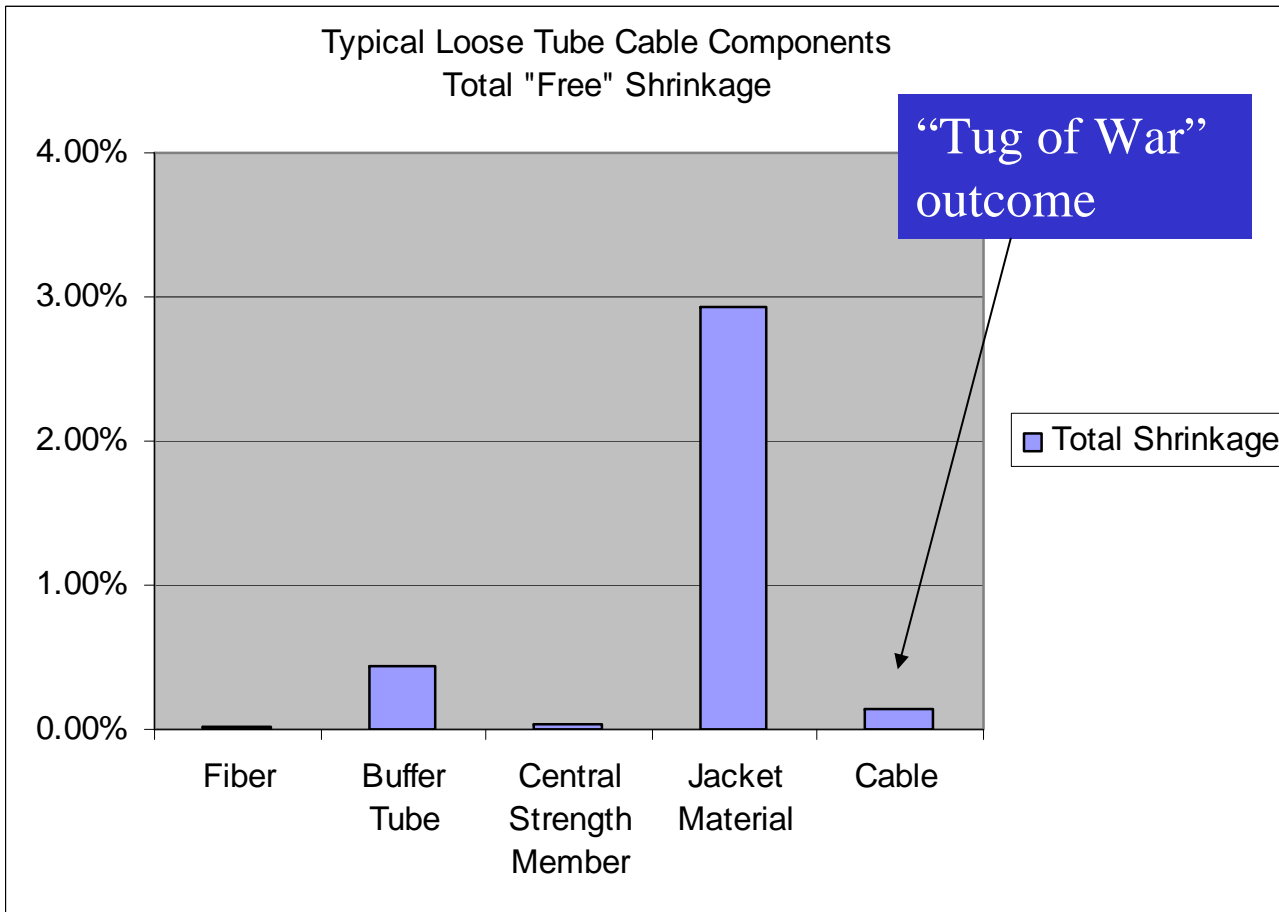


Key Design Criteria – Minimize Cable Strain

- **Minimize cable strain due to tensile loads/temperature changes**
- **High Modulus (ie. strong) strength members (anti-buckling element, yarns)**
 - High tensile strength, low elongation
- **Strength materials with low coefficient of thermal expansion minimize dimensional changes over operating temperature range (-40C to +70C)**
 - Commercially available Jacket and buffer tube materials (polymers) have much higher shrinkage at low temperatures as compared to optical fibers they protect
 - Central strength member are selected with low CTE (thermal expansion coefficient) and high Youngs Modulus (E) to reduce the effective shrinkage caused by the Jacket and buffer tube materials
- **Result is a “Tug of War”**
 - ***Jacket/buffer tube materials versus Central Strength member***



- Cable components have significantly different Thermal Expansion Coefficients, and therefore dimensional changes, across operating temperature range
- Central strength member is selected to **compensate** for Jacket/Buffer Tube shrinkage



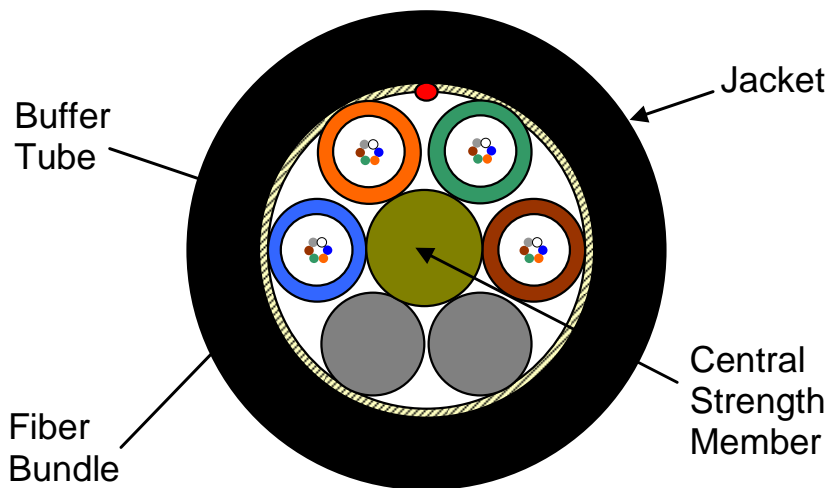
- “Tug of War” between the different components

- Effective Shrinkage of the cable determined by the rule of mixtures equation

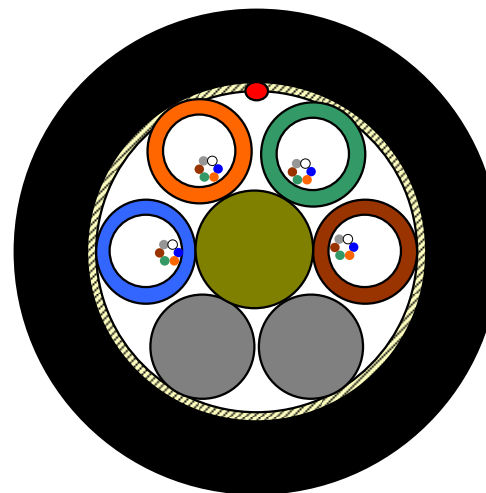
$$\alpha_{cable} = CTE_{cable} = \frac{\sum_{i=1}^n \alpha_i E_i A_i}{\sum_{i=1}^n E_i A_i}$$



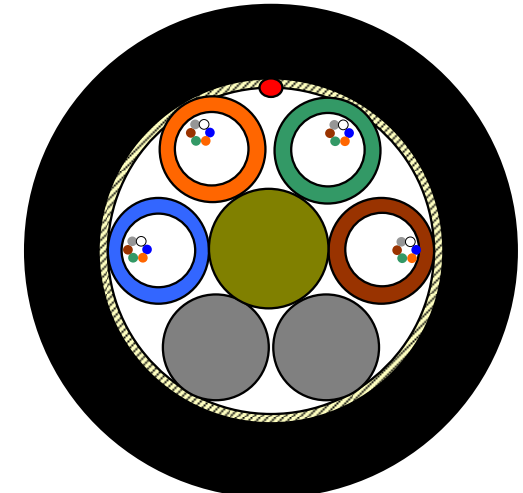
- **Create “Fiber Freedom Window”**- Cable changes length (tension/thermal shrinkage) without creating stress/strain on optical fibers
- “Fiber Window” provided when buffer tubes are stranded around a central member
- During installation loads, cable is strained (stretched) but the optical fibers move toward the center of cable (a shorter path), thereby avoiding strain and stress.
- Cable exposed to low temperatures (-40C), contracts and becomes shorter. In this case, the optical fibers move away from the center to take a longer path avoid strain.
- Fiber Window can be calculated $FF = \sqrt{(1 + \mu^2 * (D_o^2 - D_i^2) / P^2) - 1}$



No cable strain



Tensile strain (Installation)



Compression strain (Cold Temp)



To design an effective loose tube cable:

Select central member
buffer/jacket materials
to minimize cable
strains during
installation and
temperature extreme

+

Select buffer tube
dimensions and
stranding parameters
to provide fiber
freedom window
keeping fiber strains
low

=

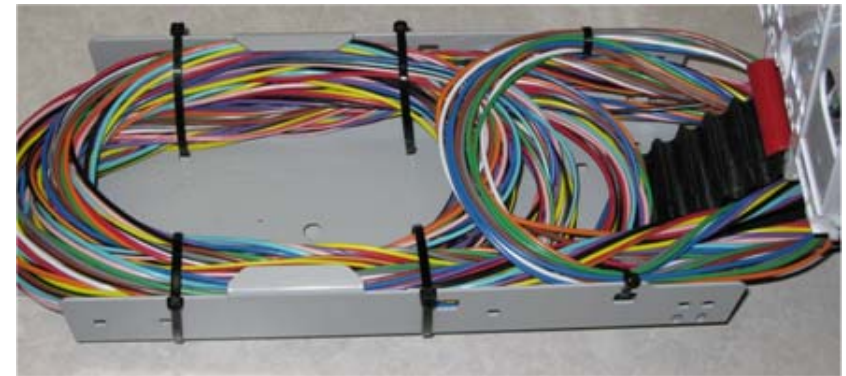
**Cable with
low fiber
strain and
excellent
long term
reliability**



- **What are the concerns when a cable is mid-span accessed and long lengths of buffer tubes are stored in closures/pedestals?**
- Why is it important to terminate the jacket and central member at mid-span access points in a properly designed closure?



- **At mid-span locations, the outer sheath is removed and buffer tubes are stored in a closure/pedestal**

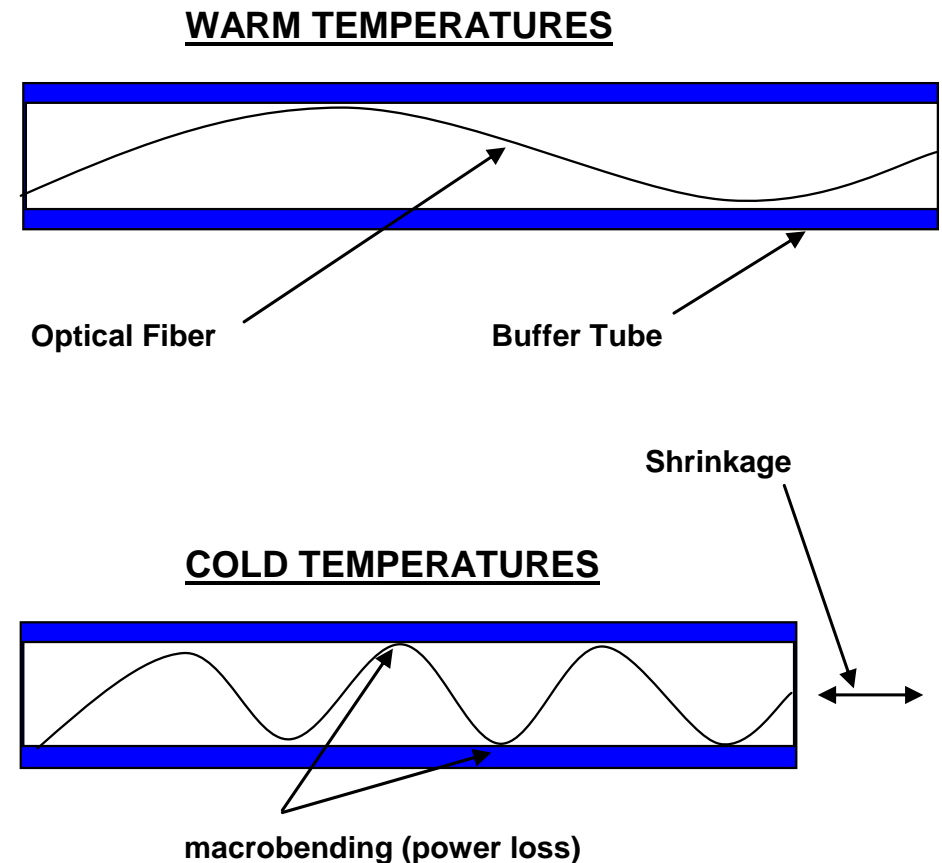


- **Two issues result**

- *Buffer tube is no longer constrained by CSM and is allowed to shrink*
- *Buffer tubes are no longer stranded so “fiber freedom window” is lost*



- Buffer tube shrinkage at cold temperatures creates excess length of fiber inside tube potentially resulting in power loss (macrobending – Accordion Effect)
- New RUS specification will require mid-span tube length up to 20 ft with power loss of ≤ 0.05 dB/km avg, 0.1 dB/km max at 1550nm
- *This performance can be achieved through the right combination of buffer tube materials, dimensions, and manufacturing process.*





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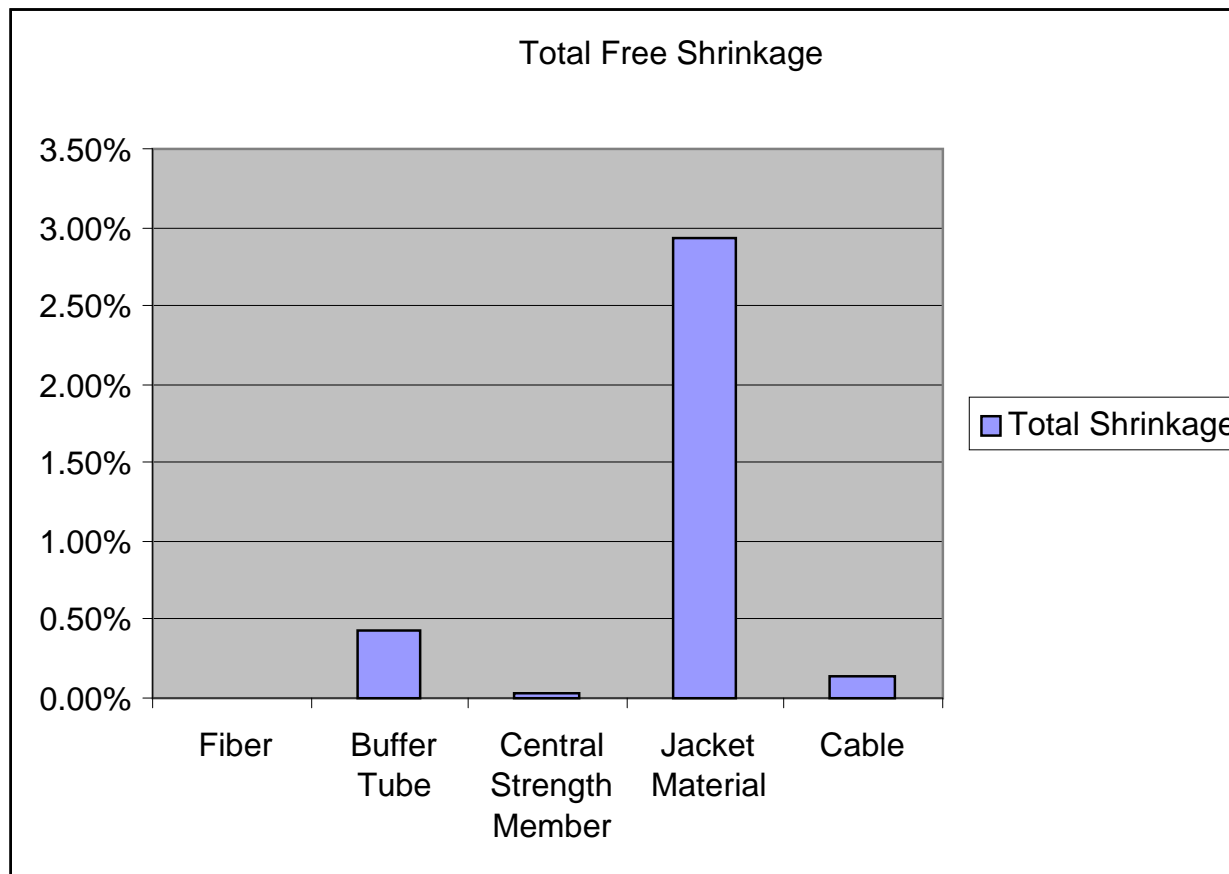
Cable Termination at Mid-Span Access Points

- **Properly terminating cables is also extremely important to avoid attenuation increases at mid-span access points**
- **Properly terminated means**
 - *Clamping of **both** the CSM and cable jacket*
 - *In a properly designed closure/pedestal*
- **“Cable Mechanics” behind improper termination are the same as mid-span tube storage**



- **Jacket and buffer materials shrink too much near the cable end if not restrained by CSM**
- **Increase power loss in the last 20 ft of cable.**

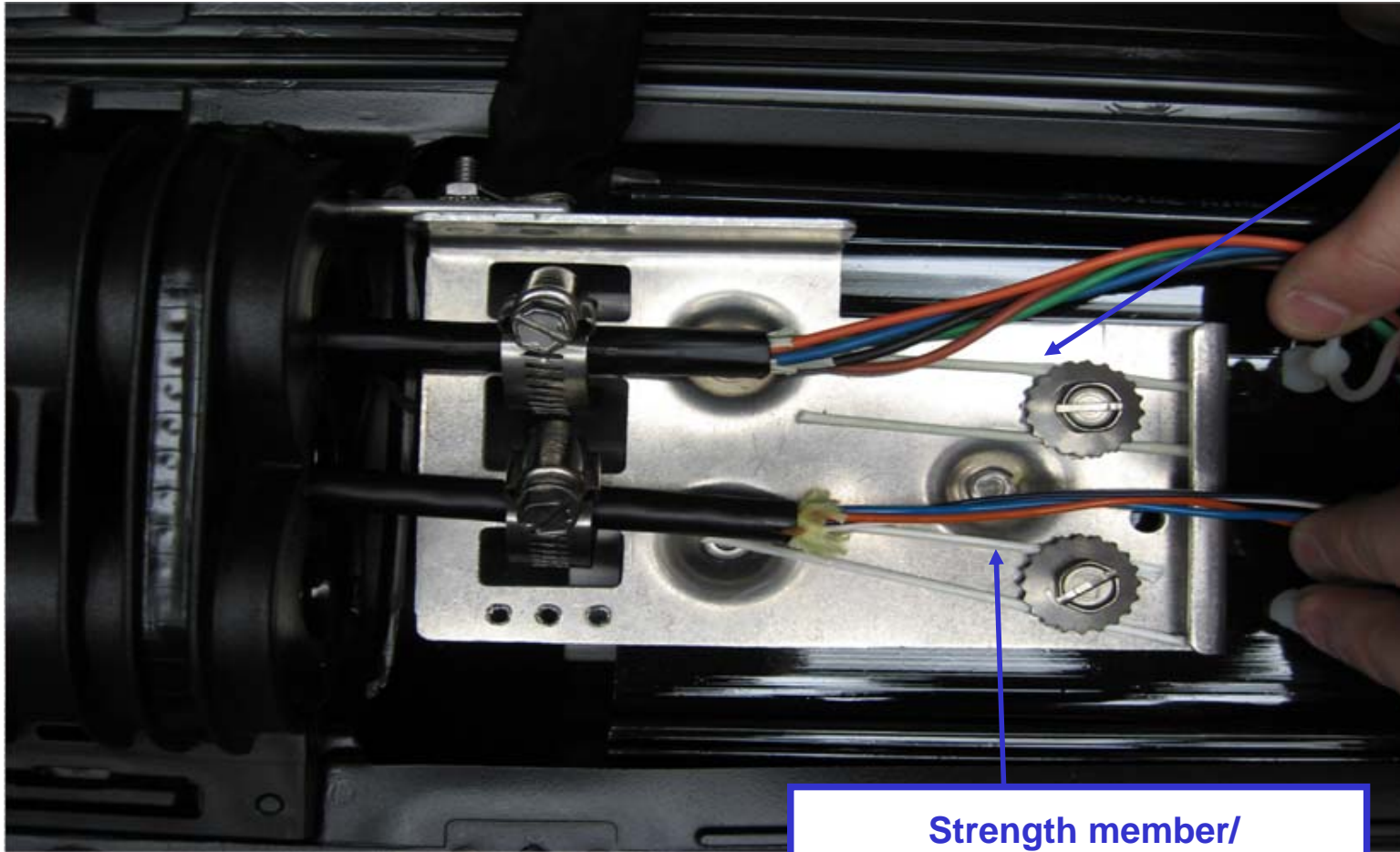
(reference Telcordia Temperature Induced Cable Loss papers published in late 90's)



Effective termination keeps cable components coupled to avoid jacket/buffer tube shrinkage and attenuation



Proper termination of the strength member / anti-buckling element



**Strength member/
Anti-buckling element is
secure**

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Anti-buckling element is
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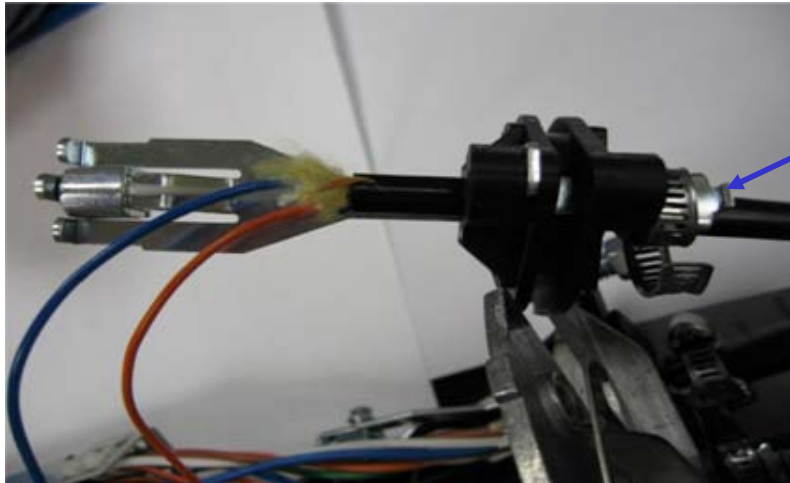


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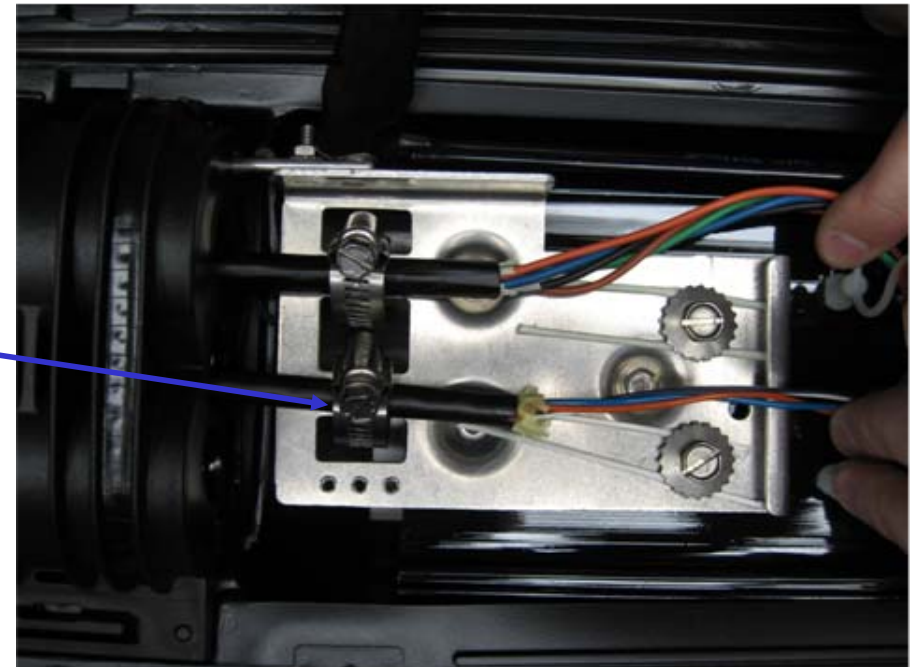
Jacket Sheath Must Be Secured

- Proper termination of the jacket sheath



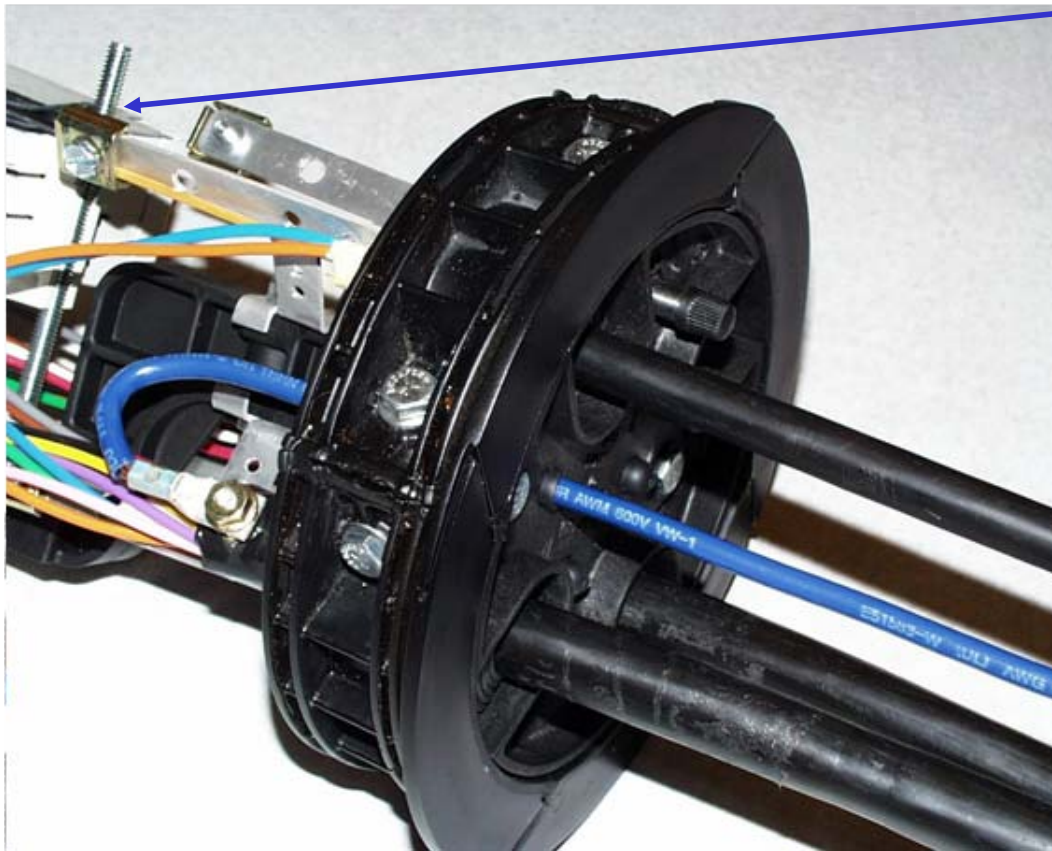
Jacket
Sheath Clamp

Jacket
Sheath Clamp





Proper termination of the strength member / anti-buckling element



**Strength
member/
Anti-buckling
element is
secure**

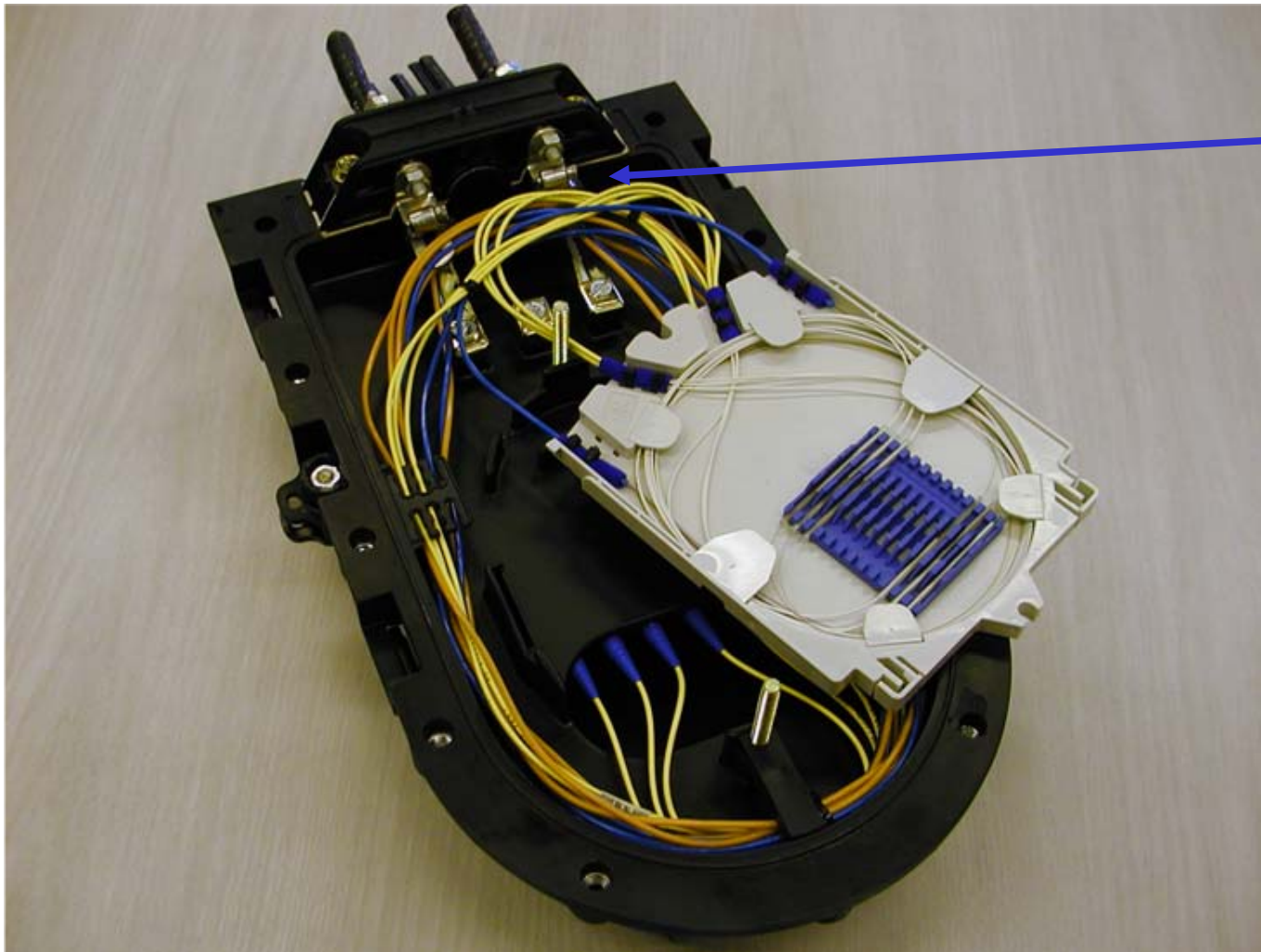


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Jacket Sheath Must Be Secured

- **Proper termination of the jacket sheath**



Jacket Sheath
Clamp

Cabling for the real world.

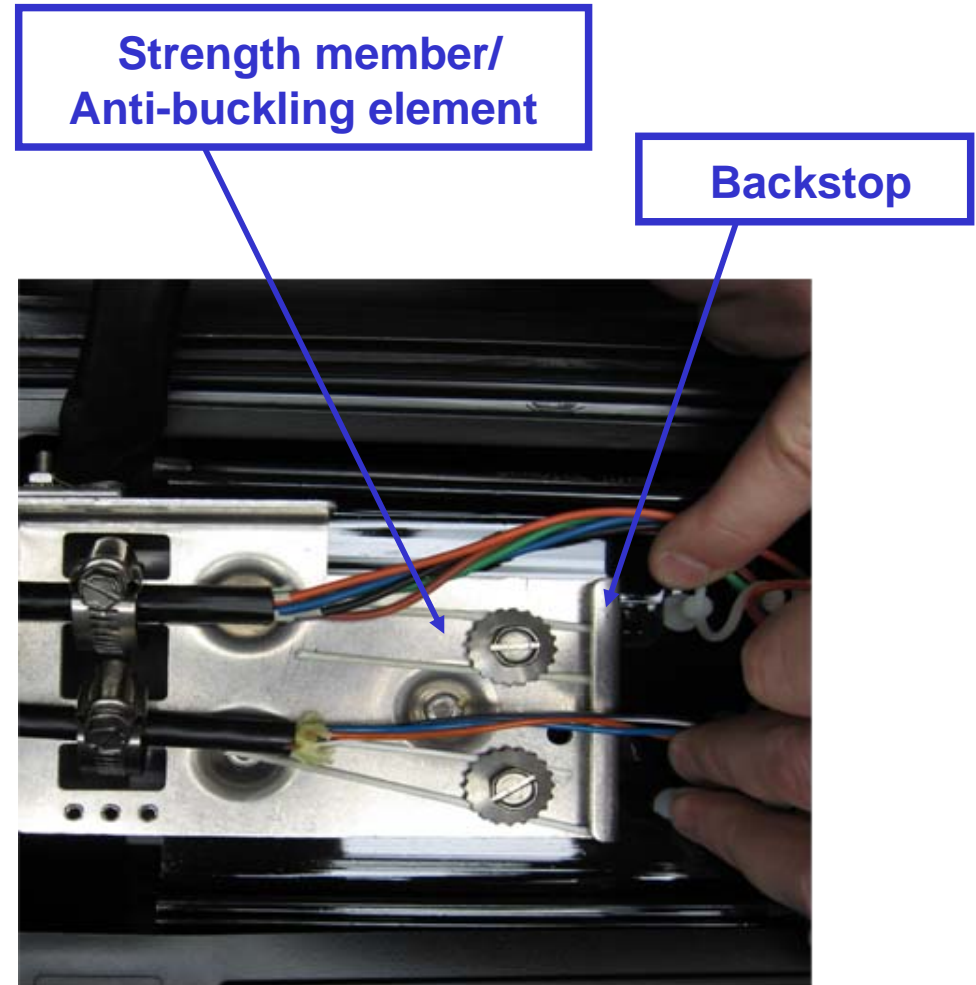
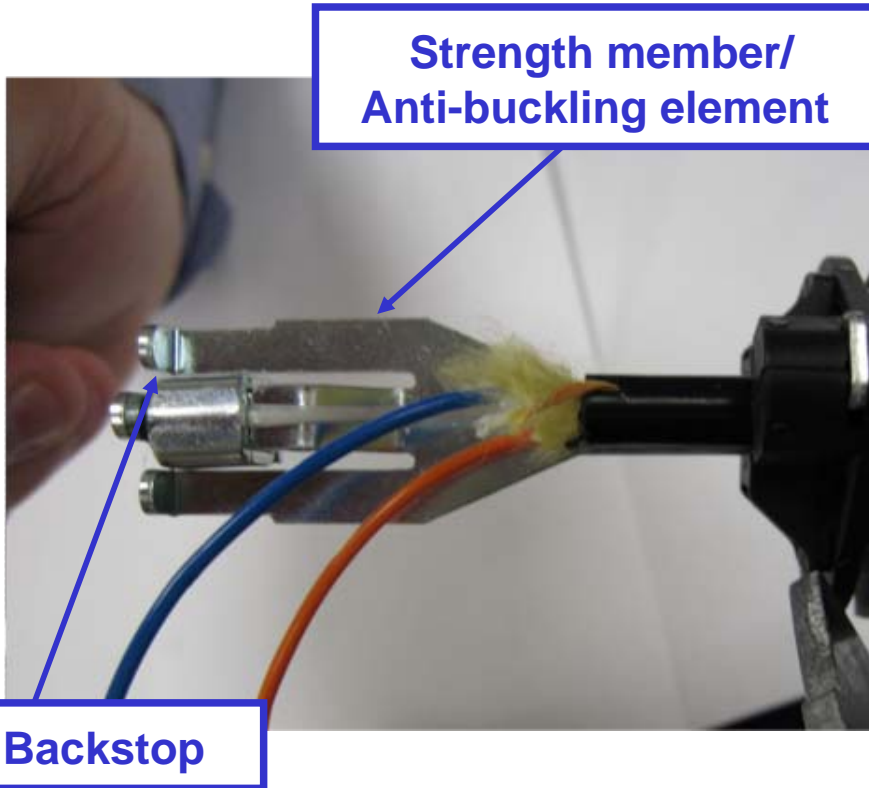
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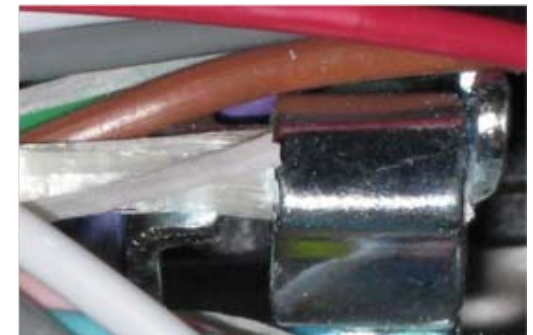
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Strength Member / Anti-buckling Element Must Have A Backstop

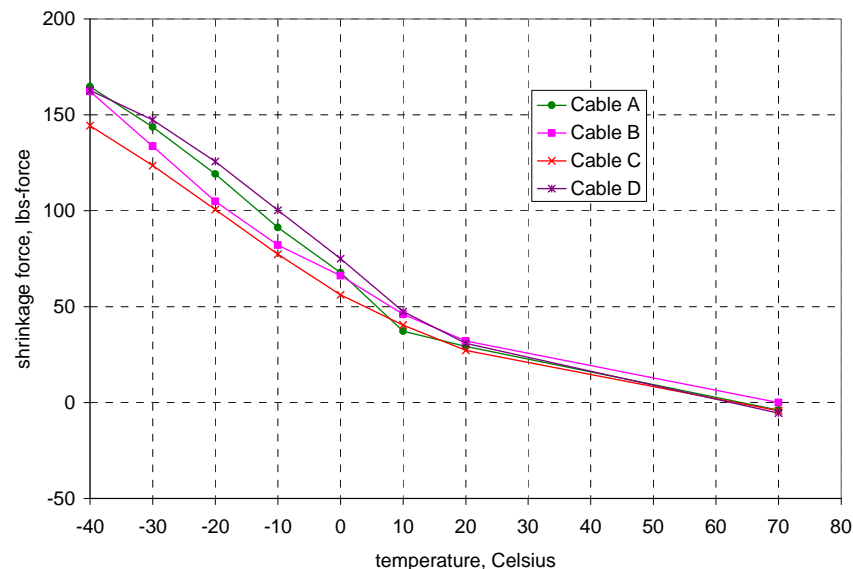




- **Closure / pedestal design is important. Some closures on the market are inadequate**
 - **CSM clamping**
 - Positive stop clamp recommended: Prevents pistoning
 - Minimize CSM routing angle and length:
 - Minimizes bowing/breaking
 - **Jacket retention sufficient to grip and hold jacket**
 - Jacket shrink forces reach 165 lbf at -40C



288F LT CABLE JACKET SHRINKAGE FORCE w/TEMPERATURE





RUS is also working on new specs for pedestals

- We expect requirements to be included for closure/pedestal termination capability





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- **Bend Insensitive Fibers will change the current Cable Design Rules**
 - Bend Insensitive Fibers can accommodate more stress (bending) without power loss (attenuation)
 - Draka's Product is *BendBright^{XS}*, other bend insensitive fibers are becoming commercially available
 - Cables with bend insensitive fibers will be smaller, lighter and easier to handle
- **Pre-connectorized cables will become more common to reduce field labor costs**
 - “Plug and Play” Methodology
- **Increased use of**
 - Ribbon cables to take advantage of mass fusion splicing
 - Totally Dry Cable Designs to take advantage of handling benefits
 - Indoor / Outdoor cables to eliminate splice points
 - Microduct cables with air-jetting installation
- **Next generation of Fiber Drop Cables will be developed**
 - Ease of use
 - Cost of use

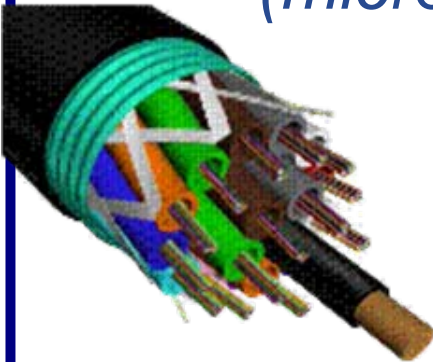


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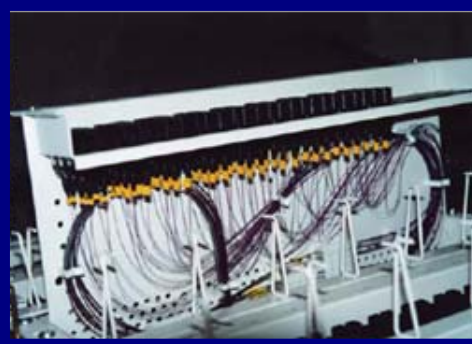
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BendBrightXS answers.....

***Severe cabling
(microbending)***



Improved tolerance to bends



***Miniaturized storage
(15 mm bend diameter)***



***Ability to guarantee these
performances up to 1625 nm***

***Nailed indoor
cable***



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Thank you for your attention!

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