Incab

Field Problems with Aerial Fiber Optic Cables, Part 1 – OPGW

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PURPOSE AND LEARNING OBJECTIVES

This course will teach you the biggest problems that utilities experience with their aerial fiber optic cables and how to prevent them (where possible).

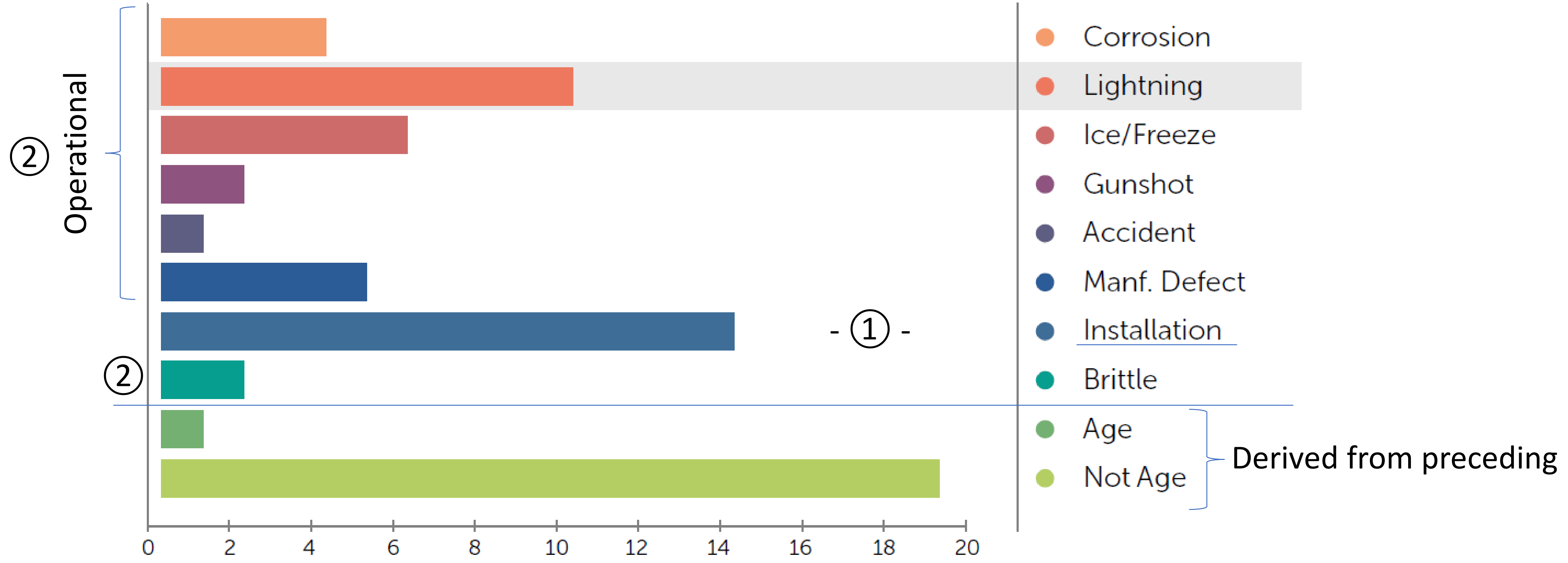
After this class, you will be able to:

1. State that most OPGW is damaged during the installation process.
2. Explain at least six (6) specific causes of damage to OPGW during installation and how to prevent each
3. State at least three (3) significant causes of OPGW failure after installation and how to mitigate against each
4. Explain Fiber Strain
    - What it is
    - Why it is important
    - How it affects OPGW
    - How it can be controlled
5. Explain why the preceding problems do not just disappear by putting fiber optic cables underground.

Incab University "School of Excellence in Fiber Optics"
Agenda

- Introduction
- Learning Objectives
- Presentation
- Q&A (Technical questions only)
- Let's start!

Consider this Graph of OPGW Failures by Type



Source: 2017 UTC Telecom & Technology presentation by Mike Unser of Salt River Project (SRP) and Dan Newman of Burns & McDonnell

Let's talk about all these problems—especially top 3—and how you can head them off

Installation-Induced Failures

Installation-induced failures

Causes and Solutions

1. **Stringing blocks** – Can kill a cable immediately, but sometimes effects linger
   - **Too small** – Insufficient bearing surface or too much bending can damage the optical unit (especially flatten aluminum pipe in such designs)
   - So-called "banana blocks", "ganged blocks", and "XS100" (distribution blocks) are **Trouble** (with a capital "T")!
     - Note: These are a variation of "too small"

Solutions:

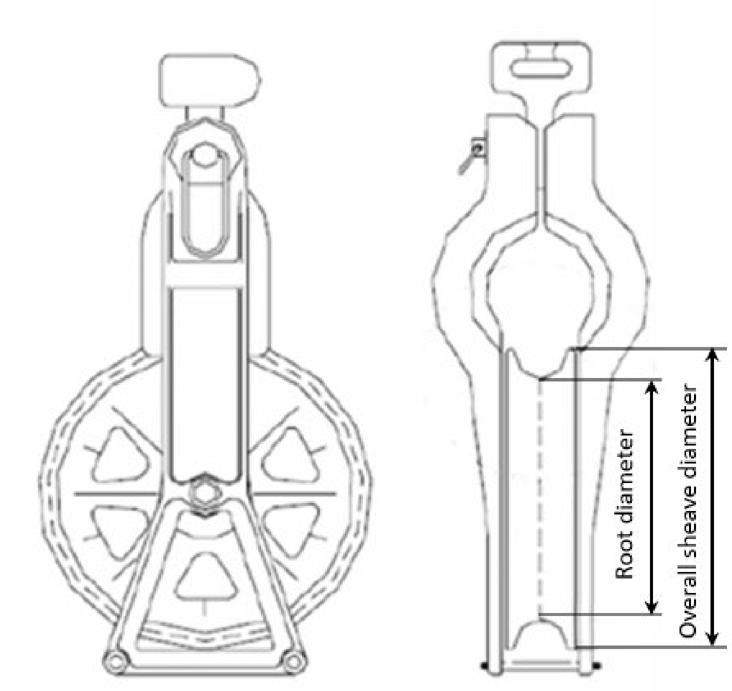
A. Follow manufacturer's guidelines!
   - 40 x cable O.D. should be your default – Supplier **may** allow smaller blocks for some design types or grant relief in special cases

B. Never, ever use "banana blocks", "ganged blocks", or "XS100" (distribution blocks)!

Installation-induced failures

Causes and Solutions

Illustrations!



Proper root diameter is essential!

Never go to the “Red Zone” of OPGW stringing!

Installation-induced failures

Causes and Solutions

2. **Excessive bending** = exceeding cable's minimum bending radius
   - Must be careful when going from a deadend down to a splice enclosure
   - During clipping-in

Solutions:

A. Be careful and always maintain the cable's **minimum bending radius**!
   - Use a generous arc when going from a deadend down to a splice enclosure

B. Must be careful during clipping-in, especially when putting slack into or taking it out of the cable

Installation-induced failures

Causes and Solutions

3. **Excessive tension** during pulling-in (> 20% RBS)
   - Should not damage the optics, but…
   - Could lead to sagging errors because initial sags and tensions assume no cable elongation; if there is elongation then…
     - Sag right, but tension higher than design, or
     - Tension right, but sag higher than design

   Solution:

   Be careful to maintain the cable's **maximum pulling tension**
     - Typically, 15 – 20% RBS, but could be less - You must check with the manufacturer!
     - If an anti-rotation device (ARD) gets stuck, *carefully* clear it
       (Don't just crank up the puller!)

Installation-induced failures

Causes and Solutions

4. **Abrasion** or **scuffing** during pull-in can lead to **corrosion.** Causes include:
   - Cable riding up out of block groove and dragging along frame
   - Block not rotating freely
   - Damaged block surface
   - Too much back-tension at payoff – Can also lead to inside end "squirting" out
   - Loose cable wind – Can lead to cable being pulled down to a lower layer
     - Cable can get stuck and then kink when getting unstuck 🡐 even bigger problem!

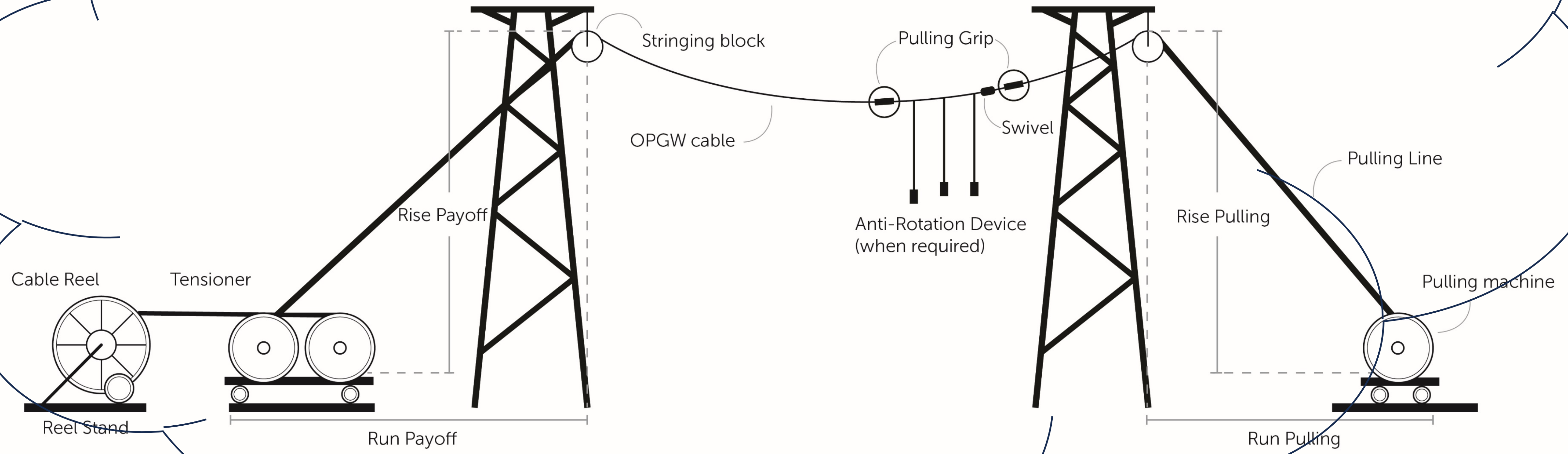
   Solutions:

   A. Ensure blocks in excellent condition before use!
      - Must rotate freely!
      - Surface must be smooth!
      - My experience: Un-lined aluminum blocks work best
        - Caution: Some suppliers *require* lined blocks

Remember…

OPGW Installation - Stringing

Controlled Tension Stringing



Typical Set-up for Controlled Tension Stringing

Installation-induced failures

Causes and Solutions

Solutions, continued:

B. Blocks must be properly supported at angles (See next slide)
   ➔ Block and cable must be in the same plane

C. Back-tension on reel should only be "hand tight"
   - You should be able to move the cable up and down by hand

D. Check reel wind and tighten all hardware on wood reels *before* starting pull
   - Tip 1 - If wind is loose, supplier can rewind the cable
   - Tip 2 - If payoff has already gone bad, try lubrication (Slick 50) and <u>lightly</u> loosening through bolts (≈ 1/4 turn)

Tip 3 -
If scuffing or abrasions occur during stringing, you should consult with the cable supplier

- Take lots of pictures
- Get a cable sample if possible – Then can check if the aluminum cladding on ACS wire has been compromised

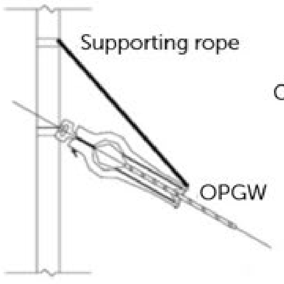
Installation-induced failures

Causes and Solutions

Illustrations!

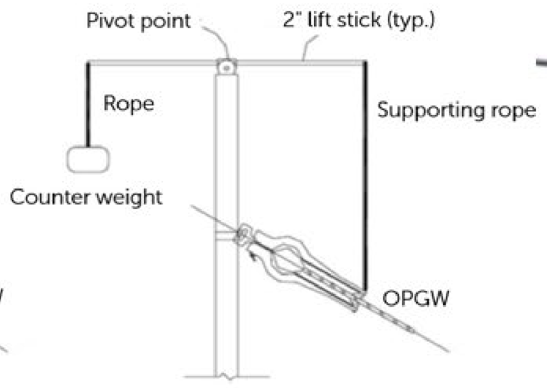
- Blocks Need Support at Angles ≥ 30°

Improperly supported sheave

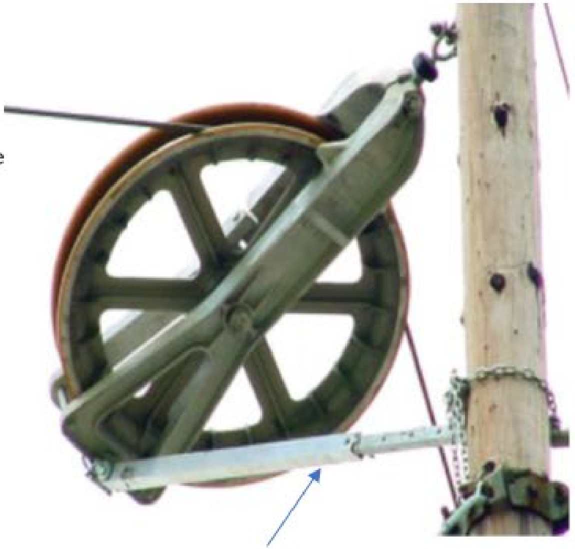


Properly supported sheave

(Can also be from underneath ➔)



Best supported sheave



Support from underneath block

The OPGW and the block must be in the same plane during the pull!

➔ If they aren't, then the cable can ride up and out of the block!

Installation-induced failures

Causes and Solutions

5. **Incorrect sagging tension** – Must be "just right" (= as designed)
    - Too high – Can cause **fiber strain** which leads to optical problems
    - Too low – Will cause too much sag
        - Could permit the cable to sag into a conductor (or something else)
        - Could also lead to shielding failures

Solution:

Follow (religiously) the engineered sag chart or table!

Installation-induced failures

Causes and Solutions

6. **Damage caused by tools and accessories** - Can be due to:
   - Poor design – Do not work as intended
   - Improper selection – Wrong size or wrong for the type of cable
   - Improper installation
     - A special "dishonorable mention" to crews who don't follow instructions, especially for bolted-type deadends

Solutions:

A. Your cable and hardware suppliers need to work together as a team
   - Get the cable supplier to review and approve the hardware that you plan to use

B. Beware of these hardware designs:
   - Bolted deadends – Are they any faster and easier to install as claimed?
   - Sliding wedge deadends – Tend to concentrate holding stress at the mouth on a coupling distance that is already short
   - "Shoe" type suspensions – "Open face" design seems to collect contamination
   - Suspensions without any rods – Inherently provide less protection for the cable

C. Crews must follow manufacturer installation procedure!
   - Suggest including all the procedures in your construction specification and package

Installation-induced failures

Causes and Solutions

Illustrations!

Never use one of these:

Or any accessory or tool with an elliptical (oval) or triangular shaped groove

Installation-induced failures

Causes and Solutions

7. **Improper grounding**
   - Creates a safety hazard for your personnel!
   - Good grounding helps prevent lightning damage

   Solutions:

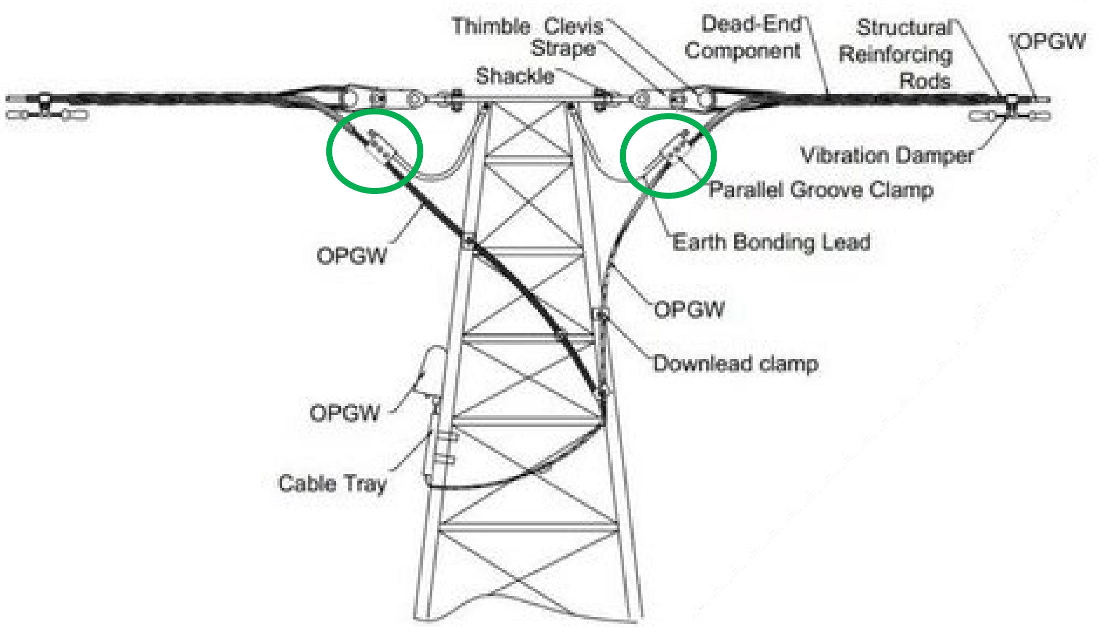
   A. Provisions for grounding must be part of your design and hardware selection

   B. Grounds must be checked after installation and, if poor, augmented or re-worked until good
      - What's "good"? Can vary or be debated, but suggest < 50 Ω

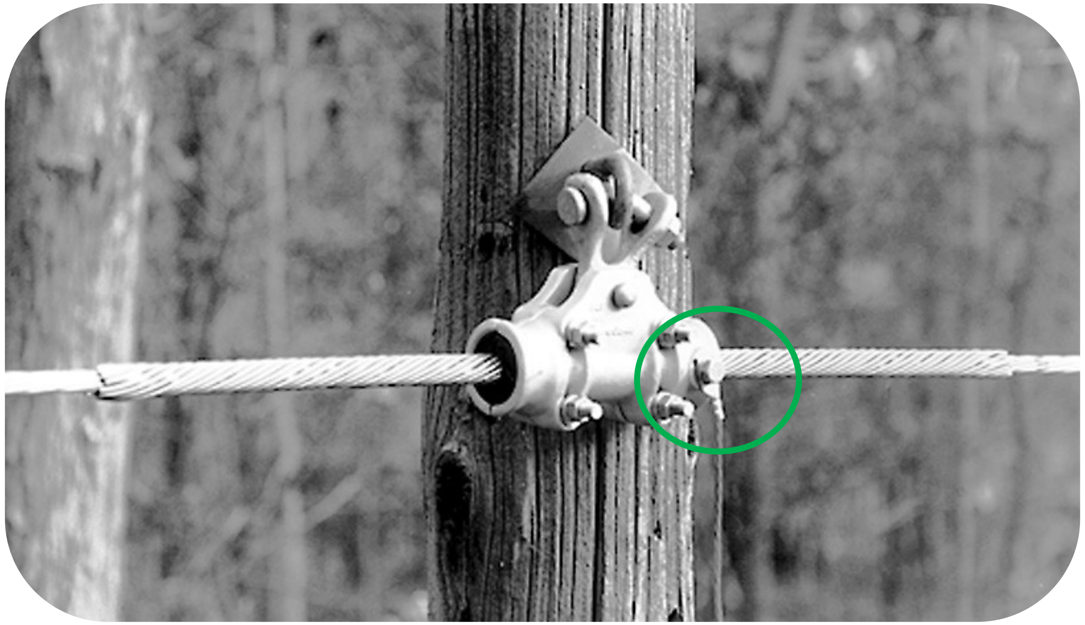
Installation-induced failures

Causes and Solutions

Illustrations! **Bonding** the cable can be done directly to the cable or through the hardware:



Bonding using PG clamps on the OPGW



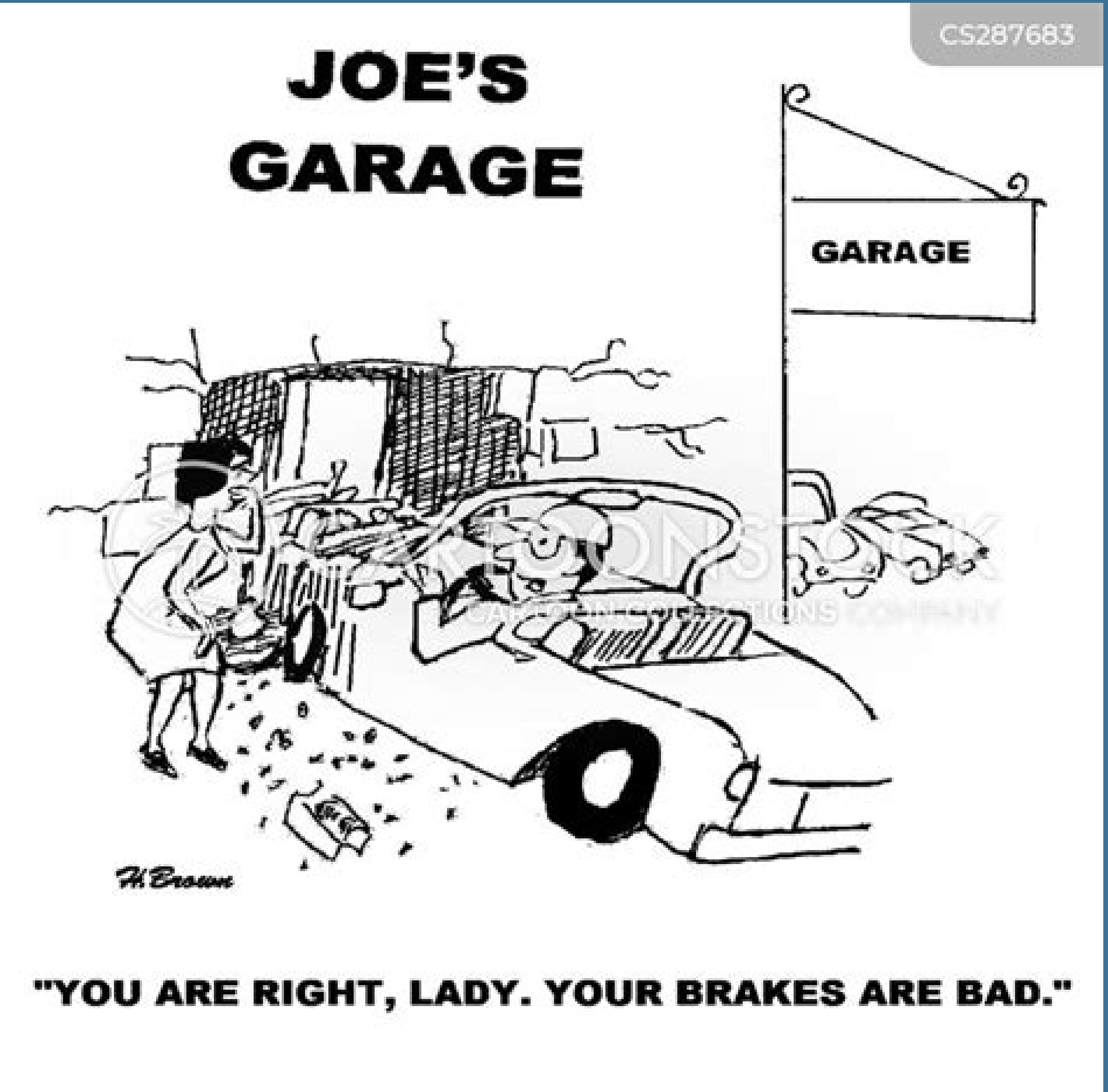
Bonding using through the hardware

Installation-induced failures

Causes and Solutions

Illustrations! Grounding at the base of a pole or structure

Operational Failures



Operational Failures

Causes and Solutions

1. Lightning – Recall: Second leading cause of OPGW failure
   - Can be immediate and catastrophic failure
   - Can be medium-term – broken wire unravels and contacts a phase conductor
   - Can be long-term – damage wire(s) corrodes, and cable eventually fails in tension

   Solutions:

   A. Cable design appropriate for your lightning conditions (separate webinar)
      - Observation: Cables with all-ACS wires on the outside seem to perform better long-term

   B. Good (= low) footing resistance correlates with better lightning performance
      - Means "good grounding" as already mentioned

   C. Respect your utility's experience with conventional shieldwire and OPGW

   D. Seek to appease the Sky Gods, or at least avoid angering them

Operational Failures

Causes and Solutions

Illustrations!

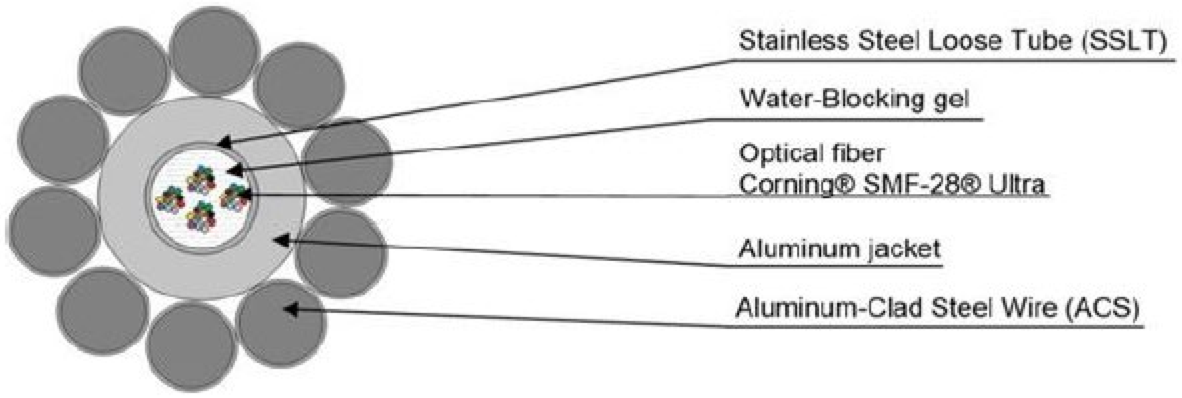
If enough wires break, the cable will fail in tension (could be delayed until an ice or wind event)

This wire could continue to unravel and lead to an arc to a phase conductor below

Operational Failures

Causes and Solutions

Illustrations! All-ACS outer layer vs. mixed ACS/AY outer layer

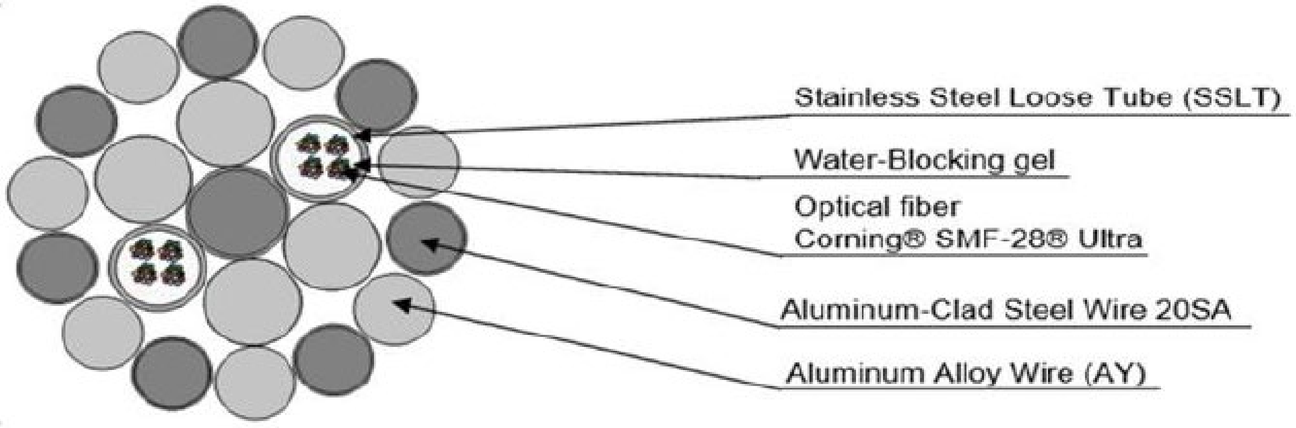


Notes:

1. There are trade-offs in design
2. Independent of design type

All-ACS outer layer

Mixed ACS/AY outer layer



Operational Failures

Causes and Solutions

2. **Gunshots** (Tie with Water/Ice for 2nd leading operational failure)
   - Small comfort to differentiate between intentional hits (OPGW as target) versus unintentional hits (target was bird or something else)
   - Usually leads to immediate optical damage

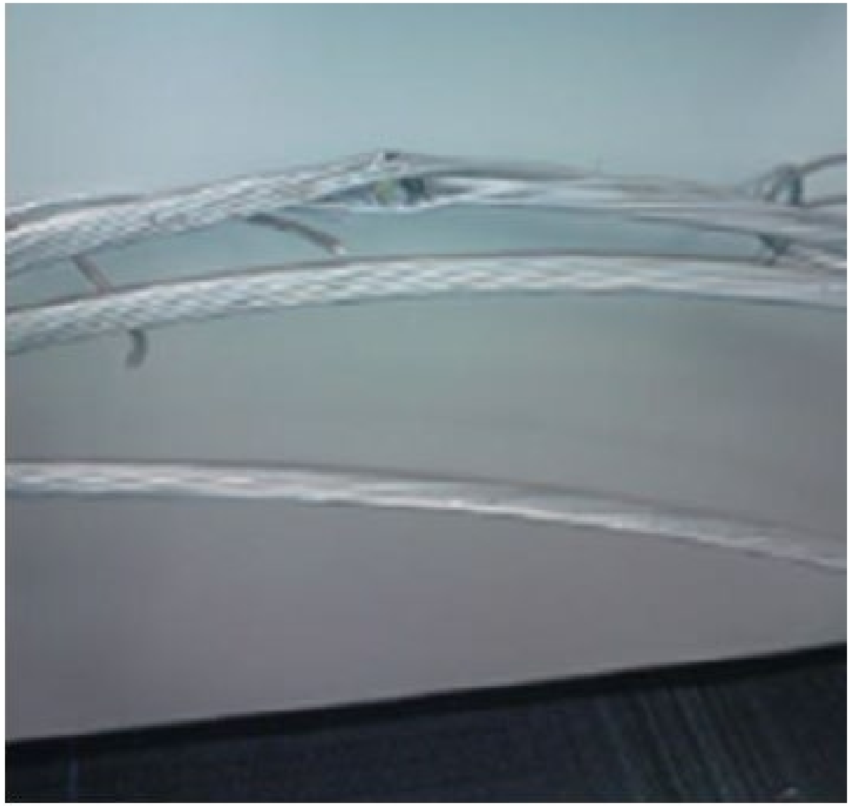
   Solutions:

   There is not a solution; only mitigating measures:
   - Be prepared to use an OTDR to pinpoint the location
   - Have a good emergency restoration plan to include:
     - Replacement cable (on a steel reel?), *plus*
     - Accessories (at least a couple of deadends and a splice enclosure)
   - Beseech your favorite Hunting Goddess (Diana, Artemis, Astarte, et al) for vengeance?

Operational Failures

Causes and Solutions

Illustrations! Gunshot damage



Operational Failures

Causes and Solutions

3. **Ice/Freezing** (Tie with Gunshots)
   - Limited (mostly?) to designs with aluminum-pipe center tubes
   - Pipe is breached, water gets inside, migrates to mid-span and freezes (expands)
     - Causes of breach: Excessive bending during installation, aeolian vibration, gunshot damage, weld failure
   - Expansion during freezing crushes or breaks optical unit, tubes, or fibers

Solutions:

A. Incorporate water-absorbing elements (tape or yarn) in the optical unit design
   - If tube breached, eventually optics still likely to fail, but you should see warning signs versus without

B. Proper installation technique is a must for aluminum-pipe type OPGW

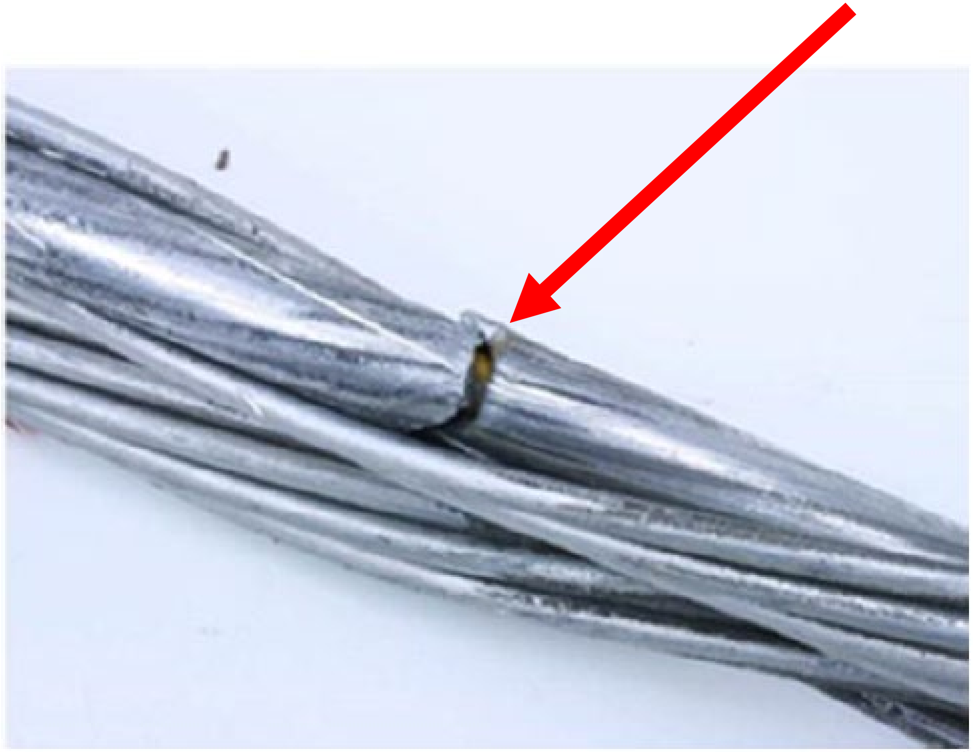
C. Proper motion control is also a must
   - SVD's are cheap insurance; air flow spoilers if in galloping prone terrain

D. Better if the aluminum pipe is made using extrusion versus welding
   - Eddy current technique does not work well with aluminum, but perhaps could be another solution

Operational Failures

Causes and Solutions

Illustrations!



Broken aluminum pipe – Water will get inside
(only bad things can happen after that)

Comment:
Attributed to break during installation, but looks like a fatigue break (aeolian vibration) to me

Operational Failures

Causes and Solutions

4. Corrosion
   - Can be a consequence of improper installation or lightning damage as already mentioned
   - Can also be a consequence of environment – especially for one now defunct design type
   - One specific type of ACS wire manufacturing is more susceptible to this problem

Solutions:

A. Good installation and good design for lightning should be givens
B. Coastal areas and locations with high salt content
   - Stranded stainless steel loose tube (SSLT) designs are thought by some to be vulnerable to corrosion in these areas, but
     - No known failures without other "comorbidities"
     - Field performance in US has been excellent for 30-ish years
   - Slotted-core type designs had failures in such environments, but no longer used
C. ACS wire should be made using the "conform" (extrusion) type process
   - Powder type process can leave microscopic cracks in the cladding

Operational Failures

Causes and Solutions

Illustrations!

Corrosion damage caused by bird guano

- Wires have corroded and broken
- Pipe breached too - You can barely see the exposed plastic buffer tubes

Operational Failures

Causes and Solutions

5. **Others** mentioned in the UTC report
   - "**Buzzards**" - A specific "flavor" of corrosion
     - Tends to occur in specific locales and cause problems at or near structures
     - Also associated with "open" suspension shoe type suspensions

       ➔ Mitigate with available protective covers (example: PLP "Raptor Protector" cover)

   - "**Manufacturing Defect**" can be:
     - Poor optical unit design or manufacturing that allows **fiber strain** (!)
     - Defective weld, whether in a stainless-steel loose tube (SSLT) or an aluminum pipe

       ➔ Buy from a quality supplier with a proven track-record

       (Comment for US utilities: Is it worth the risk of sourcing from an offshore supplier new to our market?
       - They often find our market hard and disappear after a few years…just saying)

Operational Failures

Causes and Solutions

5. **Others** mentioned in the UTC report, continued

- "Age" is stand-in for another problem such as corrosion, excessive tension, or **fiber strain** (!)
  - Plus, consider that fiber specification for **Heat Aging** and **Damp Heat ≤ 0.05 dB/km**
  - So, *any increase above this level must be something else!*

- "**Brittleness**" is either a manufacturing defect or **fiber strain** (!)
  - Poorly made fiber (fiber supplier) or poorly handled fiber (cable supplier)
  - *Not* temperature alone because standard range for fiber is -60°C - +85°C (recall "Heat Aging" above)
  - *Not* water alone because all fiber today has hydrogen protection (recall "Damp Heat" above)

- "**Accidents**" are mostly the "news of the weird" type stuff
  ➔ The best you can do is have a good emergency response plan

Notice all the references to **fiber strain**…let's look at that…

Operational Failures

Fiber Strain kills optical fibers and therefore fiber optic cables!

- What is Fiber Strain? Answer: When the fibers have tension on them
- Why should you care about it?

  Key Concepts as Background

  - Every cable has a “zero fiber strain margin” (ZFSM) point
  - Below ZFSM, the fibers do *not* have tension on them (Strain = 0% = good!)
  - Above ZFSM, the fibers do have tension on them (Strain > 0% = bad!)
  - At Maximum Rated Design Tension (MRDT = Maximum Rated Cable Load (MRCL)) there *may* be fiber strain or not, depending upon the cable design

Operational Failures

Fiber Strain kills optical fibers and therefore fiber optic cables!

- Why should you care about it?
  - Per Corning (and others), probability of fiber failure if strain = 0.2% is "very low"
    ➔ Expected life when strain = 0.2% on standard fiber is 40+ years (a probability, not a guarantee)
  - Higher strain = increasing probability of failure
    ➔ Expected life when strain = 0.3% is 40 days (Yikes!)
    - The effects of "high" strain, accumulate over time
    - That is, expected life is reduced even if strain returns to 0%
      - Why? Because of microscopic damage to the core or cladding
    - So, if this year, 1 day of strain at 0.3%, then the "allowance" of strain in the future reduced to 39 days
    - Cyclic loading is a compounding factor because fiber is glass and is strong, but brittle

Operational Failures

Fiber Strain kills optical fibers and therefore fiber optic cables!

- Where does Fiber Strain come from? Sources in Operation
  - Cable Design
    - The three design types used today have inherent different ZFSM's (See also OPGW Engineering 101)
      - Center Tube (Incab Type C or CA) ≈ 40 – 50% RBS
      - Aluminum Pipe (Incab Type AP) ≈ 50 – 60% RBS
      - Stranded SSLT (Incab Type S) ≈ 80% RBS (or more)
  - Cable Manufacturing
    - "As-made" could be lower than as designed if poor Excess Fiber Length (EFL) control
    - Poor processing can damage the fiber (microscopically)
  - Operating Conditions
    - Wind or ice conditions cause the cable to experience higher tensions than designed, and/or
    - More time under strain than expected

Operational Failures

Fiber Strain kills optical fibers and therefore fiber optic cables!

- Solutions – Let "No strain; No problem" be your general guide
  - Cable Design – Know if you can expect to have strain or not
    - Basic guideline: 0% strain "everyday" (no ice/no wind); $\leq$ 0.2% strain at your max. ice/wind load
    - Consider the cable's ZFSM given *both* code loading criteria *and* actual loading in your area
      - The code is a guideline; respect your reality
    - Every supplier knows their cable's ZFSM, but often you must ask for it
      - Consider this carefully during your cable selection process
  - Cable Manufacturing – Know that your supplier has in-process EFL control for tubes
    - All types of tube should have 0.25% or more
  - Operating Conditions
    - Collect weather data and look for weather where strain would be expected
    - Estimate the level of strain and exposure time to adjust expected life
      - Working on a guideline for this

← You can predict when your OPGW is likely to have problems!

OMG! Maybe I should go underground?!

- Seems like a high risk of problems!

- Remain calm! Consider the context

  - OPGW still has an excellent track record!
    Good cable design + Good manufacturing + Good hardware + Good installation
    = 50+ years of service life (Ontario Hydro thinks 70 years realistic)

  - Underground cables have problems too

    - Rodents, especially rats

    - (Rogue) Backhoes – Dig-ins are the #1 killer of underground systems of all types

      ➔ Repair of underground systems tends to be harder, take longer, and cost more

OPGW remains the "go to" standard for putting fiber on transmission lines!

Acknowledgement to the UTC

- The UTC Fiber Subcommittee research report on OPGW Life Cycle was my starting point for this webinar and is a huge source of information
  - Many of the illustrations are from that report

- I offer the UTC my gratitude for their work

- I offer you the tip that you can get this report from the UTC at:
  - https://utc.org/resources/#research

- They have a similar report for ADSS which will be my starting point for Part 2 of this series on Field Problems with Aerial FO Cables

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Thank you

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