Incab

OPGW ENGINEERING 102

Sag/Tension, Reel Lengths, and Splice Points

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Rev. 0 (July 17, 2020)

Registered Continuing Education Program

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ENGINEERING
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PURPOSE STATEMENT/COURSE DESCRIPTION

OPGW ENGINEERING 102 will teach you how to perform sag and tension calculations using the two most-used software platforms: PLS-CADD and Sag10. We will also explain the meaning and importance of a cable's “Maximum Rated Design Tension” (MRDT), and how it should be used in sag and tension calculations. We will explain the importance of reel lengths to the delivery of OPGW. Then we will discuss the criteria for selecting splice points, and how to use the locations to calculate a point-to-point reel length. We will close by discussing both the basic information that must be included on a purchase order for OPGW and what additional information should be included to help a project go smoothly.

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LEARNING OBJECTIVES

After this class, you will be able to:

1. Perform sag and tension calculations for OPGW using the two most commonly used software platforms in our industry: PLS-CADD and Sag10.
2. Explain the meaning and importance of a cable's Maximum Rated Design Tension (MRDT) and how it should be used in sag and tension calculations.
3. Explain the importance of reel lengths in the OPGW procurement process.
4. Determine suitable splice point locations and use them to calculate your project's required reel lengths.
5. Explain to a purchasing agent what basic information needs to be on the purchase order plus what important additional information should also be included because it will help ensure that your project's logistics proceed smoothly.

WEBINAR AGENDA and RULES

- Introduction and sound check (5 min)
- Presentation: 60 min
- Use chat for questions during presentation
- Q&A (NB! Technical questions only): 10 - 15 min
- Let’s start!

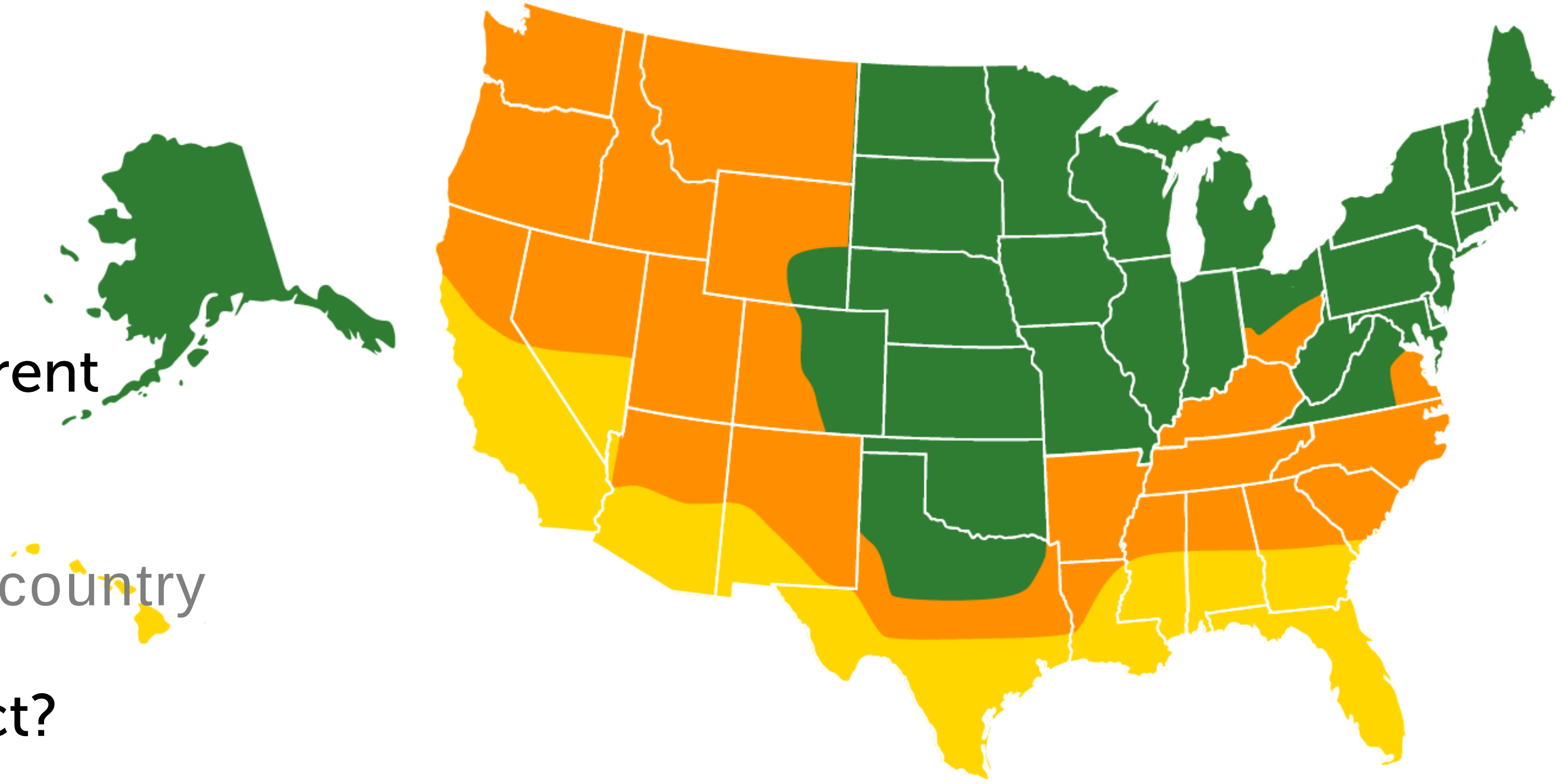
Sag and tension data generation

STEP 1: REVIEW YOUR LOADING CRITERIA

- Determine your base loading criteria
  * NESC Rule 250B loading zone
  * Alternate for your state or country

- Do you have "extreme ice" or "concurrent wind and ice" conditions?
  * NESC Rule 250C and D
  * Additional criteria for your state or country

- Criteria unique to your utility or project?
  * Tension limits?
  * Sag limits?



Sag and tension data generation

STEP 2: GET THE SPECIFICATIONS FOR THE CABLE YOU'RE USING

- The two most commonly used programs for making sag and tension calculations in the USA are Power Line System's PLS-CADD and Southwire's Sag10.
  Both need the following cable specifications:

  1. Cross-sectional area (square inches or mm^2)
  2. Outside diameter (inches or mm)
  3. Unit weight (lb/ft or kg/km)
  4. Rated Breaking Strength (lb or kN)

  You'll find these on the cable datasheet, or ask the cable manufacturer.

- Very important: You will also need the "Maximum Rated Design Tension" (MRDT)!
  * Defined in IEEE 1138, and also known as "Maximum Rated Cable Load" (MRCL)
  * The tension per your design should NEVER, EVER exceed the cable's MRDT under any loading condition!

Sag and tension data generation

STEP 3: IF USING PLS-CADD, SET-UP YOUR .WIR FILE

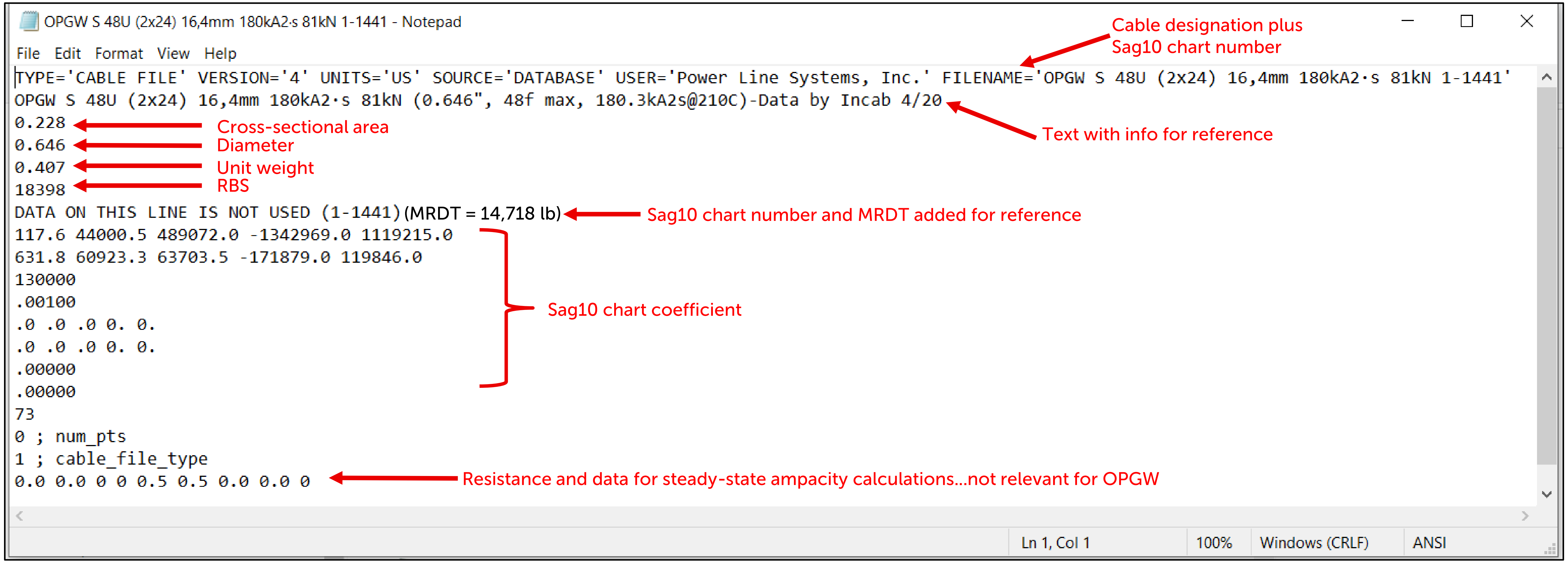
- Hint: It's good to know how to do this procedure and to understand what's in a .WIR file, but...
  - it's easier if you just ask for a .WIR file from the cable manufacturer.
  - you can find a library of .WIR files by cable manufacturer at www.powline.com/files/cables

  *Consequently, we will talk about this process very generally and very quickly

Sag and tension data generation

STEP 3A

It's best to start with a "donor" .WIR file using the same chart number as the cable you are using. Example:


OPGW S 48U (2x24) 16,4mm 180kA2·s 81kN 1-1441 - Notepad

File Edit Format View Help

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TYPE='CABLE FILE' VERSION='4' UNITS='US' SOURCE='DATABASE' USER='Power Line Systems, Inc.' FILENAME='OPGW S 48U (2x24) 16,4mm 180kA2·s 81kN 1-1441'
OPGW S 48U (2x24) 16,4mm 180kA2·s 81kN (0.646", 48f max, 180.3kA2s@210C)-Data by Incab 4/20
0.228
0.646
0.407
18398
DATA ON THIS LINE IS NOT USED (1-1441) (MRDT = 14,718 lb)
117.6 44000.5 489072.0 -1342969.0 1119215.0
631.8 60923.3 63703.5 -171879.0 119846.0
130000
.00100
.0 .0 .0 0. 0.
.0 .0 .0 0. 0.
.00000
.00000
73
0 ; num_pts
1 ; cable_file_type
0.0 0.0 0 0 0.5 0.5 0.0 0.0 0
```

Ln 1, Col 1 | 100% | Windows (CRLF) | ANSI

Sag and tension data generation

STEP 3A

Find the Sag10 chart number on the cable datasheet:

Technical Specifications		
Mechanical	**Metric**	**Customary**
Cable diameter	12.8 mm	0.504 in
Cable unit weight	566 kg/km	0.380 lb/ft
Rated breaking strength (RBS) (without SSLT's)	95.1 kN	21,376 lb
Maximum rated design tension (MRDT) (50% RBS)	47.6 kN	10,692 lb
Cross-sectional area of ACS wire	74.5 mm^2	0.115 in^2
Cross-sectional area of AY wire	22.5 mm^2	0.035 in^2
Cable total cross-sectional area	97.0 mm^2	0.150 in^2
Modulus of Elasticity, initial	102.9 kN/mm^2	14,927 ksi
Modulus of Elasticity, final	131.4 kN/mm^2	19,061 ksi
Temperature coefficient of linear expansion	13.71 E^{-6}/°C	7.61 E^{-6}/°F
Southwire Sag10™ coefficient chart number	1-1441	-
Lay direction of outer layer	Left	-

Note: This one is ours, but for other suppliers the chart number will be somewhere on their datasheet. If not, they're not experienced in the US market, and you'll have to ask.

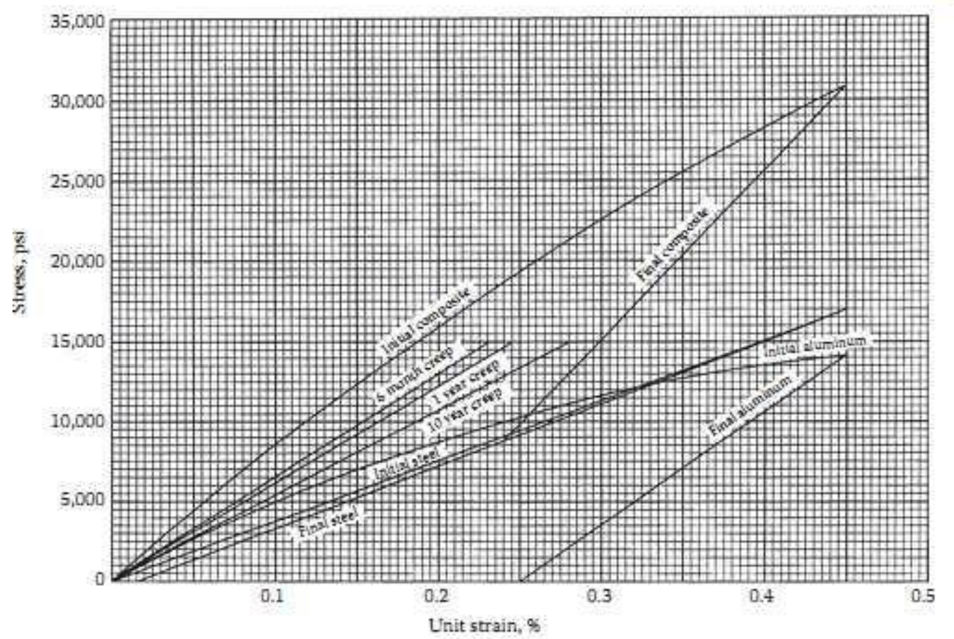
Sag and tension data generation

STEP 3A

- Here's what those coefficients in a chart mean:

DATA ON THIS LINE IS NOT USED (Chart 1-1455) (MRDT = x lb.) <===< Use Maximum rated design load from datasheet
-1114.5 137270.3 -16623.3 -113531.0 78251.0 <===< (a0) Stress-Strain polynomial coefficients (composite or aluminum if separate steel values below)
709.2   78505.3 59189.0 -132936.0 73913.0 (a1) <===< Creep polynomial coefficients (composite or aluminum if separate steel values below)

124000 <===< (a2) Modulus (in ksi x 10)
.00088 <===< (a3) Coefficient of thermal expansion (per deg F x 100)
0.0 0.0 0.0 0.0 0.0 <===< (if present, steel core stress-strain)
0.0 0.0 0.0 0.0 0.0 <===< (if present, steel core creep)
.00000 <===< (if present, steel core modulus)
.00000 <===< (if present, steel core coefficient of thermal expansion)
70 <===< Test temperature



Equations for curves (X = unit strain in %; Y = stress in psi):

Initial composite: $X = 4.07 \times 10^{-5} + (1.28 \times 10^{-5})Y - (1.18 \times 10^{-10})Y^2 + (5.64 \times 10^{-15})Y^3$
$Y = -512 + (8.617 \times 10^4)X - (1.18 \times 10^4)X^2 - (5.76 \times 10^{-4})X^3$
Initial steel: $Y = (37.15 \times 10^3)X$
Initial aluminum: $Y = -512 = (4.902 \times 10^4)X - (1.18 \times 10^4)X^2 - (5.76 \times 10^4)X^3$
Final composite: $Y = (107.55X - 17.65) \times 10^3$
Final Steel: $Y = (38.60X - 0.65) \times 10^3$
Final aluminum: $Y = (68.95X - 17.00) \times 10^3$
6 month creep: $Y = (68.75 \times 10^3)X$
1 year creep: $Y = (60.60 \times 10^3)X$
10 year creep: $Y = (53.45 \times 10^3)X$

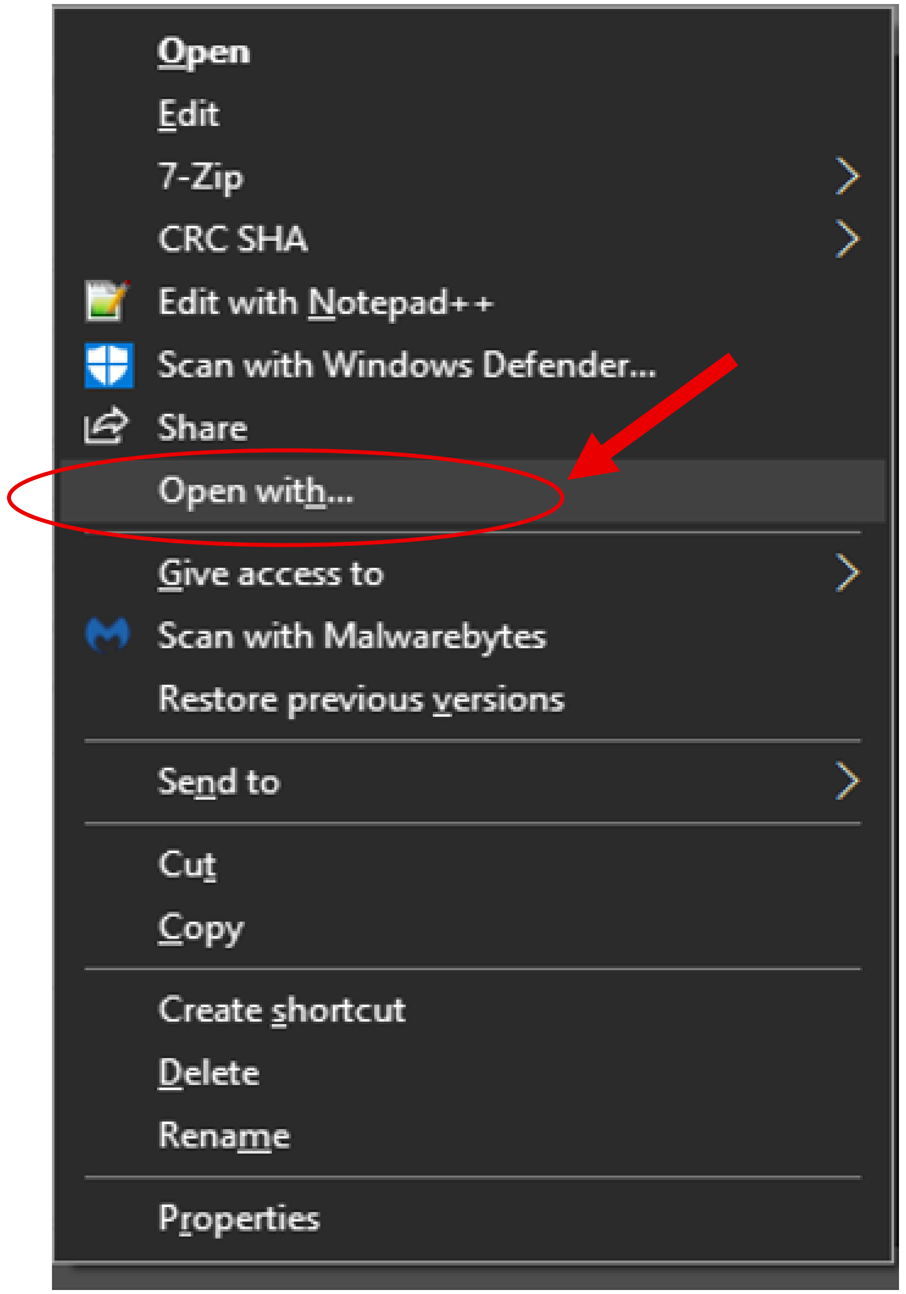
Test temperature 70°F–75°F

- If you don't use a donor file, then you have to type in all this data by hand!
  - Tedious and fraught with risk of error!

Sag and tension data generation

STEP 3A

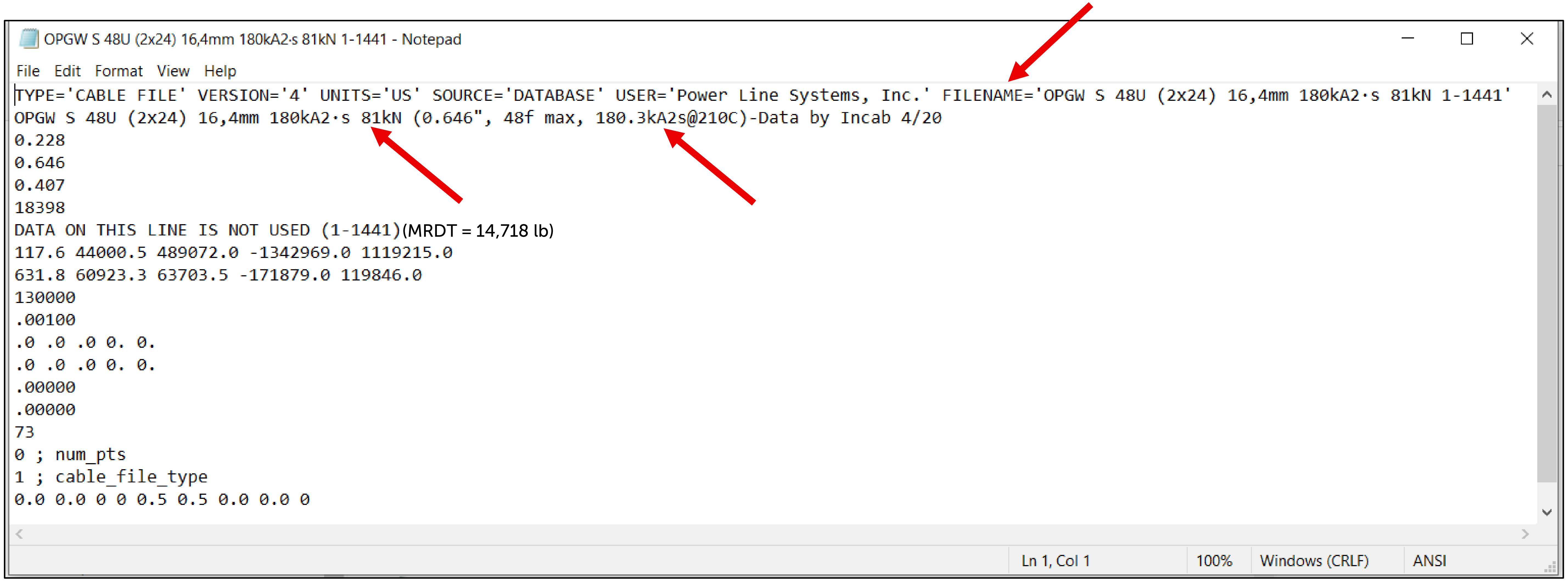
- You can open a .WIR file by right-clicking on it, selecting "Open With", and then selecting "Notepad".
- It's a text file, so Notepad works best.



Sag and tension data generation

STEP 3B

- Update the filename and header information



OPGW S 48U (2x24) 16,4mm 180kA2·s 81kN 1-1441 - Notepad

File Edit Format View Help

```
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OPGW S 48U (2x24) 16,4mm 180kA2·s 81kN (0.646", 48f max, 180.3kA2s@210C)-Data by Incab 4/20
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DATA ON THIS LINE IS NOT USED (1-1441)(MRDT = 14,718 lb)
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.00000
.00000
73
0 ; num_pts
1 ; cable_file_type
0.0 0.0 0 0 0.5 0.5 0.0 0.0 0
```

Ln 1, Col 1 100% Windows (CRLF) ANSI

Sag and tension data generation

STEP 3C

- Update the cable specifications

"Donor file"

Remember: Should have updated header info first

OPGW S 48U (2x24) 16,4mm 180kA2·s 81kN 1-1441 - Notepad

File Edit Format View Help

```
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OPGW S 48U (2x24) 16,4mm 180kA2·s 81kN (0.646", 48f max, 180.3kA2s@210C)-Data by Incab 4/20
0.228      A
0.646      B
0.407      C
18398      D
DATA ON THIS LINE IS NOT USED (1-1441) (MRDT = 14,718 lb)   E
117.6 44000.5 489072.0 -1342969.0 1119215.0
631.8 60923.3 63703.5 -171879.0 119846.0
130000
.00100
.0 .0 .0 0. 0.
.0 .0 .0 0. 0.
.00000
.00000
73
0 ; num_pts
1 ; cable_file_type
0.0 0.0 0 0 0.5 0.5 0.0 0.0 0
```

Technical Specifications

Mechanical	Metric	Customary	
Cable diameter	12.8 mm	0.504 in	B
Cable unit weight	566 kg/km	0.380 lb/ft	C
Rated breaking strength (RBS) (without SSLT's)	95.1 kN	21,376 lb	D
Maximum rated design tension (MRDT) (50% RBS)	47.6 kN	10,692 lb	E
Cross-sectional area of ACS wire	74.5 mm²	0.115 in²	
Cross-sectional area of AY wire	22.5 mm²	0.035 in²	
Cable total cross-sectional area	97.0 mm²	0.150 in²	A
Modulus of Elasticity, initial	102.9 kN/mm²	14,927 ksi	
Modulus of Elasticity, final	131.4 kN/mm²	19,061 ksi	
Temperature coefficient of linear expansion	13.71 E⁻⁶/°C	7.61 E⁻⁶/°F	
Southwire Sag10™ coefficient chart number	1-1441	-	
Lay direction of outer layer	Left	-	

Note: This is our datasheet, but these values will be found on other manufacturers' datasheets too, or you can ask for them

Sag and tension data generation

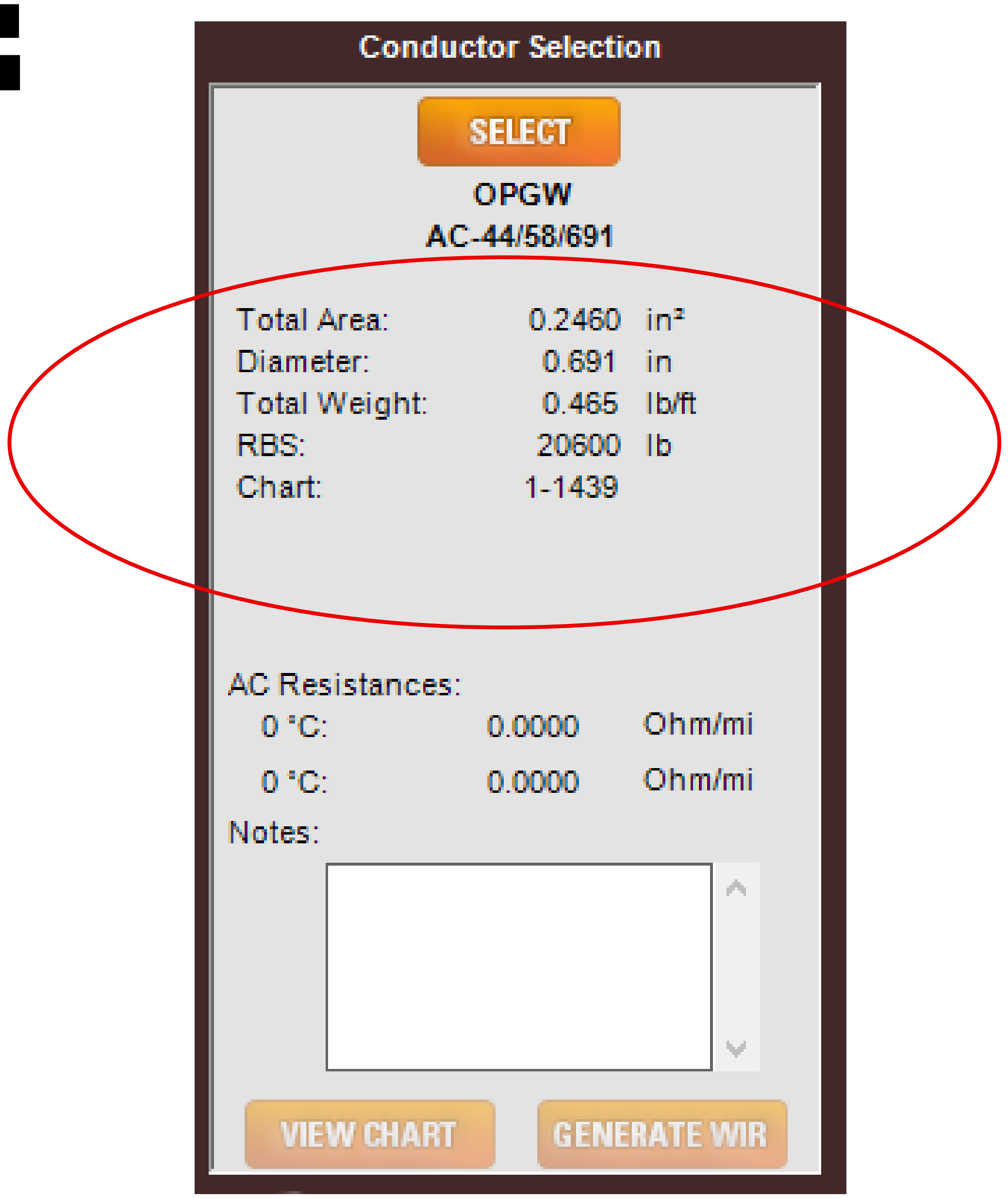
STEP 3D

- Save the new .WIR file
- Load the new .WIR file into PLS-CADD, complete your problem file, and let the program compute the sag and tensions for you

Sag and tension data generation

STEP 3: IF USING SOUTHWIRE SAG10, SET-UP A PROBLEM FILE

- Cable data entry



Sag and tension data generation

STEP 3: IF USING SOUTHWIRE SAG10, SET-UP A PROBLEM FILE

- What if the program doesn't have the chart you need?

  Get the chart coefficients from the cable manufacturer and set-up the chart in Sag10

Sag and tension data generation

TIPS

- Zero Fiber Strain Margin (ZFSM).
  To ensure long-term optical reliability, it is also good to check to make sure that under "everday" conditions (no loads) the tension on the cable is less than the cable's ZFSM.

  Ask the cable manufacturer to confirm this value if it's not on their datasheet.

Sag and tension data generation

TIPS

- Aeolian vibration limitation. Using some loading conditions, in particular the NESC rule 250B Light, can leave the final tension at 60F unloaded ("everyday") greater than 20% RBS.
  You're guaranteed to have vibration problems and need extra vibration dampers.
  To mitigate this problem, keep the tension under 20% RBS.

  * PLS-CADD includes this limit already (but check to make sure that it's there, just in case)
  * In Sag10 you need to add it yourself

Sag and tension data generation

TIPS

- For any metallic cable, the maximum sustained tension should not exceed 80% RBS.

  * This is incorporated in NESC Rule 250 C & D limits
  * Already included in PLS-CADD
  * Must be added in Sag10

Sag and tension data generation

CRITICAL FINAL STEP

Remember the cable's MRDT? It's critical!

- You must manually check in both PLS-CADD and Sag10 that tension never, ever exceeds the cable's MRDT!
  * If it does, you risk optical problems (short or long term)!
  * if it does, you risk a voided warranty!
- **Repeat:** The tension under any and all conditions must never, ever exceed the cable's MRDT! Important

OPGW specific issues

REEL LENGTHS ARE ESSENTIAL!

For two reasons:

- **Manufacturing can't actually begin without reel lengths** Important
  — ASC wire and buffer tubes are ordered/made to specific lengths

- **You must plan your splice points**
  — When a reel runs out, you have to splice the fibers in it to the next reel in order to keep going.
  1. You cannot use compression splices as you can for conventional shield wire or conductor
  2. Therefore, you must plan «splice points» where one reel will be joined to another

IMPORTANT: Quoted lead time is almost always based upon order AND reel lengths!

OPGW specific issues

REEL LENGTH SOLUTIONS

- "Master" or "Standard" reel lengths
  — All reels are the same length, typically 18,000 – 25,000 ft

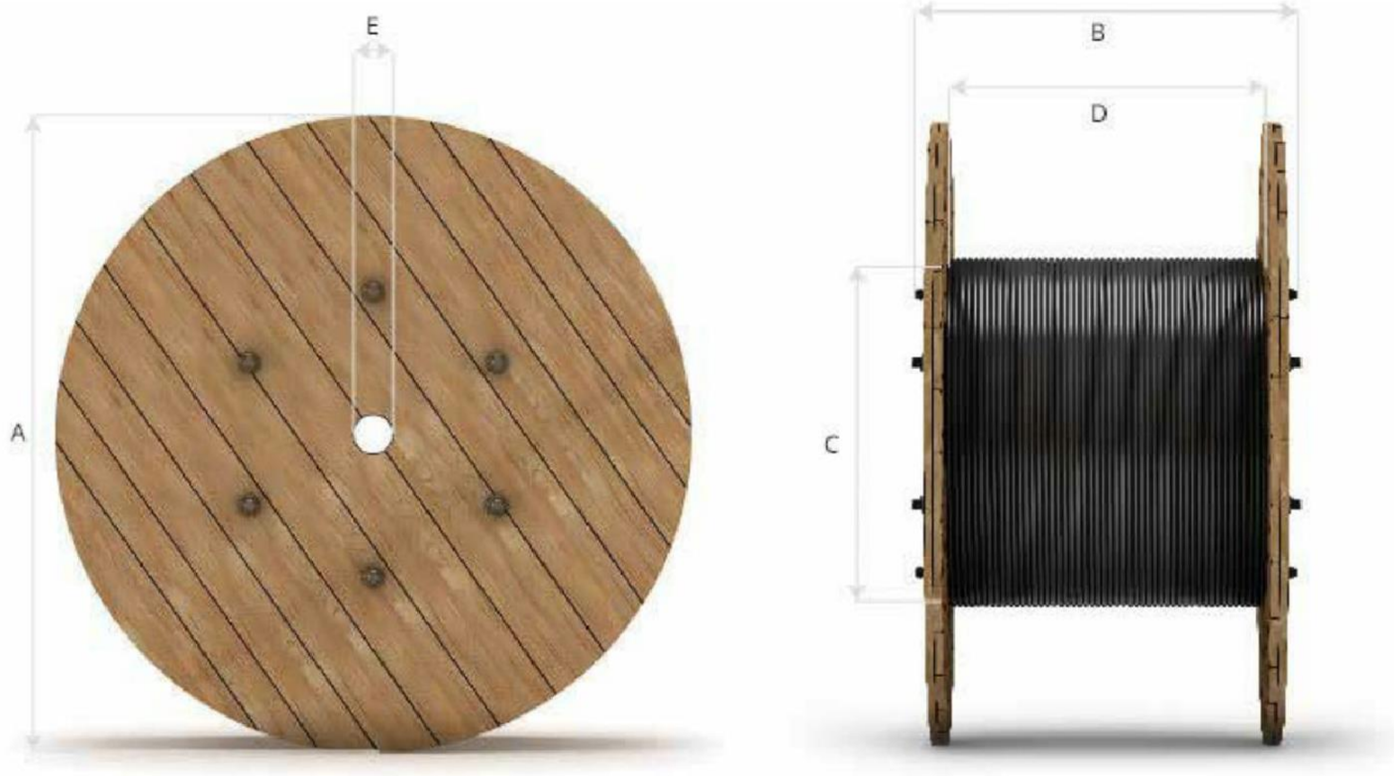
  Advantages:
  - No engineering time required, so production can start immediately
  - Reels can't get mixed up in the field

  Disadvantage:
  - More scrap

- "Specific" or "Point-to-point" reel lengths
  — A reel length is determined from one splice point to the next

  Advantage:
  - Much less scrap

  Disadvantages:
  - Requires engineering time which can delay start of production
  - Reels can get mixed up in the field



OPGW specific issues

SPLICE POINT CONSIDERATIONS

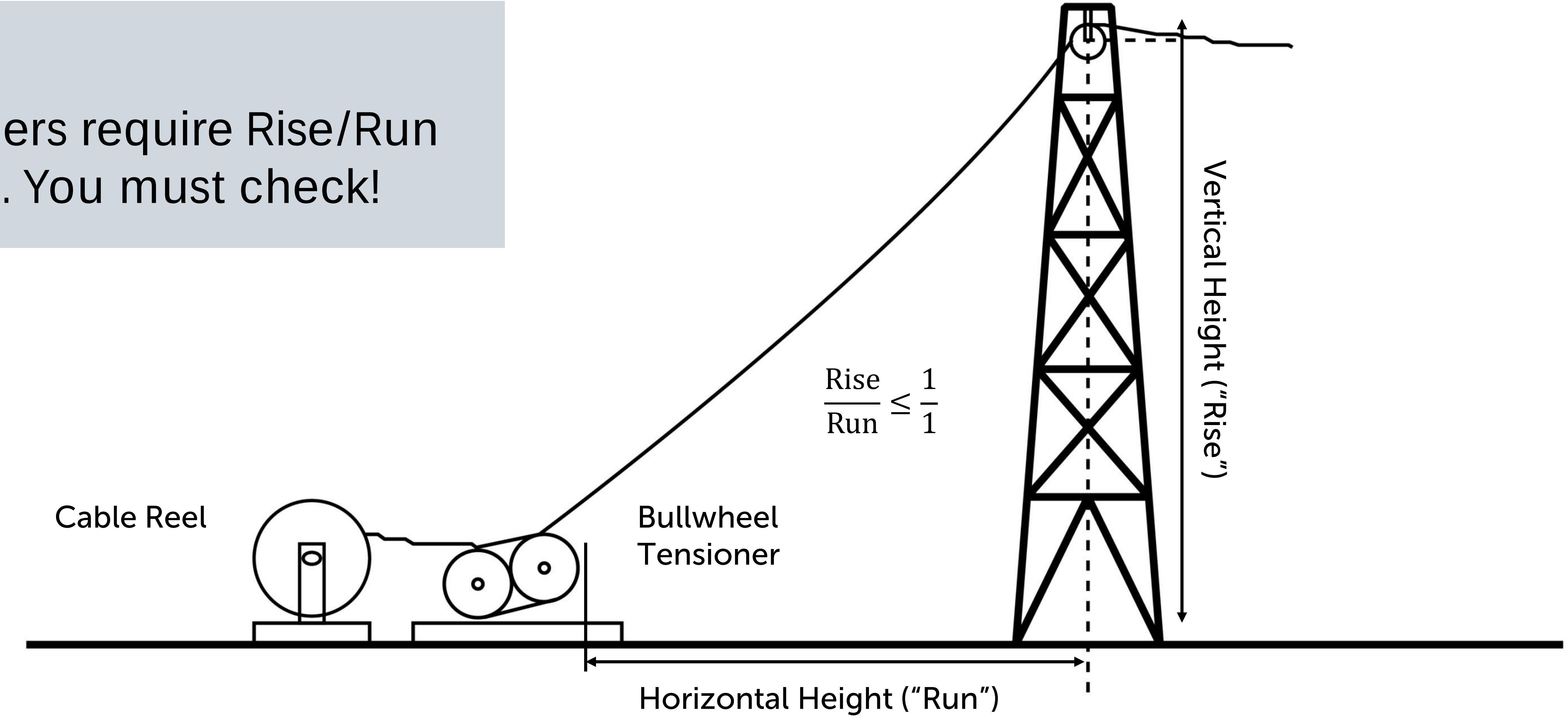
General guidelines

- Must determine possible pull locations
- Good access and satisfactory bearing
- Maintain the manufacturer's Horizontal to Vertical distance ratio

OPGW specific issues

PULL SET UP

Caution!
Some suppliers require Rise/Run of 1/3 or 1/4. You must check!



OPGW specific issues

SPLICE POINT CONSIDERATIONS

General guidelines

- **Which structures can be used as splice locations?**
  - A tangent for the phase conductors can still be good as a splice point for the OPGW
  - Take advantage of large angles
- **What is the standard maximum reel length available?**
  - Function of wire size, bobbin capacity, and reel capacity
  - Limit can be volume or weight
  - Both machine bobbins and reels have volume and weight limits
- **The maximum reel length is provided by the cable manufacturer**
  - On their datasheet, or you will have to ask

OPGW specific issues

SPLICE POINT CONSIDERATIONS

More useful guidelines:

- Maximum pulling tension
  — Quality cable will be good for up to 20% RBS

  Note: Greater than this is not needed because the concern is permanent elongation messing up sagging, not cable damage.

- Caution! The maximum available reel length can exceed the maximum safe pulling tension or pulling conditions! Important

OPGW specific issues

SPLICE POINT CONSIDERATIONS

More useful guidelines:

- Check the estimated pulling tension (reference: IEEE 524)

  Step 1. $T_{\text{Payoff}} \approx \frac{1}{2}$ Design tension, 60°F Initial, unloaded

  Step 2. $T_{Max\ (Pulling\ end)} \approx \frac{T_{\text{Payoff}}}{0.98^{N}}$ where N = number of structures

- Example:

  19,500 ft pull through 30 structures. Cable RBS = 20,000 lb. Design tension is 3,000 lb.
  20% RBS = 4,000 lb.
  Estimated tension at payoff = 1,500 lb.
  Estimated maximum tension = 1.8 * 1,500 = 2,700 lb.
  2,700 lb < 4,000 lb so OK!

OPGW specific issues

SPLICE POINT CONSIDERATIONS

More useful guidelines:

- Verify the maximum amount of horizontal line angle change that is allowed. Incab guidelines are:
  – Types C (plain center SSLT), CA (aluminum-clad center SSLT) and AP (aluminum pipe): $\leq$ 270° total, 1 $\geq$ 90°
  – Type S (stranded SSLT): $\leq$ 360° total, 2 $\geq$ 90°

- Notes:

  (1) Ignore angles $\leq$ 5°
  (2) These are guidelines only, *not* laws.

  Other suppliers could be more or less restrictive. You must check!
  Check with the cable manufacturer if you have a problem situation.

OPGW specific issues

COMPUTING YOUR REEL LENGTHS TO ORDER

Once pulling/splicing locations are determined:

1. Sum horizontal span lengths

2. Add additional length for sag (generally, 1.5% is plenty)

3. Add the attachment height for both the first and the last structure
(Example: Attachment height at tensioner end is 100 ft; at puller end is 60 ft. Additional amount is 100 + 60 = 160 ft)

4. Determine additional length for storage coil and fiber inside splice case.
(100 ft at each end = 200 ft total)

To compute the reel length, add values for 1-4 above ± 100 ft.
Remember to instruct the stringing crew how much tail you need left at the pole!

Typically, this formula works out to 3 - 5% over the linear distance.

OPGW specific issues

TIPS FOR THE PURCHASE ORDER

- Remember to include and verify the part number, quantity, and price
- Reel lengths
  - Order can be placed but recall that manufacturing cannot really begin without these lengths!
- QC Reports
  - Original attached to each reel
  - Ask for an email copy too
- Shipping information
  - Location (GPS coordinates OK), POC and phone number
  - Flat bed truck
  - Notification required
- Delivery date required — provide cushion if possible
  - 10 – 12 weeks ARO and reel lengths is standard, but…

ACES

ADVANCED CABLE ENGINEERING SYSTEM

- Our Advanced Cable Engineering System (ACES) is a unique software tool to help engineers select the optimal OPGW / ADSS design along with the associated accessories, including dead ends, suspensions, down leads, splice enclosures, and dampers

- ACES will also help engineers and planners prepare cost estimates, generate a complete bill of materials, determine reel lengths, and plan logistics

optimal cable selection

cost estimates

specifications generation

design calculations

ACES was developed by Incab in partnership with Preformed Line Products, and we very much appreciate their assistance.

Start ACES

www.incabamerica.com/aces/

Incab

THANK YOU FOR YOUR TIME!

QUESTIONS?

Let us know if you'd like to have this presentation:
webinar@incabamerica.com

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