Incab

ADSS Sag and Tension Calculations

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President

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ENGINEERING RCEP
REGISTERED CONTINUING EDUCATION PROGRAM

PURPOSE STATEMENT / COURSE DESCRIPTION

Registered continuing education program

- In this webinar we will discuss how to obtain the sag and tension data that you need for your project.

- We will explain and illustrate three methods of obtaining sag and tension data as per industry practice today:
  1. Using tabulated data supplied by cable manufacturers,
  2. Generating data using ACES CATS, and
  3. Using PLS-CADD to perform sag and tension calculations.

LEARNING OBJECTIVES

After this class, you will be able to:

- Be able to obtain basic sag and tension data for your ADSS cable using these sources:
  1. Tabulated data supplied by cable manufacturers,
  2. Self-generated data using ACES CATS (and be able to use it), and
  3. Computer programs, in particular PLS-CADD.
- Explain the meaning and importance of a cable's Maximum Rated Cable Load (MRCL), Zero Fiber Strain Margin (ZFSM) and how these should be incorporating into sag and tension data.
- State the implicit assumptions of industry practice for ADSS sag and tension data.
- Explain the difference between mechanically independent and mechanically coupled spans.
- Know when it is more appropriate to apply the ruling span concept and use PLS-CADD or other computer software to generate sag and tension data for ADSS.

Incab University “School of Excellence in Fiber Optics”
Agenda

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

ADSS Sag and Tension Data

- Let’s begin our study of ADSS sag and tension with three observations…

ADSS Sag and Tension Data

Sag and tension observation 1

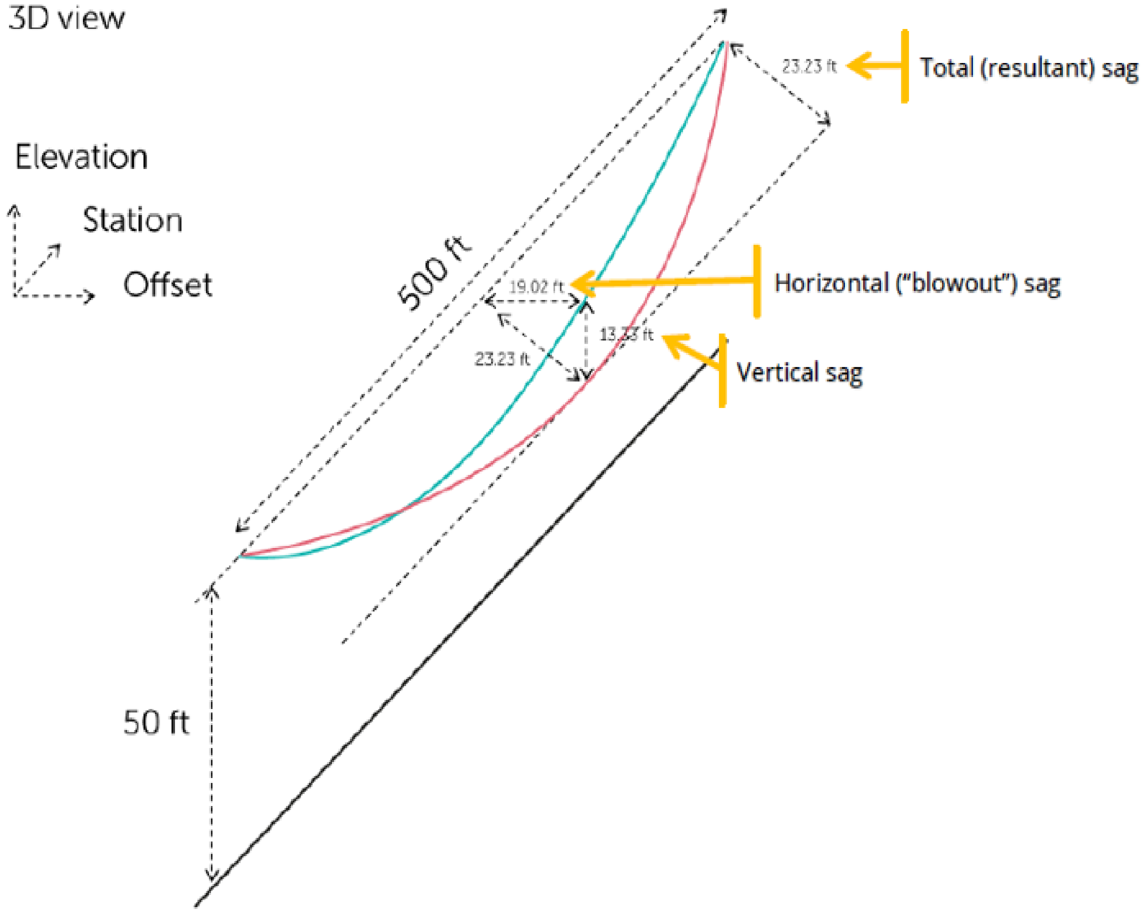
- If someone tells you:
    - "Snow and ice don't accumulate on ADSS in the field"
- Please show them this picture
- It is a myth that ice does not accumulate on ADSS!
- **Vertical sag under ice loading can exceed ground clearance, and consequently, it must be checked!**

Note how large the sag is too

ADSS Sag and Tension Data

Sag and tension observation 2

- Wind conditions are especially important for ADSS
- ADSS is light and elastic
- **Consequently, horizontal blowout during wind loading can be significant and must be checked!**



ADSS Sag and Tension Data

Sag and tension observation 3

- Because ADSS is very elastic, strength is needed to control fiber strain
  - Fiber strain can lead to optical failure over time

OK. This prompts the question: What is fiber strain, and why is it important?

ADSS Sag and Tension Data

Side Tour: A Quick Primer on Fiber Strain

What is fiber strain, and why is it important?

- Fiber strain is tension on the fiber

- Optical fiber is strong, but it is glass, so it is brittle
  - Thus, keeping tension off the fiber is a good idea ➔ enhances reliability
    - "No strain, no problems"
  - Fiber is especially vulnerable to adverse effects from cyclic loading

- Fiber Strain Margin is the difference between the tension on the cable and the tension on the fiber
  - The "Zero Fiber Strain Margin" (ZFSM) is the point at which the optical fibers begin to experience tension
  - General Guideline: The higher the ZFSM, the better

Note: Fiber strain is discussed in detail in our "Understanding the Loose Tube Design Concept" webinar

ADSS Sag and Tension Data

Let’s connect the three observations

- To properly check clearances, sag and tension calculations for ADSS must factor in ice and wind loading
- Industry practice has been to have “installation” or “everyday” (no ice, no wind) sag = 1% or 1.5% of span
  - Example: 300 ft (91 m) span at 1.5%, the sag will be 4.5 ft (1.4 m)
  - More recently, have seen 0.75% and even 0.5%
    - Risky, in my opinion, because of increased tension to do this

And…

ADSS Sag and Tension Data

Let’s connect the three observations

- **Fiber strain** should be **minimized** (or zero fiber strain margin maximized)

  - “Best Practice” or "Ideal" is zero fiber strain through “MRCL” (defined on next slide)
    ➔ This is Incab’s design standard, but sometimes not practical

- Acceptable alternates (with increasing risk):
  - Zero fiber strain at nominal (unloaded) tension (“everyday”), and…
  - Limited fiber strain at maximum (loaded) tension (MRCL)
    - Good, ≤ 0.2%
      - Conservative limit derived from Corning research
    - Not too bad, ≤ 0.3%
      - Acceptable for today’s fiber, but does have some risk
    - Risky, ≤ 0.4% 🡐 Greater than this is just plain crazy!

All cable suppliers have a design policy on fiber strain!
(Often you must ask what it is)

Sag and Tension Data Generation

Maximum Rated Cable Load (MRCL)

- MRCL (= MRDT “maximum rated design tension” the term used for OPGW) is an especially important cable specification!
  - MRCL = The tension the cable should *NEVER, EVER* exceed under *any* design loading condition!
  - MRCL is *NOT* the same as Rated Breaking Strength (RBS)!
  - MRCL is typically in the range of 50 – 65% of RBS

Sag and Tension Data Generation

Data Generation in 3 Easy Steps!

- Step 1 = Review your loading criteria
- Step 2 = Get the cable specifications
- Step 3 = Get or generate the data

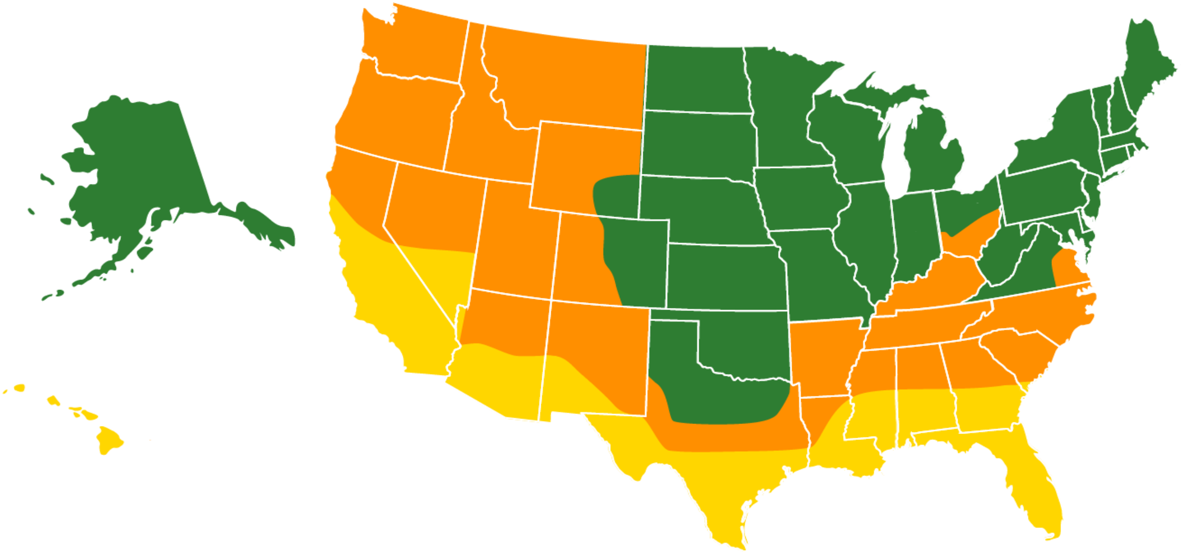
Let’s explore each step…

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
- Criteria unique to your utility or project?
    - Tension limits?
    - Sag limits?
- Do you have "extreme ice" or "concurrent wind and ice" conditions?
    - NESC Rule 250C and D
    - Additional criteria for your state or country

Few do, but…



Sag and Tension Data Generation

Step 2: Get The Cable Specifications

- Basic cable specifications are needed to generate sag and tension data:

  1. Outside diameter (inches or mm)
  2. Unit weight (lb/ft or kg/km)
  3. Maximum Rated Cable Load (MRCL)
  4. Cable modulus (Which to use? We'll come back to that.)
  5. Linear expansion coefficient
  6. Strain limit. Ideally the "zero fiber strain margin" (ZFSM)

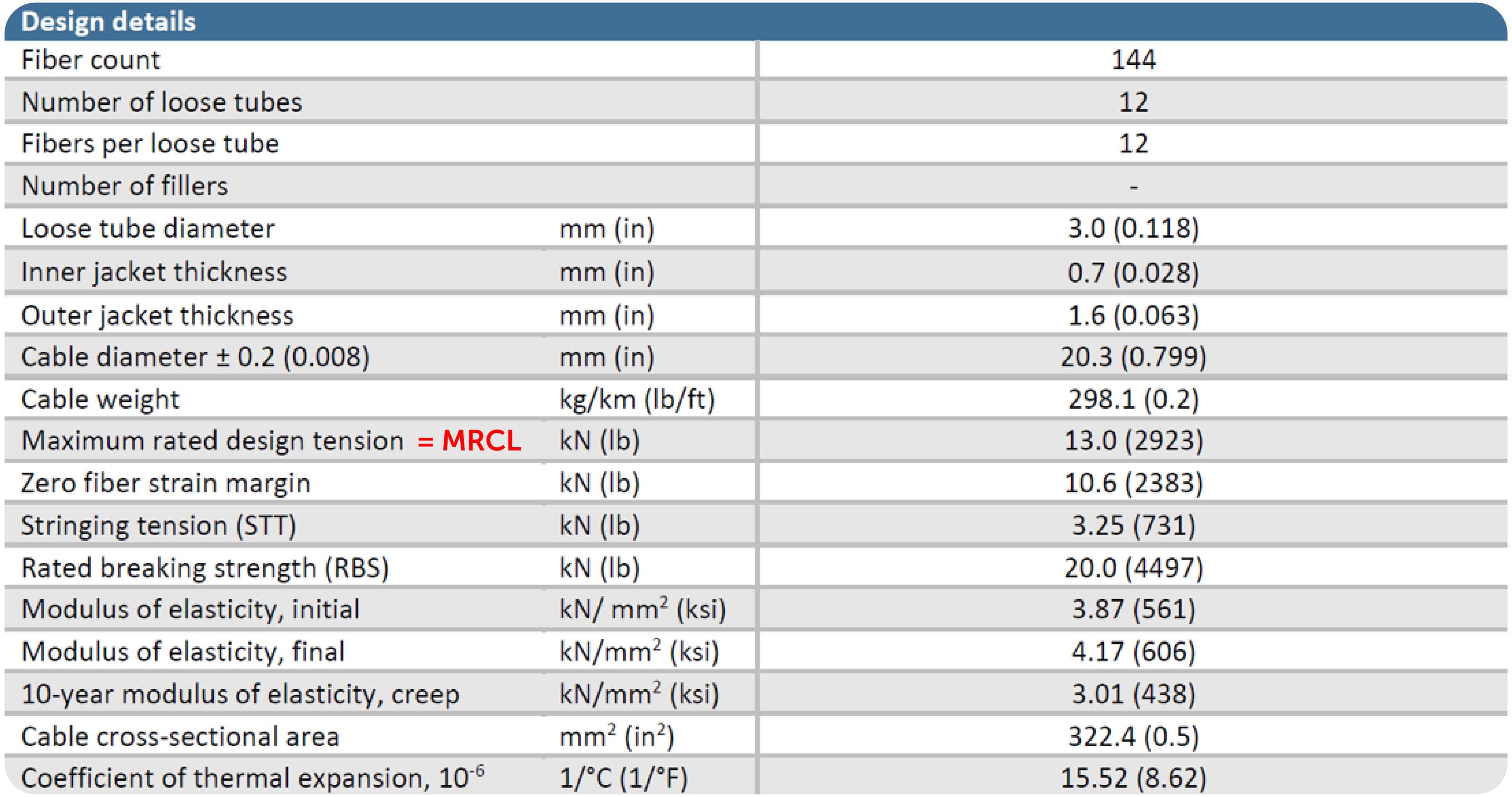
- You'll find these on the cable datasheet or ask the cable manufacturer

➔ Let's look at typical cable datasheets from various suppliers and see how they present this information....

Sag and Tension Data Generation

Step 2: Getting The Specifications - Incab

- **InAir ADSS DJ-144U (12x12)-13kN**



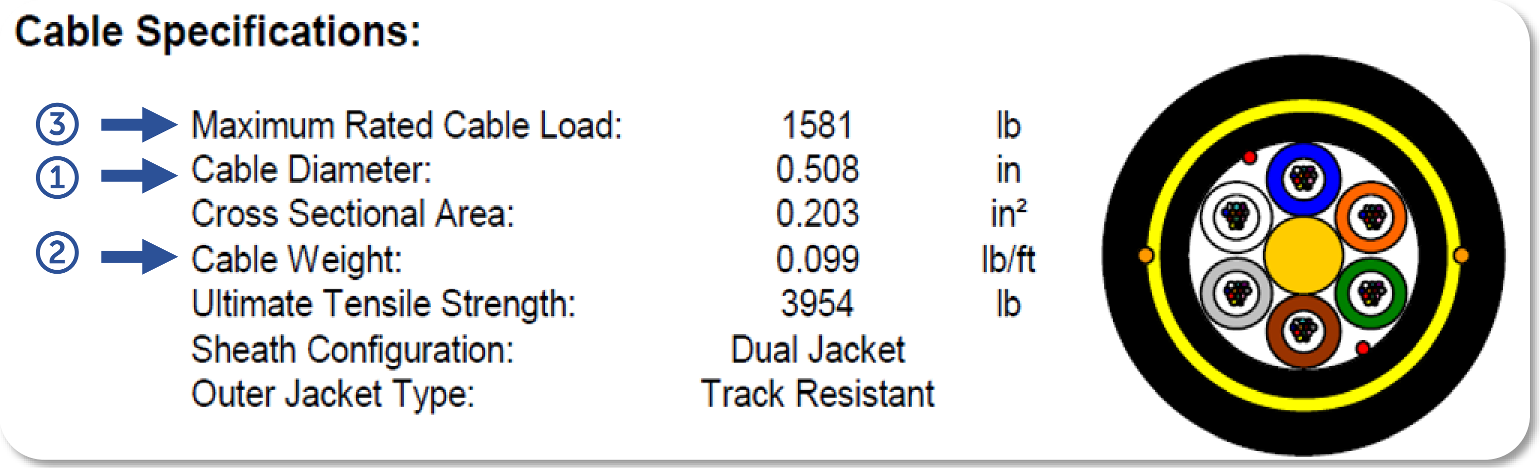
	Design details		
	Fiber count		144
	Number of loose tubes		12
	Fibers per loose tube		12
	Number of fillers		-
	Loose tube diameter	mm (in)	3.0 (0.118)
	Inner jacket thickness	mm (in)	0.7 (0.028)
	Outer jacket thickness	mm (in)	1.6 (0.063)
① →	Cable diameter ± 0.2 (0.008)	mm (in)	20.3 (0.799)
② →	Cable weight	kg/km (lb/ft)	298.1 (0.2)
③ →	Maximum rated design tension = MRCL	kN (lb)	13.0 (2923)
⑥ →	Zero fiber strain margin	kN (lb)	10.6 (2383)
	Stringing tension (STT)	kN (lb)	3.25 (731)
	Rated breaking strength (RBS)	kN (lb)	20.0 (4497)
④ →	Modulus of elasticity, initial	kN/ mm^2 (ksi)	3.87 (561)
	Modulus of elasticity, final	kN/mm^2 (ksi)	4.17 (606)
	10-year modulus of elasticity, creep	kN/mm^2 (ksi)	3.01 (438)
	Cable cross-sectional area	mm^2 (in^2)	322.4 (0.5)
⑤ →	Coefficient of thermal expansion, 10^{-6}	1/°C (1/°F)	15.52 (8.62)

Note: We will discuss modulus later

Sag and Tension Data Generation

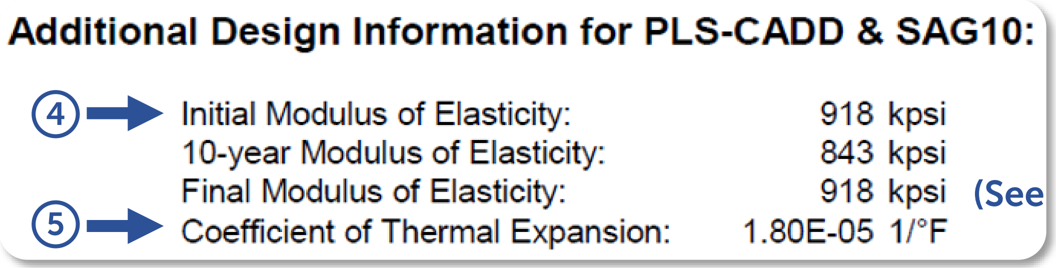
Step 2: Getting The Specifications - Prysmian

- **72F SM ADSS LONG SPAN PKP 1581LB (12F/T) TR (#ADLT1581-12-HB-072)**



Cable Specifications:

③ →	Maximum Rated Cable Load:	1581	lb
① →	Cable Diameter:	0.508	in
	Cross Sectional Area:	0.203	in²
② →	Cable Weight:	0.099	lb/ft
	Ultimate Tensile Strength:	3954	lb
	Sheath Configuration:	Dual Jacket	
	Outer Jacket Type:	Track Resistant	



Additional Design Information for PLS-CADD & SAG10:

④ →	Initial Modulus of Elasticity:	918	kpsi
	10-year Modulus of Elasticity:	843	kpsi
	Final Modulus of Elasticity:	918	kpsi (See note 2)
⑤ →	Coefficient of Thermal Expansion:	1.80E-05	1/°F

Maximum Tension At Maximum Span:

⑥	Long Term: (See note 1)	638 lb	≤ ZFSM
	Short Term:	1575 lb	≤ MRCL = OK

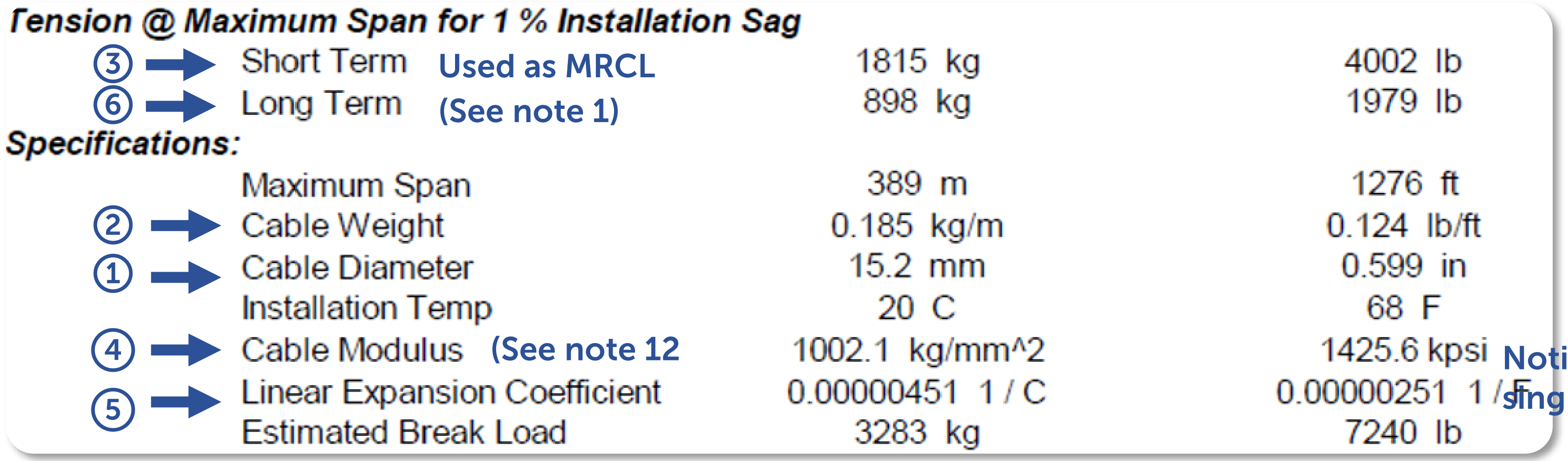
Note 1: Fiber Strain Margin ⑥ is not directly shown, but is factored into their sag & tension data (will see this later)

Note 2: Initial = Final = Not really. This is a simplification that's OK in the distribution world...More on this later

Sag and Tension Data Generation

Step 2: Getting The Specifications - OFS

- **AT-XXX27D6-048-TMEE-JX**



Tension @ Maximum Span for 1 % Installation Sag

③	Short Term	Used as MRCL	1815 kg	4002 lb
⑥	Long Term	(See note 1)	898 kg	1979 lb

Specifications:

	Maximum Span		389 m	1276 ft
②	Cable Weight		0.185 kg/m	0.124 lb/ft
①	Cable Diameter		15.2 mm	0.599 in
	Installation Temp		20 C	68 F
④	Cable Modulus	(See note 12	1002.1 kg/mm^2	1425.6 kpsi
⑤	Linear Expansion Coefficient		0.00000451 1 / C	0.00000251 1 / F
	Estimated Break Load		3283 kg	7240 lb

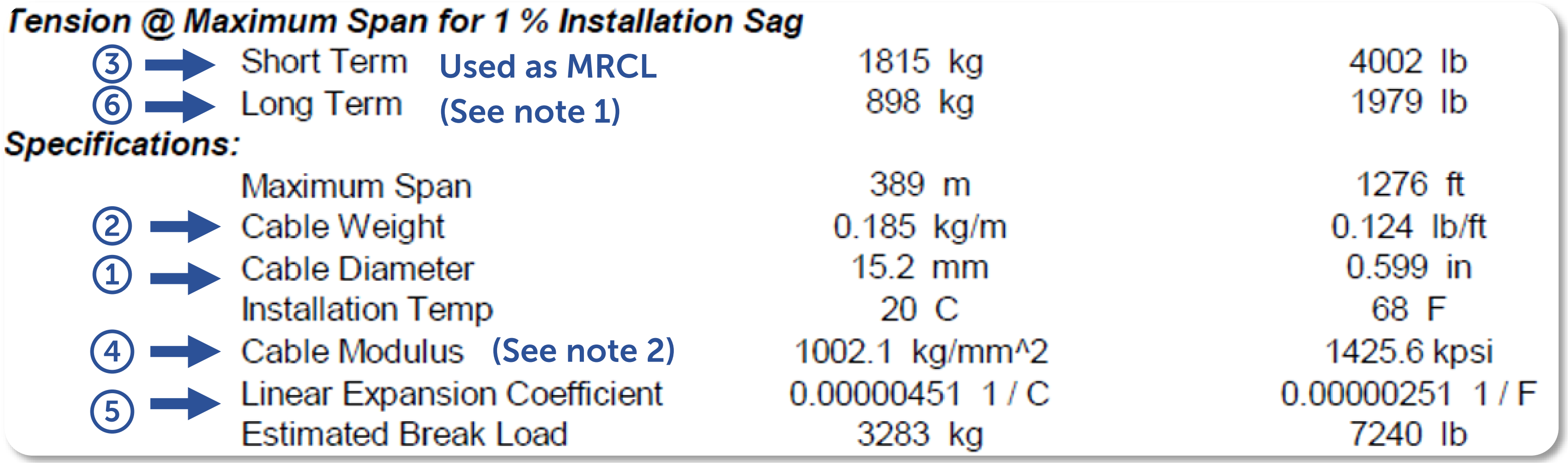
Notice oly a single value

Note 1 ⑥ Fiber Strain Margin is not directly shown. The "Long Term" tension is used as the maximum "everyday" (no ice, no wind) tension, but this tells you <u>nothing</u> about the fiber strain or ZFSM

Sag and Tension Data Generation

Step 2: Getting The Specifications - OFS

- **AT-XXX27D6-048-TMEE-JX**



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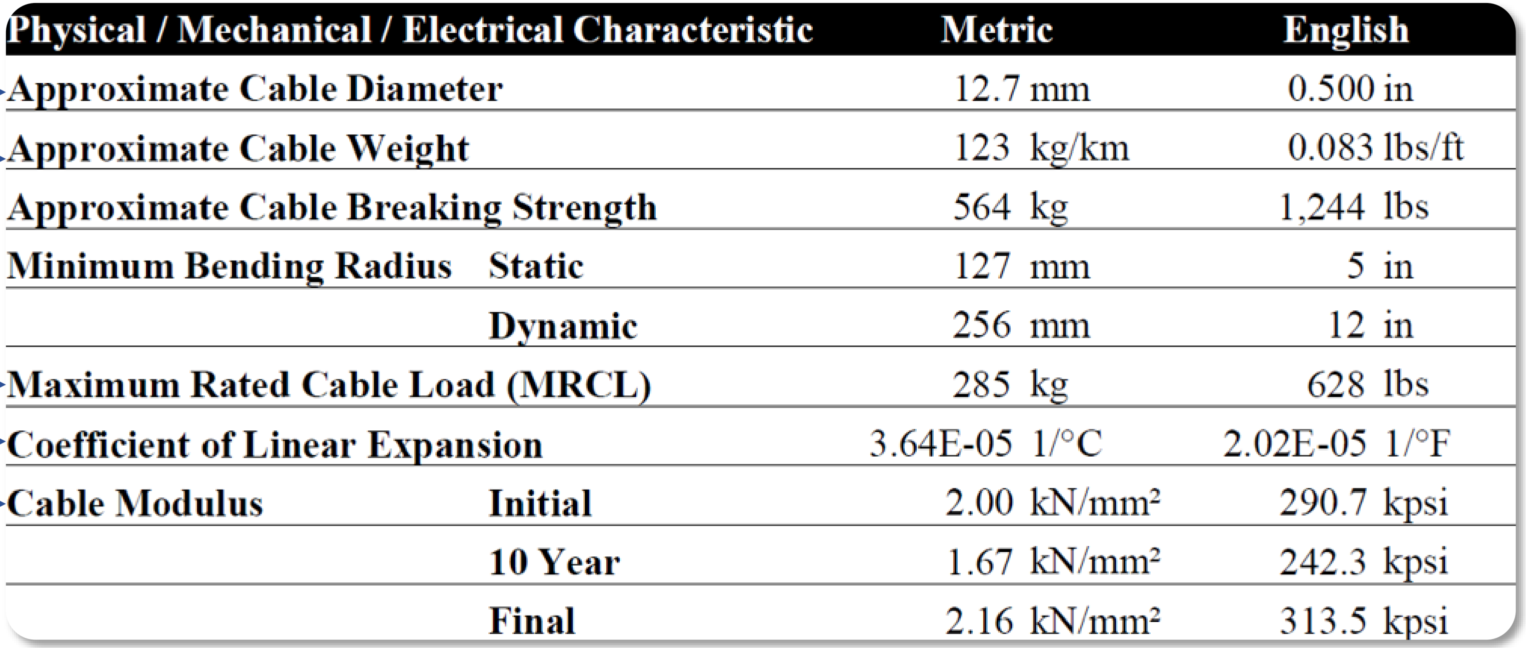
Note 1 ⑥ Fiber Strain Margin is not directly shown. The "Long Term" tension is used as the maximum "everyday" (no ice, no wind) tension, but this tells you nothing about the fiber strain or ZFSM

Note 2 ④ Notice that only a single value is given. More about this soon.

Sag and Tension Data Generation

Step 2: Getting The Specifications - AFL

- **AE0489C521AA1**



Physical / Mechanical / Electrical Characteristic		Metric	English
① Approximate Cable Diameter		12.7 mm	0.500 in
② Approximate Cable Weight		123 kg/km	0.083 lbs/ft
Approximate Cable Breaking Strength		564 kg	1,244 lbs
Minimum Bending Radius	Static	127 mm	5 in
	Dynamic	256 mm	12 in
③ Maximum Rated Cable Load (MRCL)		285 kg	628 lbs
⑤ Coefficient of Linear Expansion		3.64E-05 1/°C	2.02E-05 1/°F
④ Cable Modulus	Initial	2.00 kN/mm²	290.7 kpsi
	10 Year	1.67 kN/mm²	242.3 kpsi
	Final	2.16 kN/mm²	313.5 kpsi

Notice that three values are given

⑥ Fiber Strain Margin - Not provided by this supplier, nor an “everyday” or long-term limit. You must ask them.

Sag and Tension Data Generation

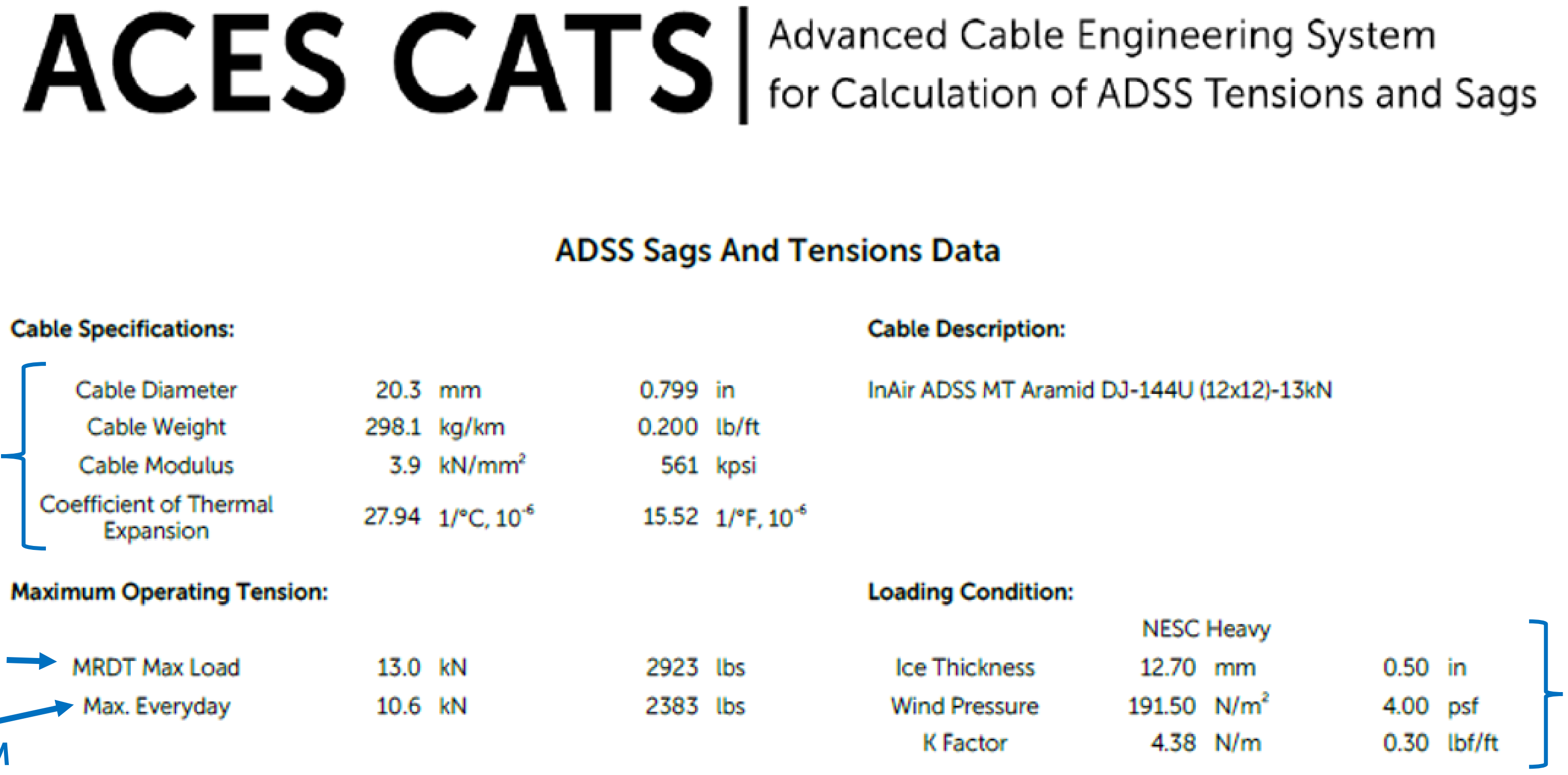
Step 3: Getting Sag and Tension Data

- **Three sources**
  - Traditionally: Manufacturer-provided tables
    - Generally limited to standard NESC loading conditions
    - Ask cable supplier if you need other conditions
  - ACES CATS – A new, fun, and useful way to generate the data that you need!
    - Can be used for any supplier's cable!
  - Generate your own data using Power Line® Systems PLS-CADD or Southwire™ Sag10®
    - Will only consider PLS-CADD today

Let's look at each source, starting with data tables from the same four suppliers

Sag and Tension Data Generation

Data Tables – Incab Header



ACES CATS | Advanced Cable Engineering System for Calculation of ADSS Tensions and Sags

ADSS Sags And Tensions Data

Cable Specifications:

Cable Diameter	20.3	mm	0.799	in
Cable Weight	298.1	kg/km	0.200	lb/ft
Cable Modulus	3.9	kN/mm^2	561	kpsi
Coefficient of Thermal Expansion	27.94	1/°C, 10^{-6}	15.52	1/°F, 10^{-6}

Cable Description:

InAir ADSS MT Aramid DJ-144U (12x12)-13kN

Maximum Operating Tension:

MRDT Max Load	13.0	kN	2923	lbs
Max. Everyday	10.6	kN	2383	lbs

Loading Condition:

	NESC Heavy			
Ice Thickness	12.70	mm	0.50	in
Wind Pressure	191.50	N/m^2	4.00	psf
K Factor	4.38	N/m	0.30	lbf/ft

Cable Specs

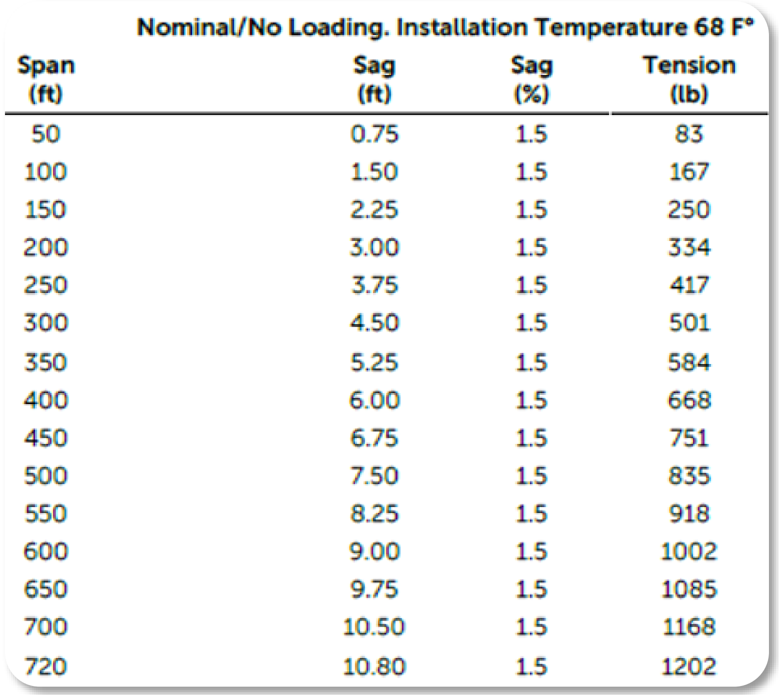
MRCL →

“Maximum Everyday” = ZFSM

Loading Conditions

Sag and Tension Data Generation

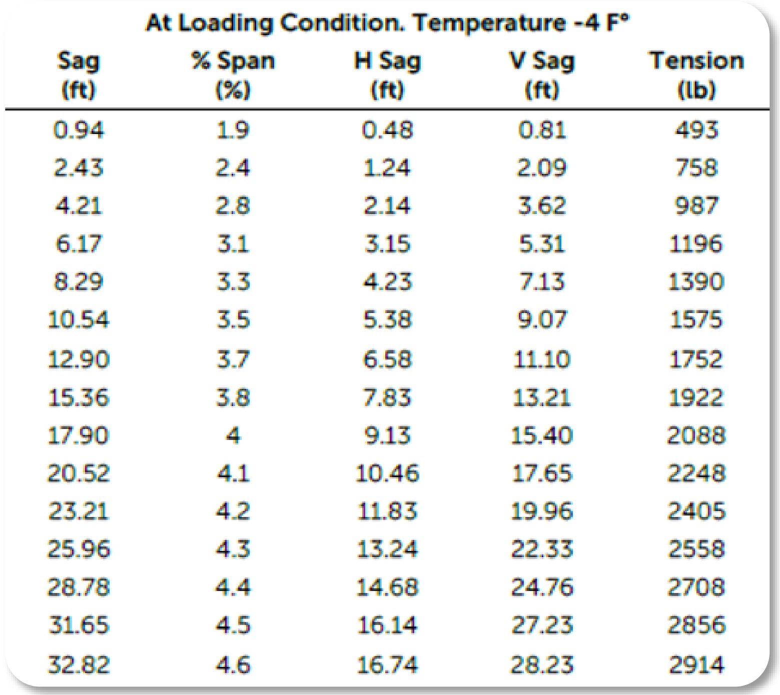
Data Tables – Incab Data



Nominal/No Loading. Installation Temperature 68 F°

Span (ft)	Sag (ft)	Sag (%)	Tension (lb)
50	0.75	1.5	83
100	1.50	1.5	167
150	2.25	1.5	250
200	3.00	1.5	334
250	3.75	1.5	417
300	4.50	1.5	501
350	5.25	1.5	584
400	6.00	1.5	668
450	6.75	1.5	751
500	7.50	1.5	835
550	8.25	1.5	918
600	9.00	1.5	1002
650	9.75	1.5	1085
700	10.50	1.5	1168
720	10.80	1.5	1202

Data for “Everyday” condition (no wind, no ice)



At Loading Condition. Temperature -4 F°

Sag (ft)	% Span (%)	H Sag (ft)	V Sag (ft)	Tension (lb)
0.94	1.9	0.48	0.81	493
2.43	2.4	1.24	2.09	758
4.21	2.8	2.14	3.62	987
6.17	3.1	3.15	5.31	1196
8.29	3.3	4.23	7.13	1390
10.54	3.5	5.38	9.07	1575
12.90	3.7	6.58	11.10	1752
15.36	3.8	7.83	13.21	1922
17.90	4	9.13	15.40	2088
20.52	4.1	10.46	17.65	2248
23.21	4.2	11.83	19.96	2405
25.96	4.3	13.24	22.33	2558
28.78	4.4	14.68	24.76	2708
31.65	4.5	16.14	27.23	2856
32.82	4.6	16.74	28.23	2914

Data for loaded condition

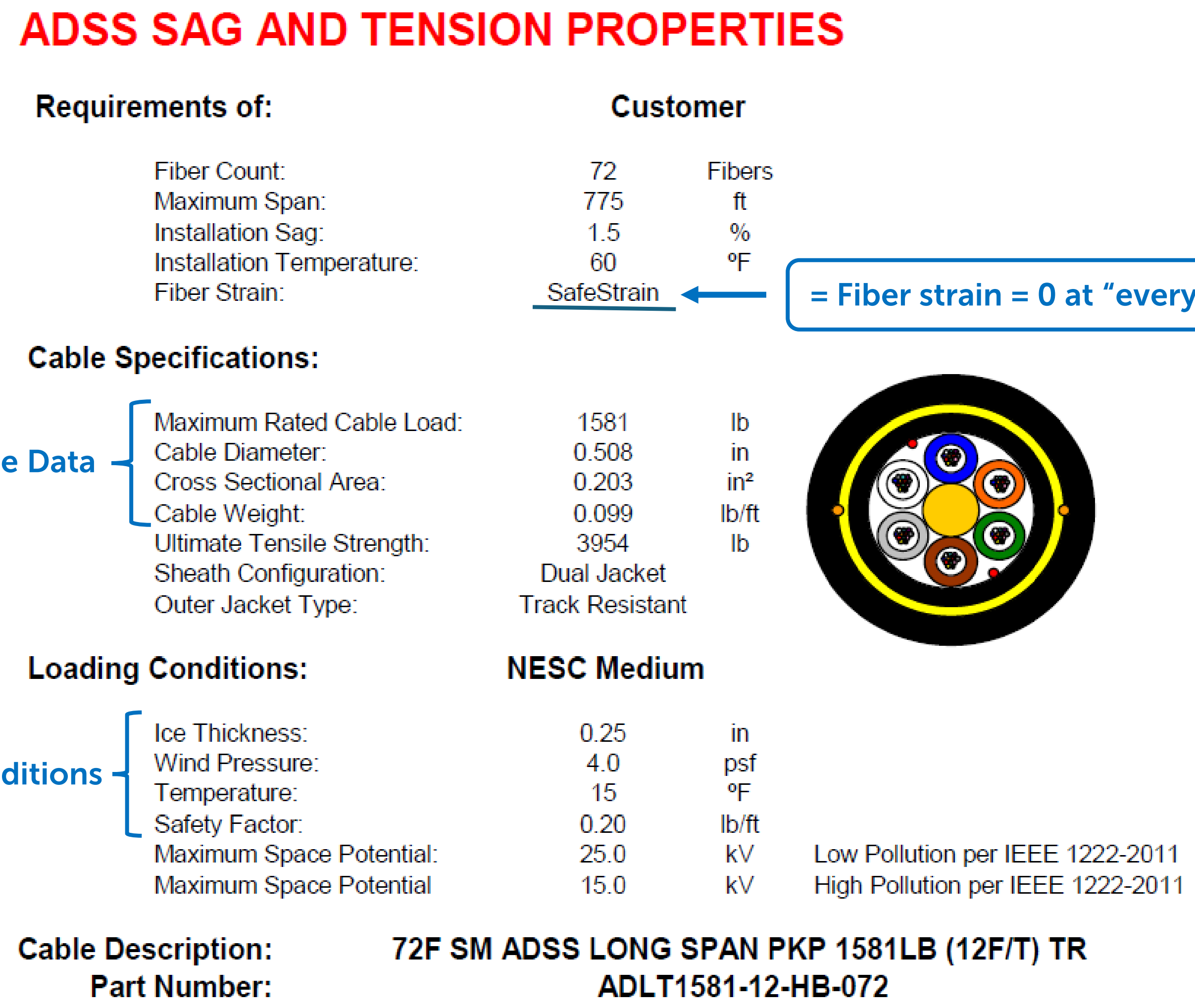
“Sag” is total.

“H Sag” = horizontal component to check blowout

“V Sag” = vertical component to check ground clearance

Sag and Tension Data Generation

Data Tables – Prysmian Header



ADSS SAG AND TENSION PROPERTIES

Requirements of:	**Customer**		
Fiber Count:	72	Fibers	
Maximum Span:	775	ft	
Installation Sag:	1.5	%	
Installation Temperature:	60	ºF	
Fiber Strain:	SafeStrain		

= Fiber strain = 0 at “everyday” and ≤ 0.2% at MRCL

Cable Specifications:

Cable Data

Maximum Rated Cable Load:	1581	lb	
Cable Diameter:	0.508	in	
Cross Sectional Area:	0.203	in²	
Cable Weight:	0.099	lb/ft	
Ultimate Tensile Strength:	3954	lb	
Sheath Configuration:	Dual Jacket		
Outer Jacket Type:	Track Resistant		

Loading Conditions

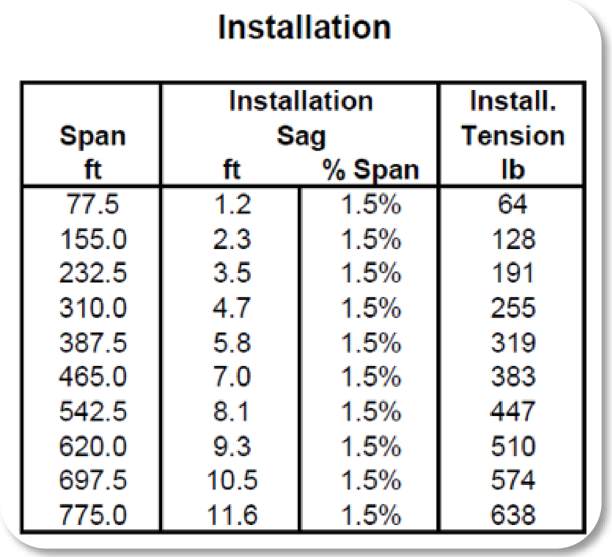
Loading Conditions:	**NESC Medium**		
Ice Thickness:	0.25	in	
Wind Pressure:	4.0	psf	
Temperature:	15	ºF	
Safety Factor:	0.20	lb/ft	
Maximum Space Potential:	25.0	kV	Low Pollution per IEEE 1222-2011
Maximum Space Potential	15.0	kV	High Pollution per IEEE 1222-2011

Cable Description: 72F SM ADSS LONG SPAN PKP 1581LB (12F/T) TR
Part Number: ADLT1581-12-HB-072

For comparison.
“ZeroStrain” means:
Fiber strain = 0 at “everyday”
and 0 at MRCL

Sag and Tension Data Generation

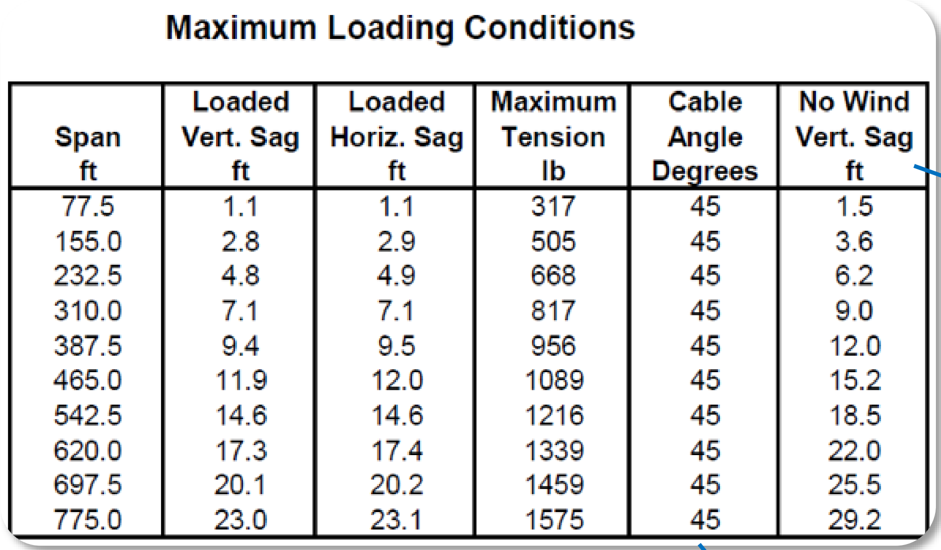
Data Tables – Prysmian Data



Installation

Span ft	Installation Sag		Install. Tension lb
	ft	% Span	
77.5	1.2	1.5%	64
155.0	2.3	1.5%	128
232.5	3.5	1.5%	191
310.0	4.7	1.5%	255
387.5	5.8	1.5%	319
465.0	7.0	1.5%	383
542.5	8.1	1.5%	447
620.0	9.3	1.5%	510
697.5	10.5	1.5%	574
775.0	11.6	1.5%	638

Data for installation and "Everyday" condition (no wind, no ice)



Maximum Loading Conditions

Span ft	Loaded Vert. Sag ft	Loaded Horiz. Sag ft	Maximum Tension lb	Cable Angle Degrees	No Wind Vert. Sag ft
77.5	1.1	1.1	317	45	1.5
155.0	2.8	2.9	505	45	3.6
232.5	4.8	4.9	668	45	6.2
310.0	7.1	7.1	817	45	9.0
387.5	9.4	9.5	956	45	12.0
465.0	11.9	12.0	1089	45	15.2
542.5	14.6	14.6	1216	45	18.5
620.0	17.3	17.4	1339	45	22.0
697.5	20.1	20.2	1459	45	25.5
775.0	23.0	23.1	1575	45	29.2

Data for loaded condition

Notice: "Ice Only" vertical sag

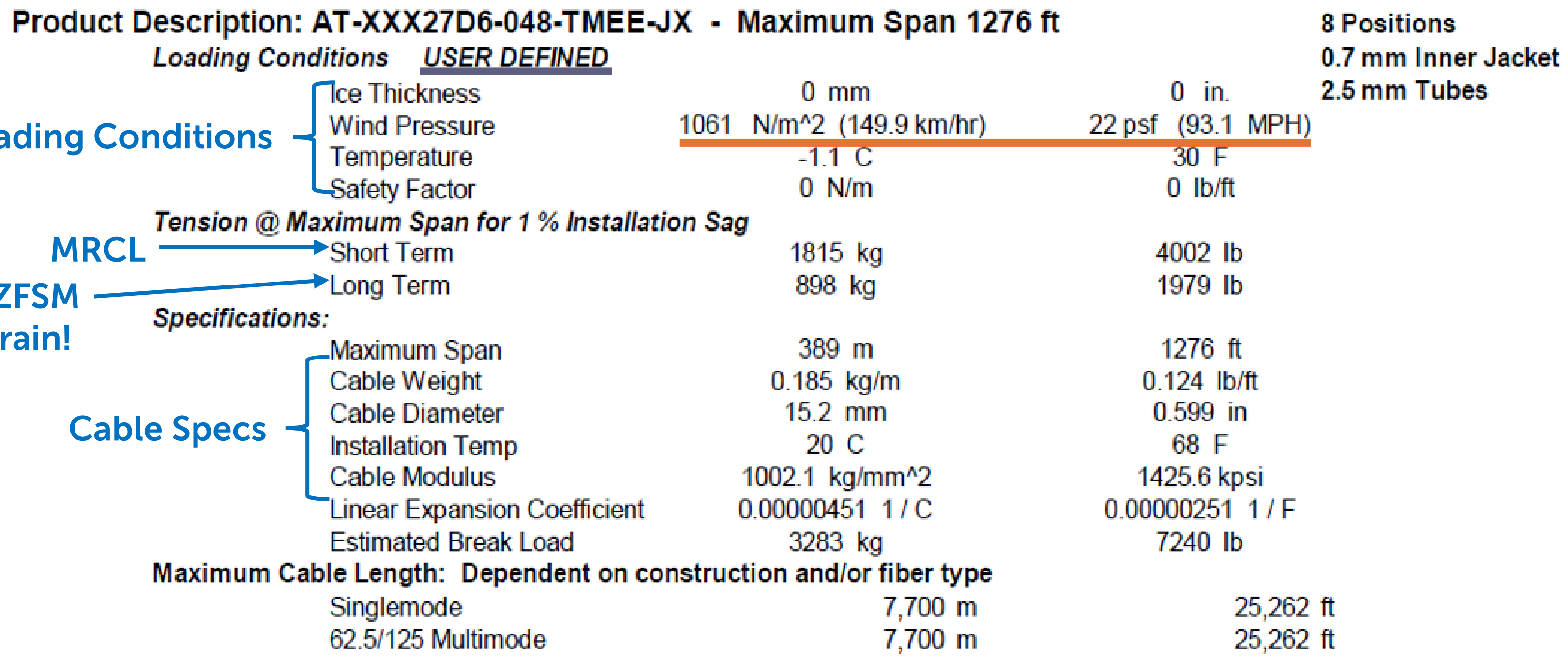
"Horiz. Sag" = horizontal sag to check blowout

"Vert. Sag" = vertical sag to check ground clearance

Notice that the sag is set to 1.5% of span

Sag and Tension Data Generation

Data Tables – OFS Header



Product Description: AT-XXX27D6-048-TMEE-JX - Maximum Span 1276 ft

8 Positions
0.7 mm Inner Jacket
2.5 mm Tubes

Loading Conditions ***USER DEFINED***

Ice Thickness	0 mm	0 in.
Wind Pressure	1061 N/m^2 (149.9 km/hr)	22 psf (93.1 MPH)
Temperature	-1.1 C	30 F
Safety Factor	0 N/m	0 lb/ft
Tension @ Maximum Span for 1 % Installation Sag		
Short Term	1815 kg	4002 lb
Long Term	898 kg	1979 lb
Specifications:		
Maximum Span	389 m	1276 ft
Cable Weight	0.185 kg/m	0.124 lb/ft
Cable Diameter	15.2 mm	0.599 in
Installation Temp	20 C	68 F
Cable Modulus	1002.1 kg/mm^2	1425.6 kpsi
Linear Expansion Coefficient	0.00000451 1 / C	0.00000251 1 / F
Estimated Break Load	3283 kg	7240 lb
Maximum Cable Length: Dependent on construction and/or fiber type		
Singlemode	7,700 m	25,262 ft
62.5/125 Multimode	7,700 m	25,262 ft

Loading Conditions

MRCL

“Maximum Everyday” ≠ ZFSM
Gives no info about fiber strain!
You must ask

Cable Specs

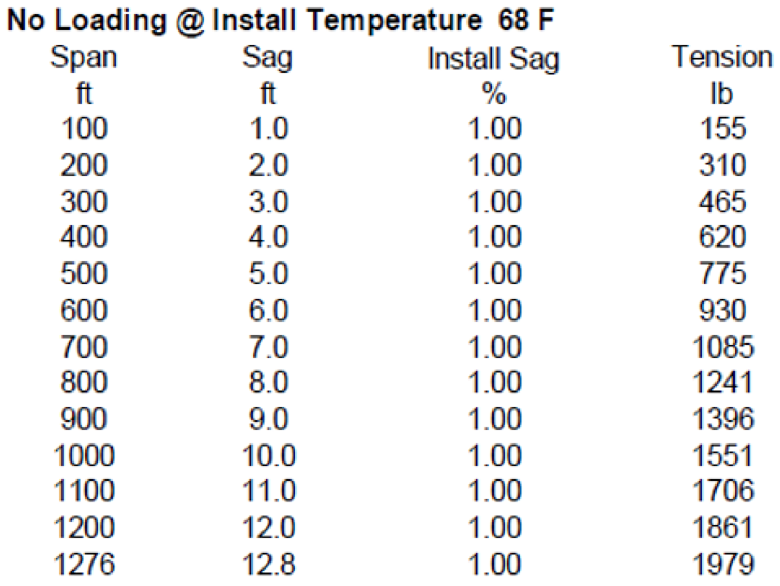
Sag and Tension Data Generation

Data Tables – OFS Data

Data for “Everyday” condition
(no wind, no ice)

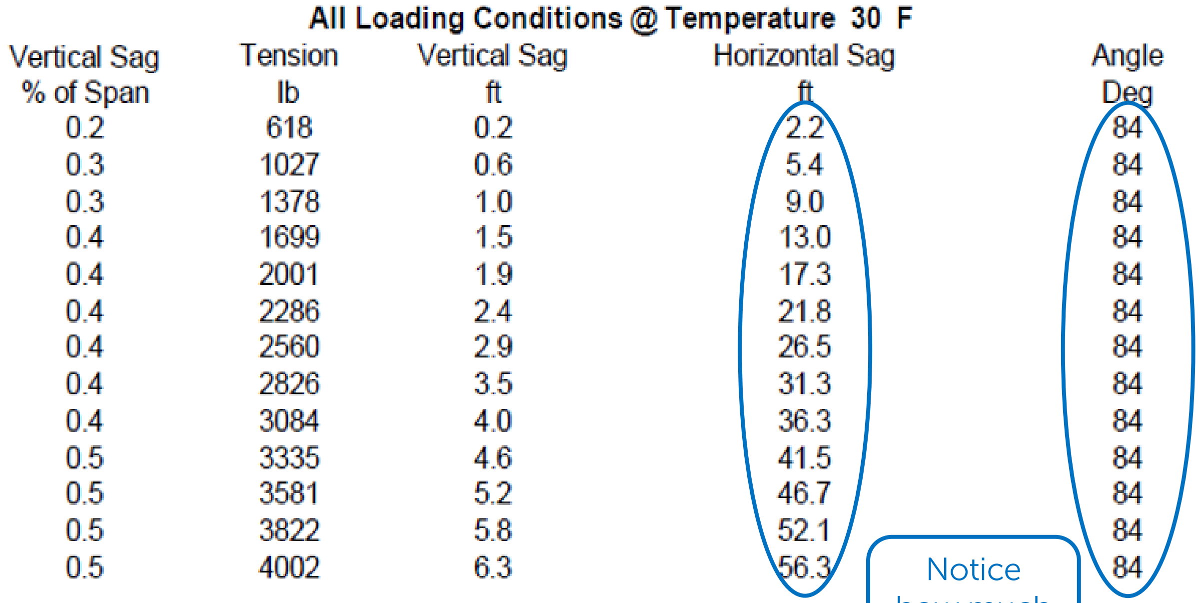
Data under loaded conditions

“H Sag” = horizontal sag to check blowout
“V Sag” = vertical sag to check ground clearance



No Loading @ Install Temperature 68 F

Span ft	Sag ft	Install Sag %	Tension lb
100	1.0	1.00	155
200	2.0	1.00	310
300	3.0	1.00	465
400	4.0	1.00	620
500	5.0	1.00	775
600	6.0	1.00	930
700	7.0	1.00	1085
800	8.0	1.00	1241
900	9.0	1.00	1396
1000	10.0	1.00	1551
1100	11.0	1.00	1706
1200	12.0	1.00	1861
1276	12.8	1.00	1979



All Loading Conditions @ Temperature 30 F

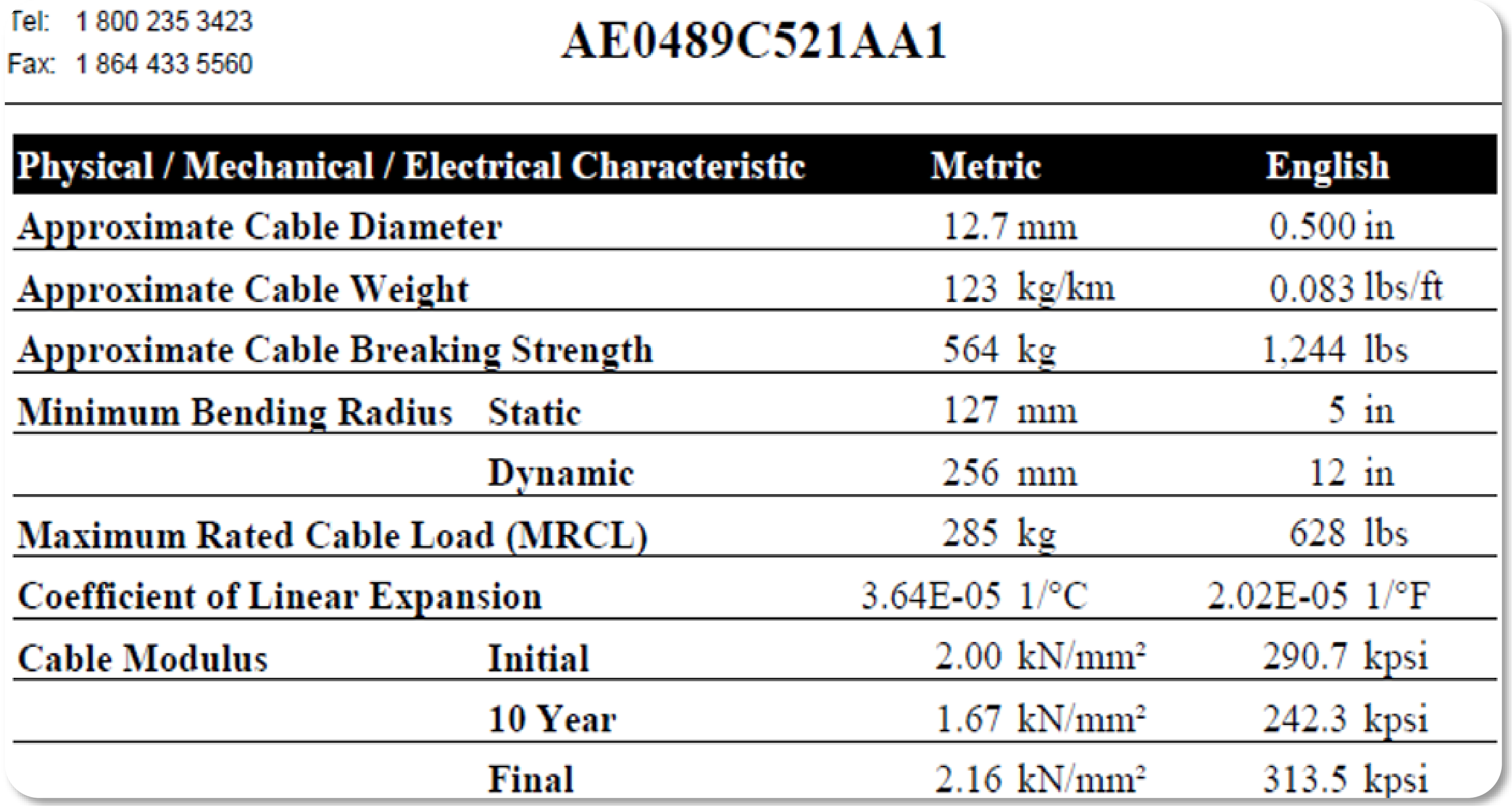
Vertical Sag % of Span	Tension lb	Vertical Sag ft	Horizontal Sag ft	Angle Deg
0.2	618	0.2	2.2	84
0.3	1027	0.6	5.4	84
0.3	1378	1.0	9.0	84
0.4	1699	1.5	13.0	84
0.4	2001	1.9	17.3	84
0.4	2286	2.4	21.8	84
0.4	2560	2.9	26.5	84
0.4	2826	3.5	31.3	84
0.4	3084	4.0	36.3	84
0.5	3335	4.6	41.5	84
0.5	3581	5.2	46.7	84
0.5	3822	5.8	52.1	84
0.5	4002	6.3	56.3	84

Notice how much blowout!

Notice that the sag is set to 1.0% of span

Sag and Tension Data Generation

Data Tables – AFL Header



Tel: 1 800 235 3423
Fax: 1 864 433 5560

AE0489C521AA1

Physical / Mechanical / Electrical Characteristic		Metric	English
Approximate Cable Diameter		12.7 mm	0.500 in
Approximate Cable Weight		123 kg/km	0.083 lbs/ft
Approximate Cable Breaking Strength		564 kg	1,244 lbs
Minimum Bending Radius	Static	127 mm	5 in
	Dynamic	256 mm	12 in
Maximum Rated Cable Load (MRCL)		285 kg	628 lbs
Coefficient of Linear Expansion		3.64E-05 1/°C	2.02E-05 1/°F
Cable Modulus	Initial	2.00 kN/mm^2	290.7 kpsi
	10 Year	1.67 kN/mm^2	242.3 kpsi
	Final	2.16 kN/mm^2	313.5 kpsi

Cable Specs

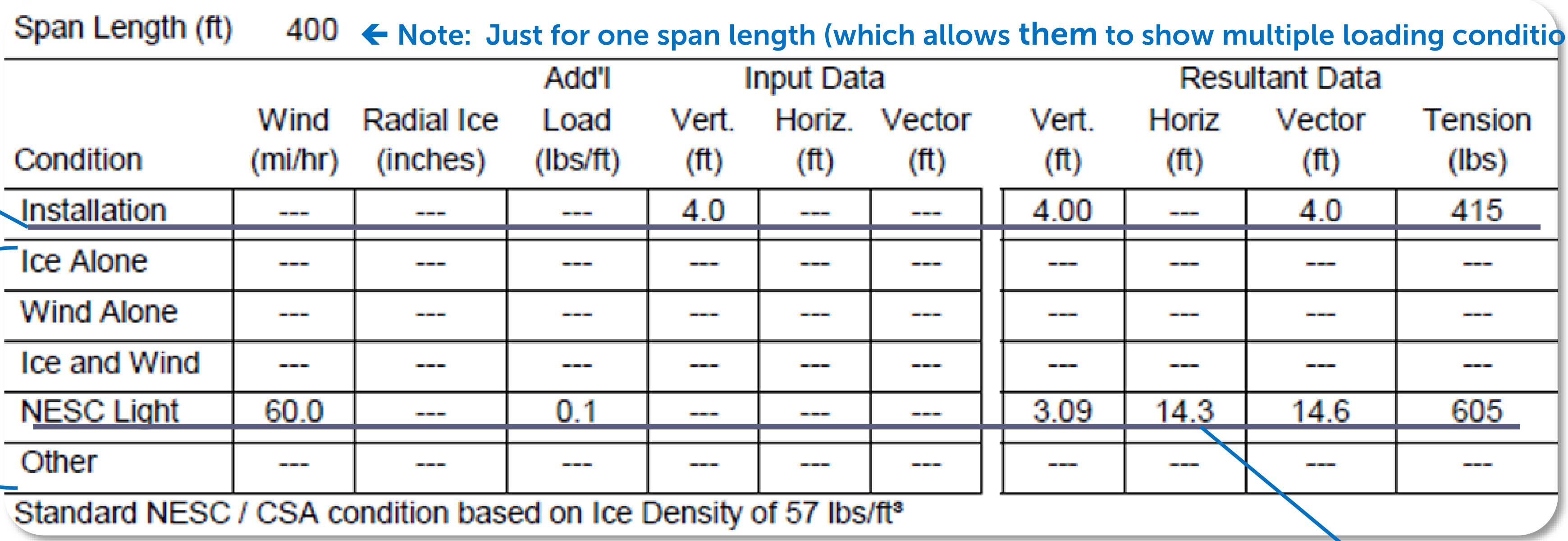
Note: Neither "Maximum Everyday" nor ZFSM/fiber strain info shown You must ask

Sag and Tension Data Generation

Data Tables – AFL Data

Data for “Everyday” condition (no wind, no ice)

Loading Conditions



Span Length (ft) 400

← **Note: Just for one span length (which allows them to show multiple loading conditions)**

				Input Data			Resultant Data			
Condition	Wind (mi/hr)	Radial Ice (inches)	Add'l Load (lbs/ft)	Vert. (ft)	Horiz. (ft)	Vector (ft)	Vert. (ft)	Horiz (ft)	Vector (ft)	Tension (lbs)
Installation	---	---	---	4.0	---	---	4.00	---	4.0	415
Ice Alone	---	---	---	---	---	---	---	---	---	---
Wind Alone	---	---	---	---	---	---	---	---	---	---
Ice and Wind	---	---	---	---	---	---	---	---	---	---
NESC Light	60.0	---	0.1	---	---	---	3.09	14.3	14.6	605
Other	---	---	---	---	---	---	---	---	---	---

Standard NESC / CSA condition based on Ice Density of 57 lbs/ft³

“Horiz.” = horizontal sag to check blowout

“Vert.” = vertical sag to check ground clearance

Sag and Tension Data Generation

Generating Your Own Data Using ACES CATS

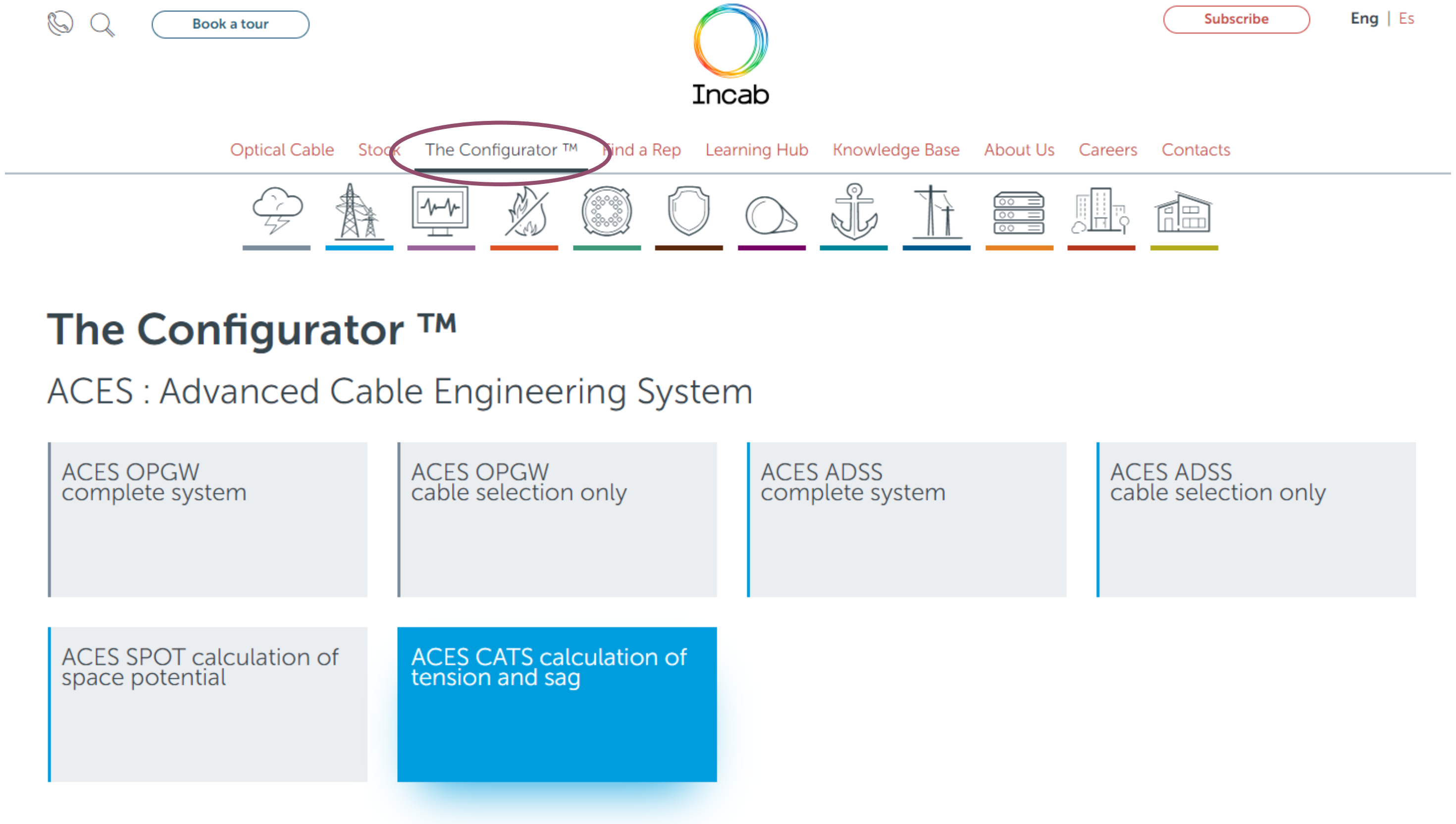
Recall your second option is to generate your own data using ACES CATS

- It's your data and you need it now!
- Greatly facilitates "what if" analysis
- Fast, easy, and fun
    - (Perhaps I've been working with aerial cables too long)
- Can use for *any* supplier's cable!
    - You just need the basic cable data that we have discussed

Sag and Tension Data Generation

Generating Your Own Data Using ACES CATS

- Go to www.incabamerica.com and then select The Configurator™ followed by ACES CATS…



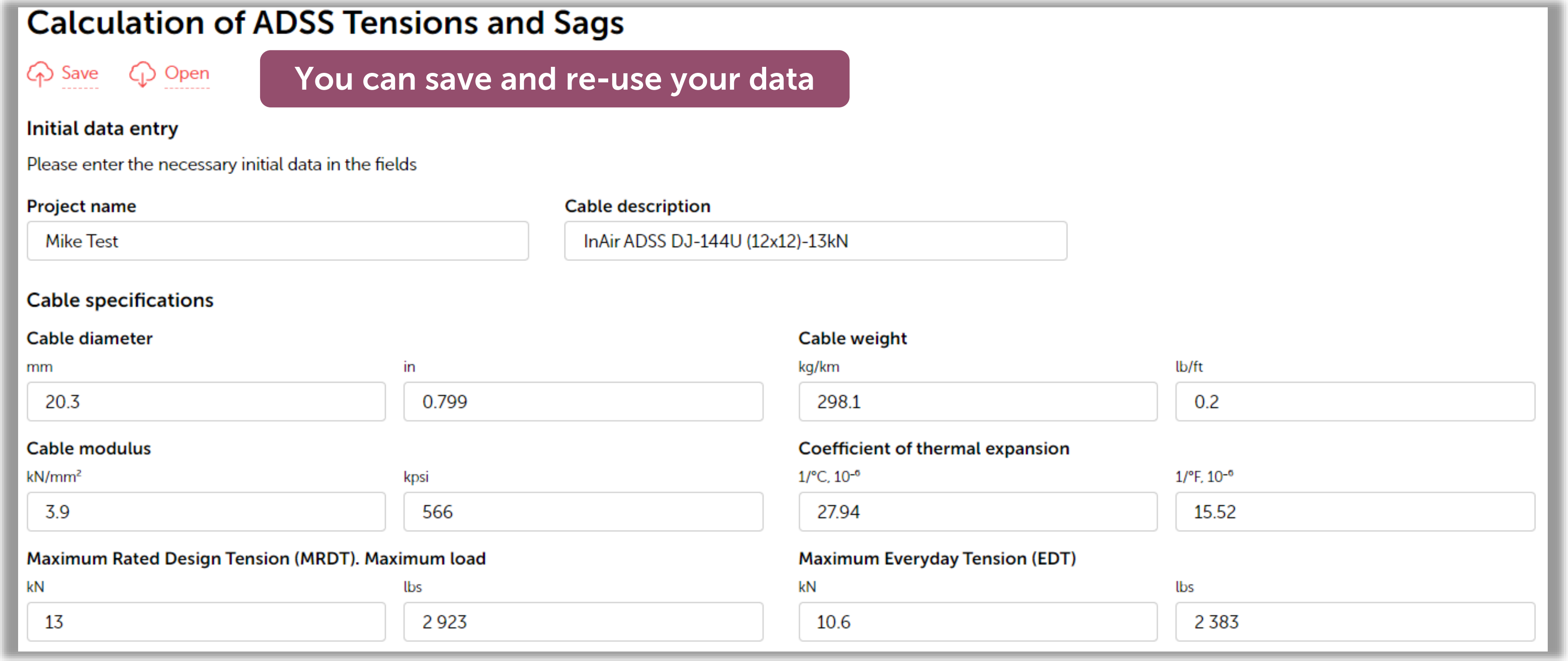
The Configurator ™

ACES : Advanced Cable Engineering System

Sag and Tension Data Generation

Generating Your Own Data Using ACES CATS

- Enter the cable data (all as we have discussed) in either customary or metric units (enter in either units…program automatically converts to the other)



Calculation of ADSS Tensions and Sags

You can save and re-use your data

Initial data entry

Please enter the necessary initial data in the fields

Project name	Cable description
Mike Test	InAir ADSS DJ-144U (12x12)-13kN

Cable specifications

Cable diameter		Cable weight	
mm	in	kg/km	lb/ft
20.3	0.799	298.1	0.2

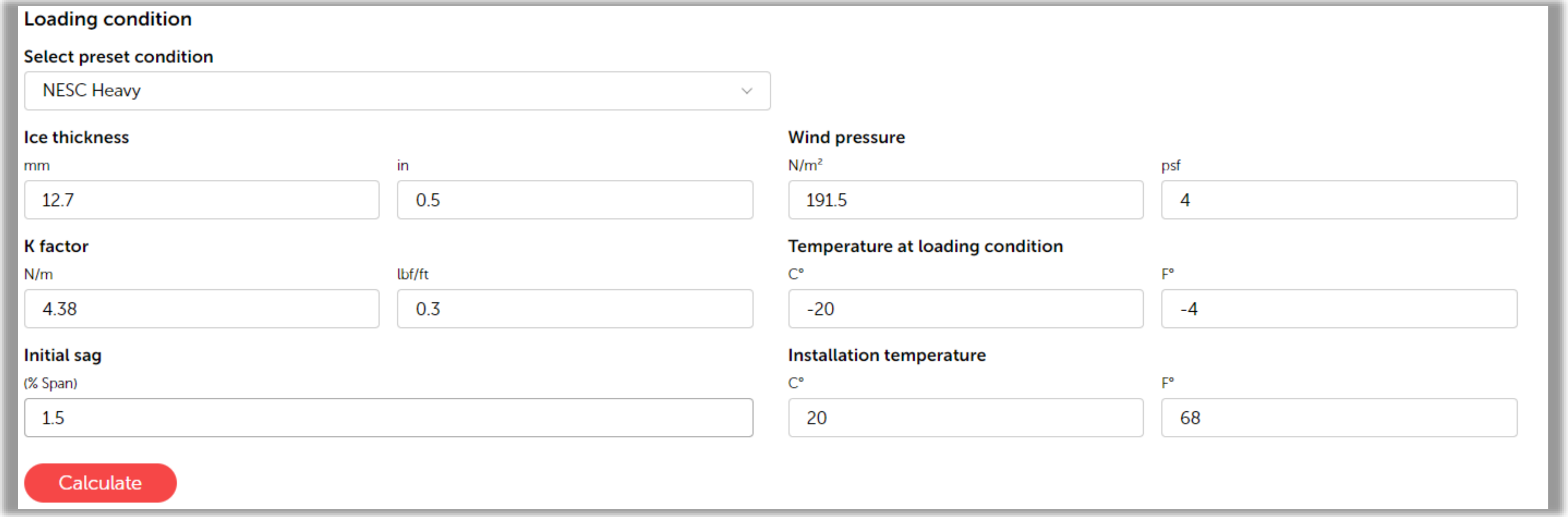
Cable modulus		Coefficient of thermal expansion	
kN/mm^2	kpsi	1/°C, 10^{-6}	1/°F, 10^{-6}
3.9	566	27.94	15.52

Maximum Rated Design Tension (MRDT). Maximum load		Maximum Everyday Tension (EDT)	
kN	lbs	kN	lbs
13	2 923	10.6	2 383

Sag and Tension Data Generation

Generating Your Own Data Using ACES CATS

- Select loading conditions or enter your own



Loading condition

Select preset condition

NESC Heavy

Ice thickness

mm: 12.7

in: 0.5

Wind pressure

N/m²: 191.5

psf: 4

K factor

N/m: 4.38

lbf/ft: 0.3

Temperature at loading condition

C°: -20

F°: -4

Initial sag

(% Span): 1.5

Installation temperature

C°: 20

F°: 68

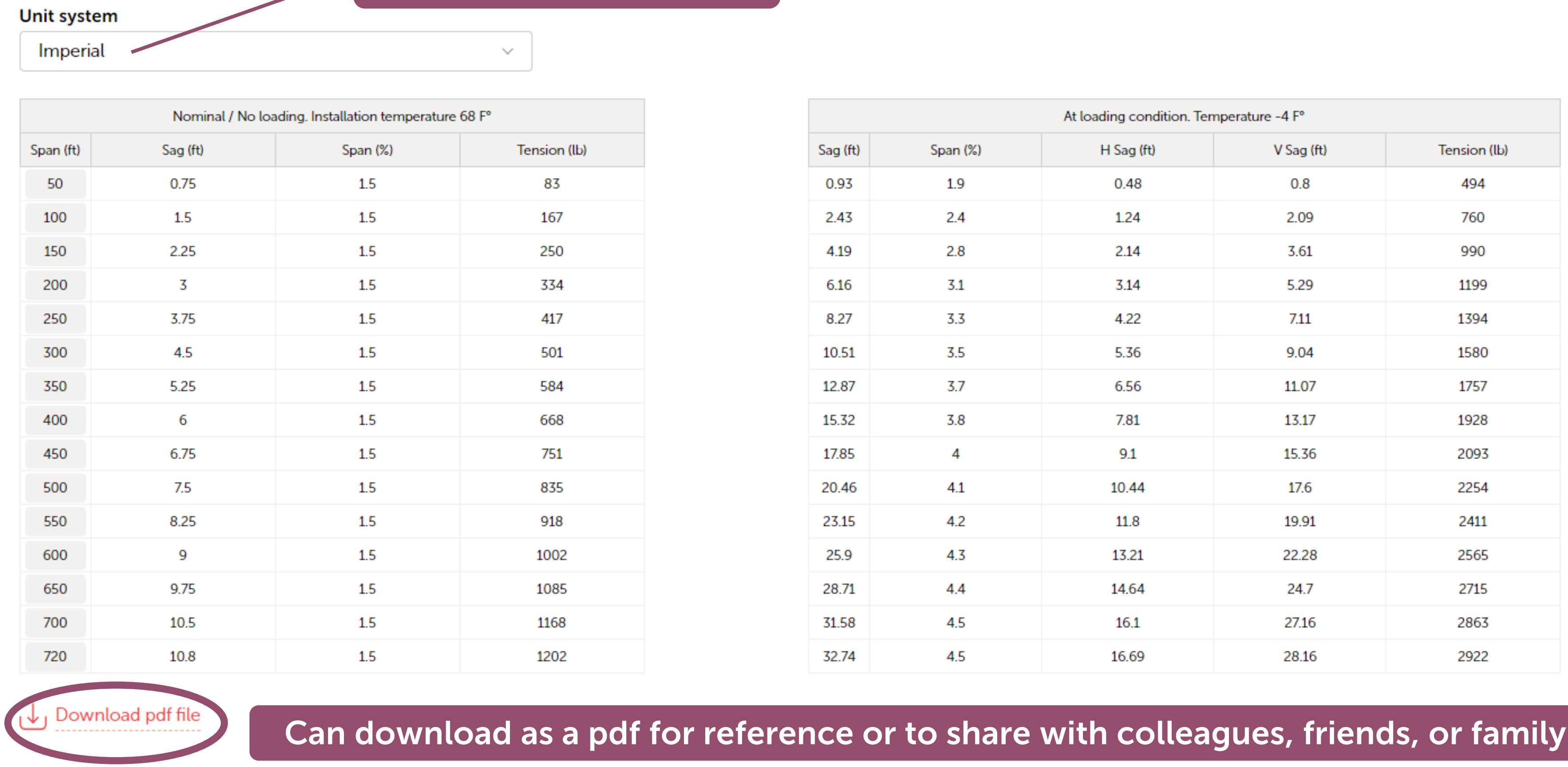
Then hit "Calculate"

Sag and Tension Data Generation

Generating Your Own Data Using ACES CATS

- Receive your data!

Can change unit system



Unit system

Imperial

Nominal / No loading. Installation temperature 68 F°			
Span (ft)	Sag (ft)	Span (%)	Tension (lb)
50	0.75	1.5	83
100	1.5	1.5	167
150	2.25	1.5	250
200	3	1.5	334
250	3.75	1.5	417
300	4.5	1.5	501
350	5.25	1.5	584
400	6	1.5	668
450	6.75	1.5	751
500	7.5	1.5	835
550	8.25	1.5	918
600	9	1.5	1002
650	9.75	1.5	1085
700	10.5	1.5	1168
720	10.8	1.5	1202

At loading condition. Temperature -4 F°				
Sag (ft)	Span (%)	H Sag (ft)	V Sag (ft)	Tension (lb)
0.93	1.9	0.48	0.8	494
2.43	2.4	1.24	2.09	760
4.19	2.8	2.14	3.61	990
6.16	3.1	3.14	5.29	1199
8.27	3.3	4.22	7.11	1394
10.51	3.5	5.36	9.04	1580
12.87	3.7	6.56	11.07	1757
15.32	3.8	7.81	13.17	1928
17.85	4	9.1	15.36	2093
20.46	4.1	10.44	17.6	2254
23.15	4.2	11.8	19.91	2411
25.9	4.3	13.21	22.28	2565
28.71	4.4	14.64	24.7	2715
31.58	4.5	16.1	27.16	2863
32.74	4.5	16.69	28.16	2922

Can download as a pdf for reference or to share with colleagues, friends, or family!

Sag and Tension Data Generation

Critically Important Caveat!

All of the preceding reflects current industry practice, but strictly speaking, it is *not* correct!

- **Two things are “not quite right”…**

1. Using only the **initial value** for **modulus** implies that ADSS is perfectly elastic with no difference between initial and final modulus, plus no creep!
    - We know this is *not* the case
    - Confirmed by the fact that 3 of 4 manufacturers gave different modulus values for initial, final, and 10-year/creep

Sag and Tension Data Generation

Critically Important Notes!

2. Spans are treated **individually**, as if each is double-dead-ended
   - Only true if each span strung and clipped individually
     - Yields "**Mechanically Independent**" spans (Illustrated on next slide)
     - Such as "moving reel" installation with trunnion-type **support** clamps

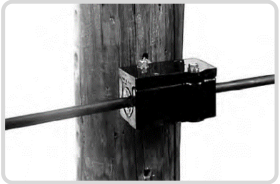
   - In contrast, often(?) "controlled tension" stringing (tensioner and pulling line) across multiple spans is used
     - **Plus, with suspension clamps instead of trunnion-type supports**
     - "**Mechanically coupled**" spans
     - Therefore, the "**ruling span**" concept governs the sag and tension
     - Tension equalizes across all spans with sag greatest in longer spans
       - Effectively, a weighted average (exact formula to follow soon)

Yikes! Was everything to this point just a waste?

Hold that question for just a few moments, please

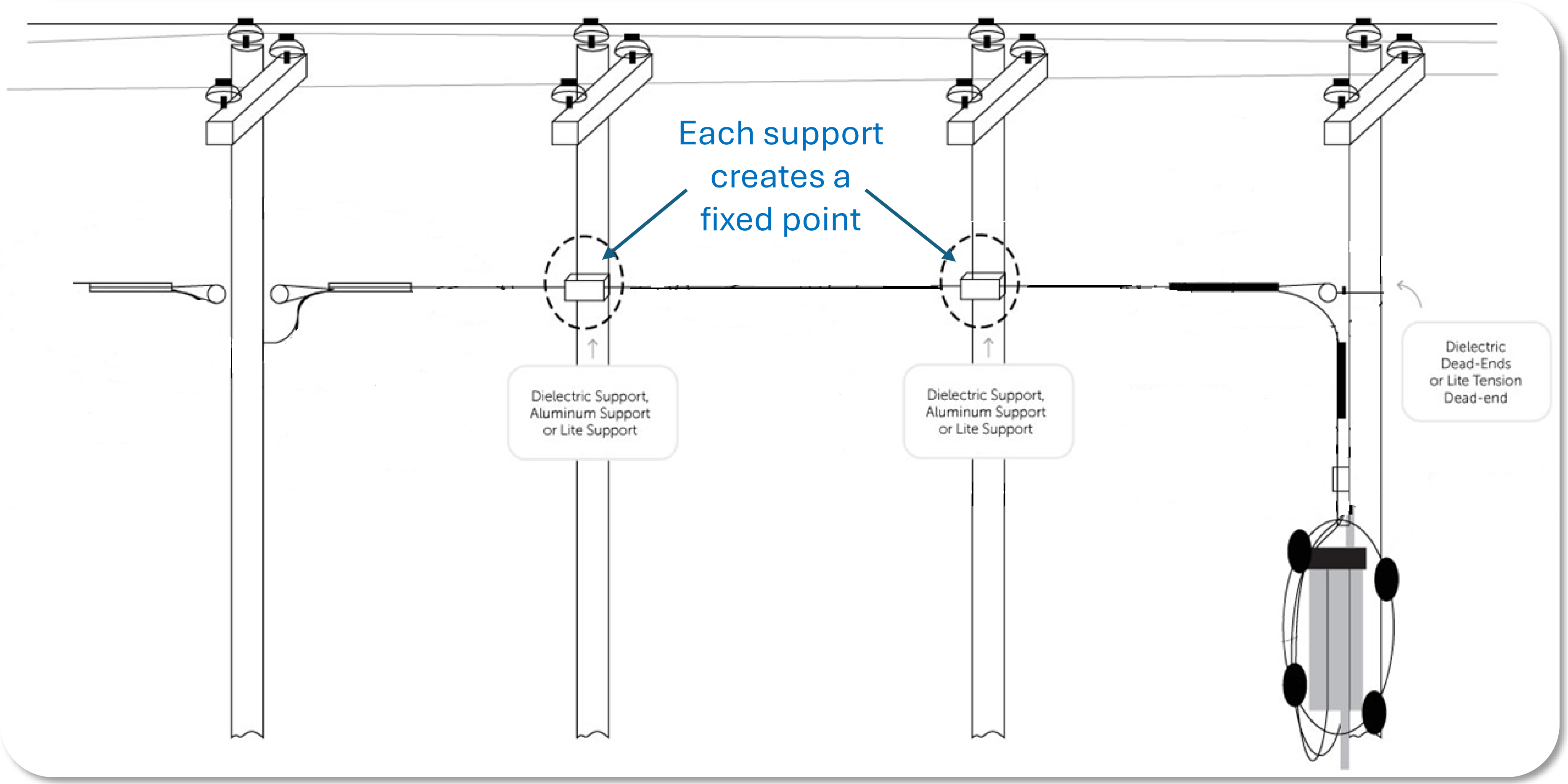
Sag and Tension Data Generation

Mechanically Independent Spans



or

These types do *not* move to equalize tension

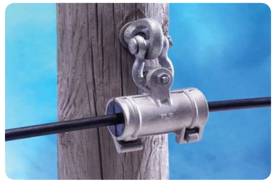


Each support creates a fixed point

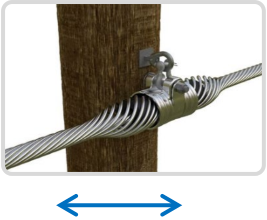
Supports create fixed points at each pole, so spans are mechanically independent

Sag and Tension Data Generation

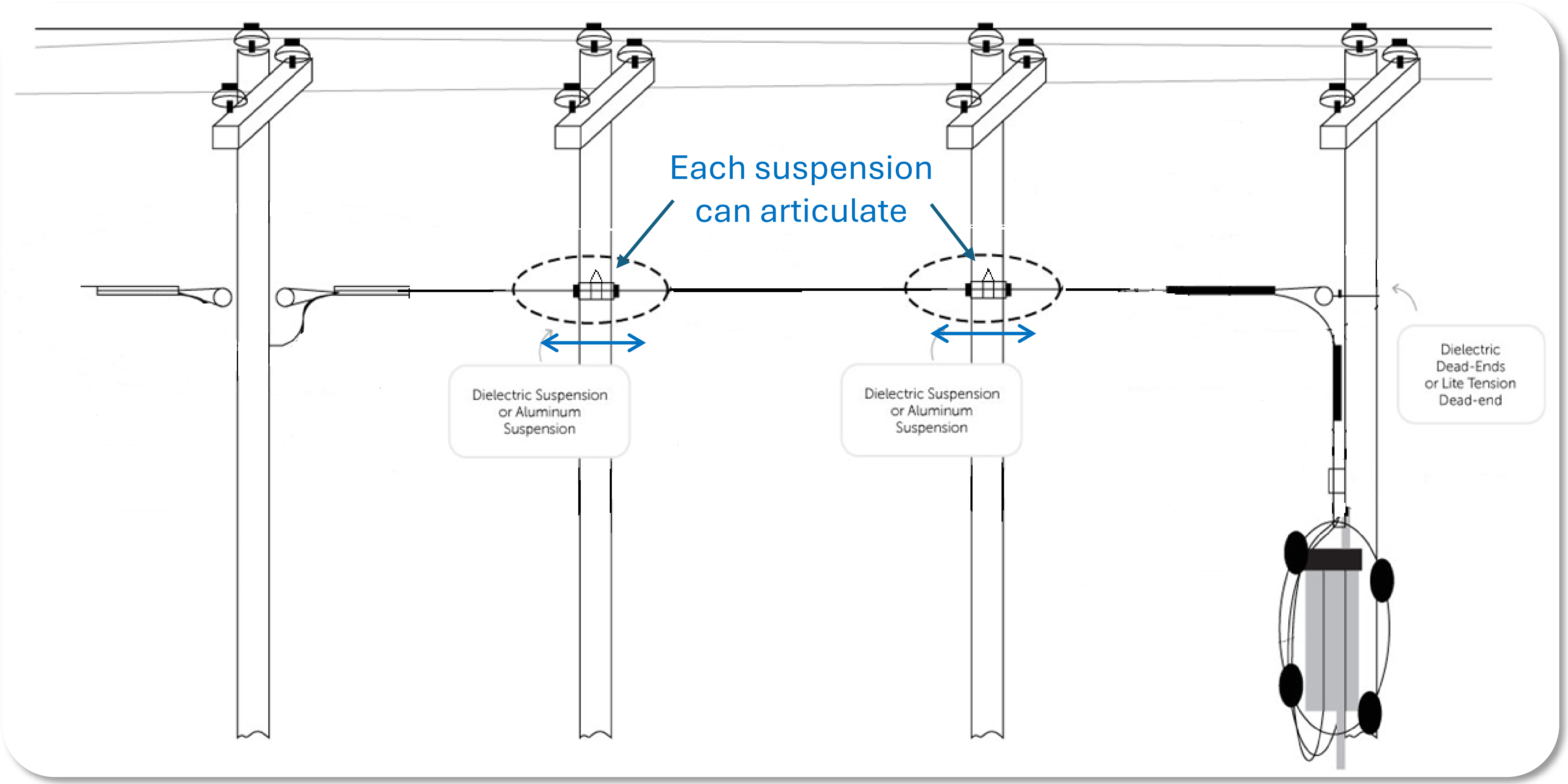
Mechanically Coupled Spans



or



These types *do* move to equalize tension



Each suspension can articulate

The articulation of a suspension clamp makes the spans mechanically coupled

Sag and Tension Data Generation

Understand The Limitations

- So, was everything up to slide 36 a waste?

No! It just means you need to understand the limitations of our methodology so far!

- For "**short**" to "**medium**" **spans** in a distribution environment, the **theoretical error** is **acceptable**
  - We know this is from experience, i.e. *No problems in reality*
  - For ADSS, the change in sag and tension between installation (initial modulus) and final (final plus creep modulus) conditions is much lower than for metal cables (about half)
  - Consider too sagging inaccuracies in the field
    - This "real world factor" alone likely washes out the theoretical error
- Ergo ipso facto: Consider our method thus far the "**Simplified Sag and Tension Solution**"

Sag and Tension Data Generation

When To Use What

- **OK, but now this leads to two questions:**

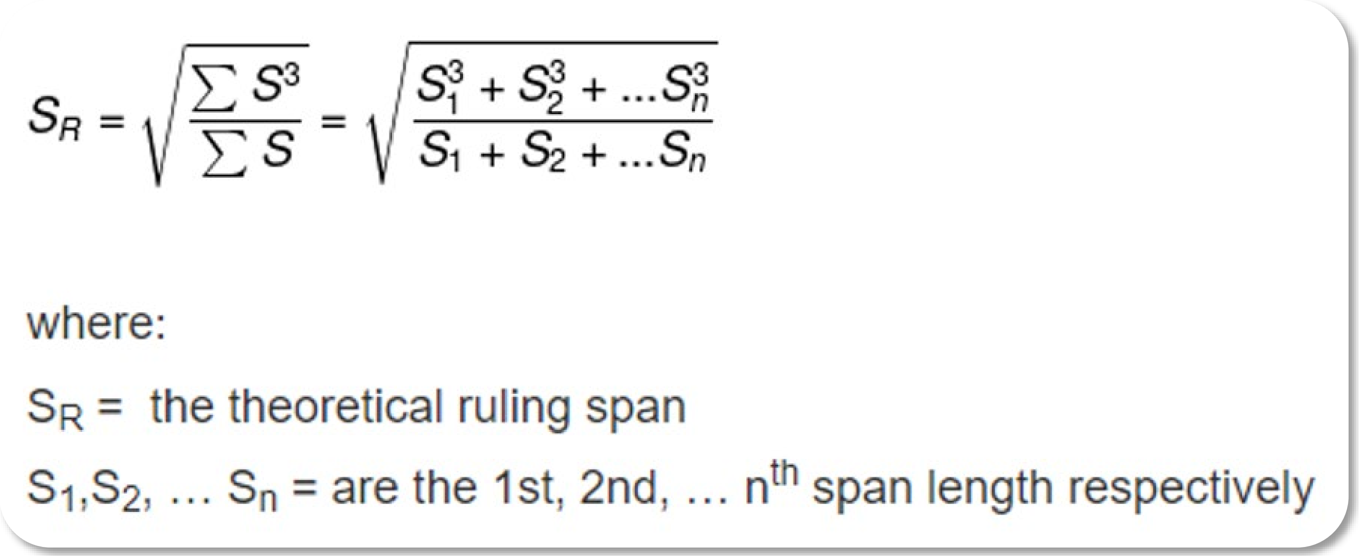
1. When is it appropriate to use the so-called Simplified Solution?
    - First consider: What's a "short" and "medium" span?
        - Spans under 500 – 600 ft (≈ 150 – 200 m) and standard NESC loading conditions (or similar if outside the US)
    - Distribution circuits

2. What should I use when the so-called Simplified Solution is *not* appropriate?
    ➔ Use the **Ruling Span** concept in conjunction with sag and tension analysis software such as Power Line® Systems **PLS-CADD** or Southwire™ **Sag10**®
        - Recall that these are the third source of sag and tension data

Sag and Tension Data Generation

Ruling Span Concept - Defined

- Mathematically:



$$S_R = \sqrt{\frac{\sum S^3}{\sum S}} = \sqrt{\frac{S_1^3 + S_2^3 + \ldots S_n^3}{S_1 + S_2 + \ldots S_n}}$$

where:

S_R = the theoretical ruling span

$S_1, S_2, \ldots S_n$ = are the 1st, 2nd, … nth span length respectively

- In words: The square root of the sum of the spans cubed divided by the sum of the spans
  - Effectively a weighted average leaning towards the longer spans

Note: The ruling span is very easily calculated in Excel from a list of the spans. PLS-CADD can also do it for you.

Sag and Tension Data Generation

Ruling Span Concept - Example

Span	Section	Span Length	
		ft	m
1	Pole 1 - Pole 2	217	66
2	Pole 2 - Pole 3	197	60
3	Pole 3 - Pole 4	246	75
4	Pole 4 - Pole 5	213	65

$S_R = \sqrt{}(217^3 + 197^3 + 246^3 + 213^3)/(217 + 197 + 246 + 213) =$ **220.4** ft

$S_R = \sqrt{}(66^3 + 60^3 + 75^3 + 65^3)/(66 + 60 + 75 + 65) =$ **67.2** m

Compare: Average span = 218.25 ft or 66.5 m, so difference about 1%

Sag and Tension Data Generation

Back To 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

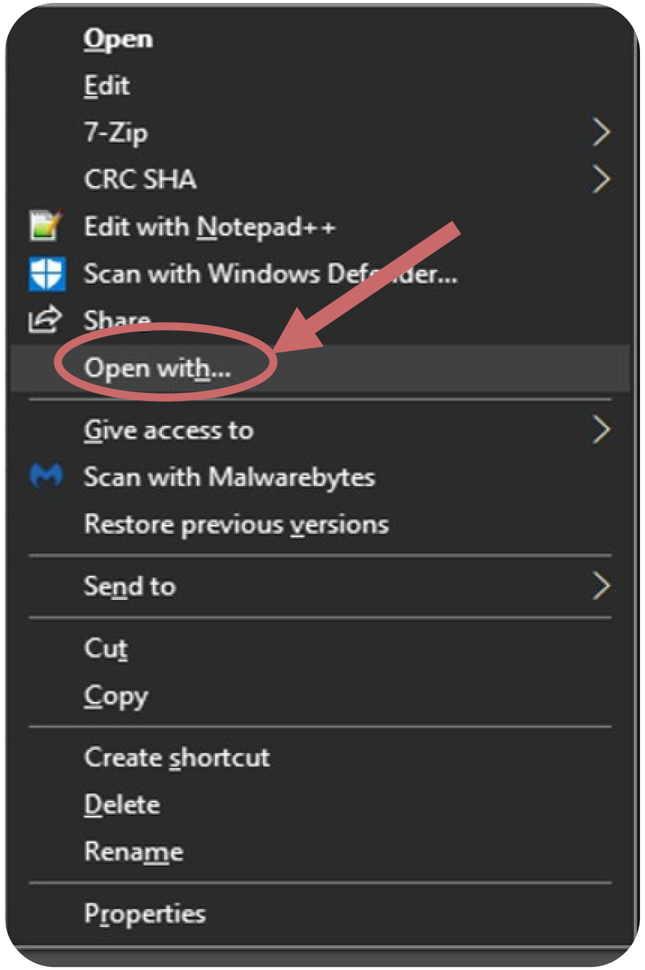
➔ Editing .WIR files for ADSS is not for the faint of heart!

- **Proceed with extreme care!**

Sag and Tension Data Generation

Working With .WIR Files

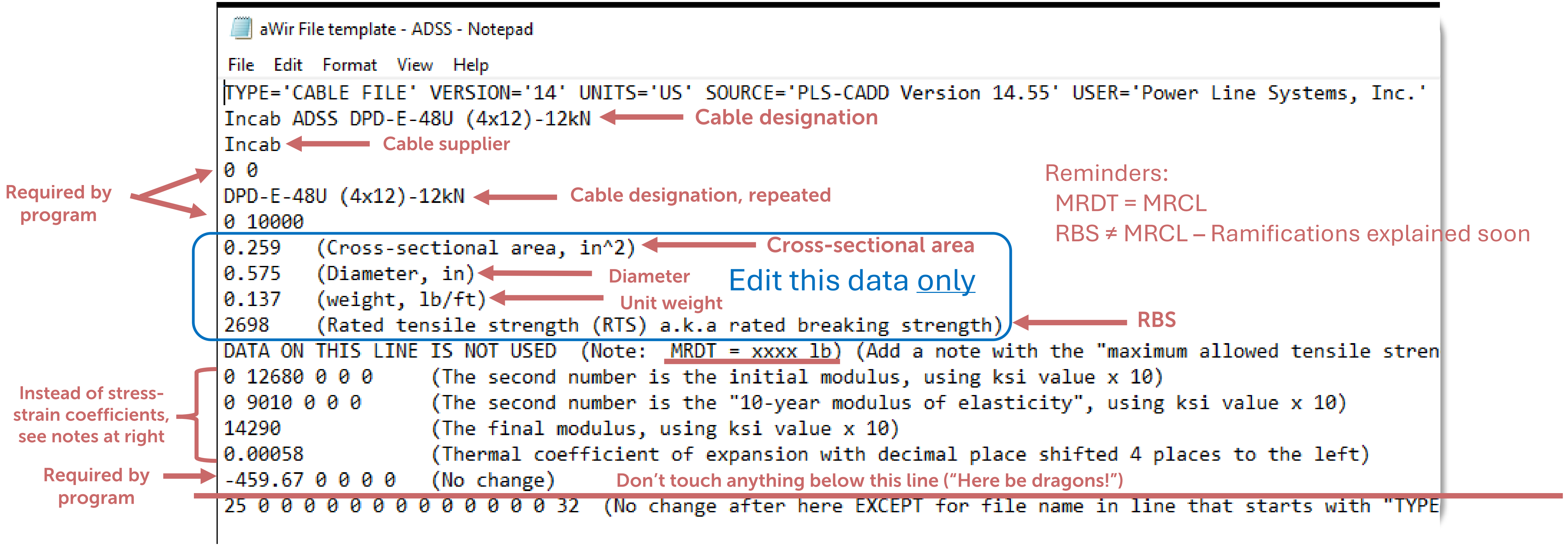
- You can open a .WIR file by right-clicking on it, selecting "Open With", and then selecting "Notepad"
  - It's a text file, so Notepad works best
- After editing it, save the new .WIR file
- Then, load the new .WIR file into PLS-CADD, complete your problem file, and let the program compute the sag and tensions for you



Sag and Tension Data Generation

Back To PLS-CLADD - Set up Your .WIR File

- It's best to start with a "donor" .WIR file for ADSS and edit the data as in this example:



```
TYPE='CABLE FILE' VERSION='14' UNITS='US' SOURCE='PLS-CADD Version 14.55' USER='Power Line Systems, Inc.'
Incab ADSS DPD-E-48U (4x12)-12kN
Incab
0 0
DPD-E-48U (4x12)-12kN
0 10000
0.259    (Cross-sectional area, in^2)
0.575    (Diameter, in)
0.137    (weight, lb/ft)
2698     (Rated tensile strength (RTS) a.k.a rated breaking strength)
DATA ON THIS LINE IS NOT USED  (Note:  MRDT = xxxx lb) (Add a note with the "maximum allowed tensile stren
0 12680 0 0 0       (The second number is the initial modulus, using ksi value x 10)
0 9010 0 0 0        (The second number is the "10-year modulus of elasticity", using ksi value x 10)
14290               (The final modulus, using ksi value x 10)
0.00058             (Thermal coefficient of expansion with decimal place shifted 4 places to the left)
-459.67 0 0 0 0     (No change)
25 0 0 0 0 0 0 0 0 0 0 0 0 0 32  (No change after here EXCEPT for file name in line that starts with "TYPE
```

Cable designation

Cable supplier

Required by program

Cable designation, repeated

Cross-sectional area

Diameter

Unit weight

Edit this data only

RBS

Instead of stress-strain coefficients, see notes at right

Required by program

Don't touch anything below this line ("Here be dragons!")

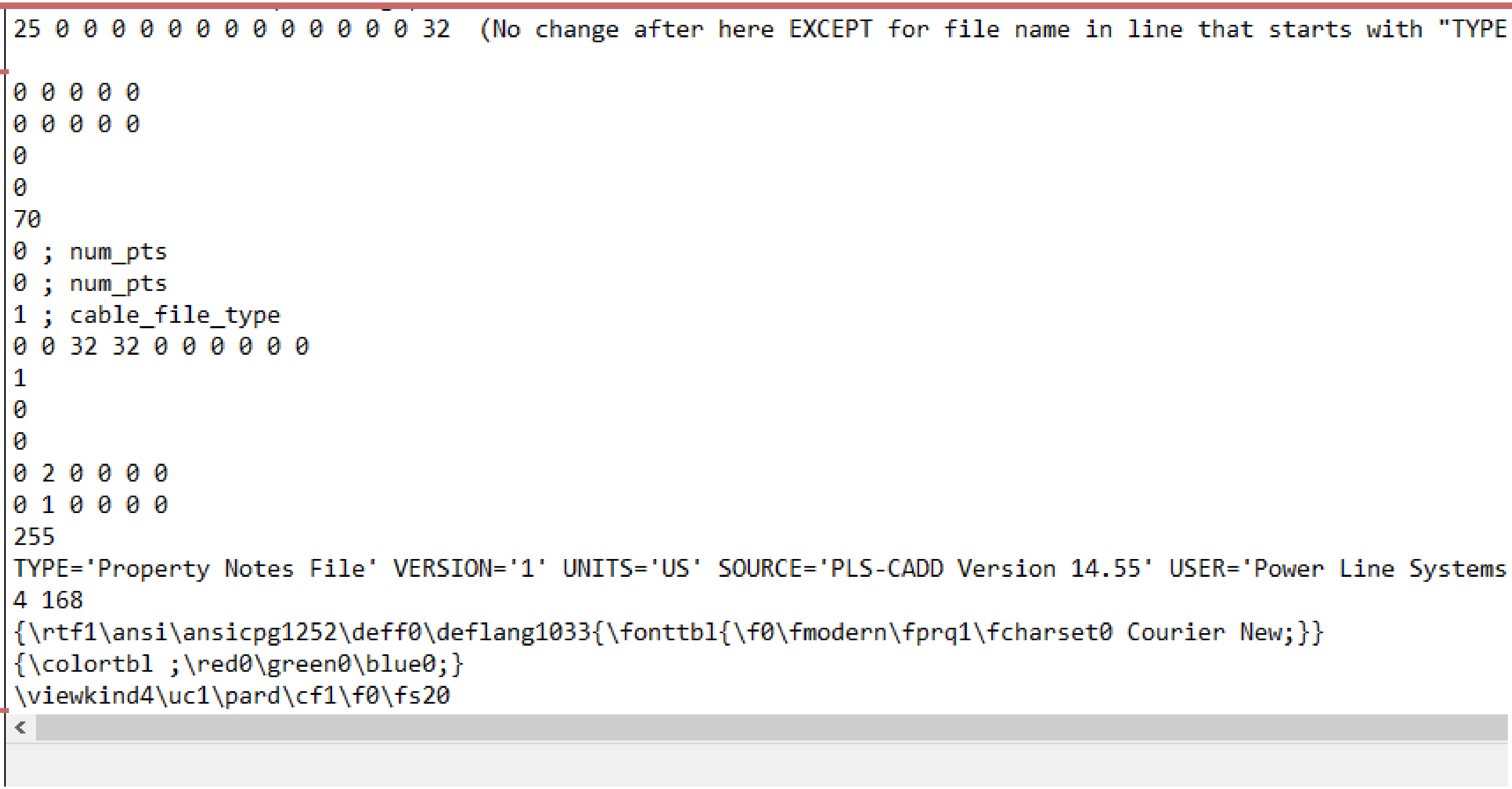
Reminders:
MRDT = MRCL
RBS ≠ MRCL – Ramifications explained soon

Continued on next slide...

Sag and Tension Data Generation

Back To PLS-CLADD - Set up Your .WIR File

Don’t touch anything below this line (“Here be dragons!”)



```
25 0 0 0 0 0 0 0 0 0 0 0 0 0 32  (No change after here EXCEPT for file name in line that starts with "TYPE

0 0 0 0 0
0 0 0 0 0
0
0
70
0 ; num_pts
0 ; num_pts
1 ; cable_file_type
0 0 32 32 0 0 0 0 0 0
1
0
0
0 2 0 0 0 0
0 1 0 0 0 0
255
TYPE='Property Notes File' VERSION='1' UNITS='US' SOURCE='PLS-CADD Version 14.55' USER='Power Line Systems
4 168
{\rtf1\ansi\ansicpg1252\deff0\deflang1033{\fonttbl{\f0\fmodern\fprq1\fcharset0 Courier New;}}
{\colortbl ;\red0\green0\blue0;}
\viewkind4\uc1\pard\cf1\f0\fs20
```

Required by program

Sag and Tension Data Generation

Critical Final Step

Remember MRCL? It's critical! And, ZFSM is darn important too!

- You must manually check that tension never, ever exceeds the cable's MRCL in PLS-CADD and Sag10!
  - If it does, you risk optical problems (short term, long term, or both)!
  - If it does, you risk a voided warranty!

- **Repeat:** The tension under any and all conditions must never, ever exceed the cable's MRCL! **Important**

- You must also check the “everyday” condition to make sure that that tension does not exceed the cable’s ZFSM! **Important**

Recap

Now you know…

- How to obtain basic sag and tension data for your ADSS
- The three means of obtaining that basic sag and tension data
- The meaning and importance of ZFSM and MRCL
  - Plus, guidelines to what ZFSM and MRCL you should specify
- The difference between mechanically coupled and mechanically independent spans and how this is important to sag and tension calculations
- The differences between “simplified sag and tension calculations” and those made using the “ruling span concept” and when each method is appropriate
- How to run your own ADSS sag and tension calculations

Homework!

Please reinforce your learning today by putting it into action!

- Please take a test run of Incab's ACES CATS
  - Reminder: select The Configurator™ at www.incabamerica.com

- Ask at least one other ADSS supplier for their sag and tension data for an ADSS
  - Identify all the key data that's needed for sag and tension calculations (reference slide 16)
  - Identify the cable's ZFSM (Ask the supplier, if necessary)
  - Identify the cable's MRCL
  - Identify the cable's fiber strain at MRCL (Ask the supplier, if necessary)

- Bonus: Run sag and tension calculations on any ADSS cable using PLS-CADD or Sag10

Note: I will maintain "office hours" to help in the form of being available via MS Teams (mike.riddle@incabamerica.com)

Incab

Thank you

Questions?

INCABAMERICA.COM