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Why is Creep ALWAYS a Factor?

Introduction

Many critical decisions in line design are made based on two points in a cable's service life: its "Initial" state, and its "Final" state. A cable in its "Initial" state is as-manufactured, and has never experienced stress due to tension. Generally, line tensions are greatest at the time of cable installation, and so "Initial" tensions will govern the strength capacity of structures, hardware, and more. However, greatest sag and therefore minimum clearance generally occur at a cable's "Final" state. This state describes a cable that has experienced inelastic deformation due to one of two causes: an extreme weather loading event, or a phenomenon known as "creep."

PLS-CADD, PLS-CADD/LITE and PLS-CADD/ULTRALITE refer to these causes as two separate "Final" cable conditions: **Load** and **Creep**, respectively. In some menus, such as "Display Condition" at ***Sections/Table***, there is also a "Max Sag" option. This option simply displays the cable at either the **Creep** or **Load** condition depending on which results in the greatest sag for the span in question.

Engineers often want to know the sag and tension values associated with a cable's "Initial" and "Final" states. We are frequently asked why PLS-CADD, PLS-CADD/LITE and PLS-CADD/ULTRALITE sag-tension reports include both the **Creep** and **Load** conditions instead of just a single "Final" condition. This is done because wire creep is always a factor regardless of whether a heavy loading event occurs or not. This Technical Note explains why the **Creep** condition *always* matters.

First, let's explain the differences between the **Creep** and **Load** conditions of a cable:

- **Creep** refers to a cable after permanent elongation over time due to everyday tensions. Since temperatures fluctuate year-round, it is common practice that this "everyday tension" be averaged as the tension that occurs in the cable at 60°F (≈15°C). In warmer regions, this assumed average temperature may be greater (*this decreases the average tensions, resulting in less permanent elongation and decreases the effect of Creep*). In colder regions, this assumed average temperature may be lower (*this increases the average tensions, resulting in more permanent elongation and increases the effect of Creep*). A cable elongating due to creep never reaches an "endpoint" at which elongation ceases entirely; however, it is typical to consider the amount of elongation due to creep which has occurred after 10 years as a cable's "fully-crept" state. After the cable has crept, all sag and tension calculations are affected by the permanent elongation.

- **Load** refers to a cable after permanent elongation due to a heavy loading event such as heavy ice or extreme wind. A heavy loading event will result in permanent elongation of the cable at any point in the cable's service life: the day after it is installed, or anytime over the cable's life. The likelihood of heavy loading event occurring is related to the design return period: 25, 50, or even 100 years. After a heavy loading event has occurred, all sag and tension calculations are affected by the permanent elongation. One key difference between this Load condition and the Creep condition is that *a heavy loading condition may never actually occur,* whereas permanent elongation due to Creep is guaranteed for many types of cables.

Figure 1 below shows the menu in PLS-CADD and PLS-CADD/LITE for selecting weather cases used in calculating permanent cable deformation at both the **Creep** and **Load** conditions.

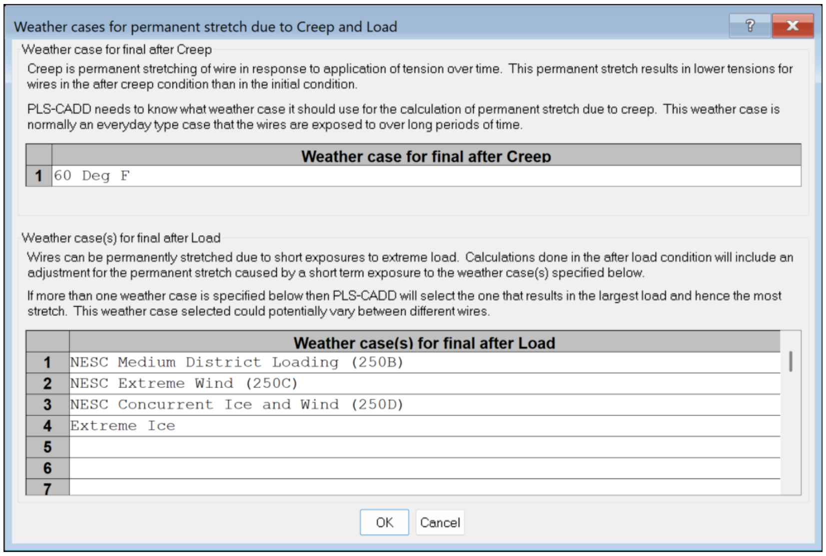


Figure 1: "Weather cases for permanent stretch due to Creep and Load" table as found at ***Criteria/Creep-Stretch***

Note that multiple weather cases may be input for the **Load** condition calculations. PLS-CADD, PLS-CADD/LITE and PLS-CADD/ULTRALITE will automatically determine the weather case resulting in the greatest permanent deformation, and use that case for wire modeling at the **Load** condition.

Cable conditions are discussed in depth in CIGRE Brochure 324, Task Force B2.12.03 "Sag-Tension Calculation Methods for Overhead Lines", which can be purchased at the eCIGRE online bookstore. This document is an excellent resource for any questions about the behavior of sag and tension or understanding the underlying theories and calculations.

Creep vs. Load: Designing for the "Worst" Case

Now that we understand the basics of the **Creep** and **Load** conditions, let's discuss why these concepts are important and why both should always be considered by the engineer.

A good design accounts for the "worst" case scenarios. In the context of this Technical Note, we are primarily concerned with sag and tension: greatest tension values, and greatest sag. Let's consider Figure 2 for a moment:

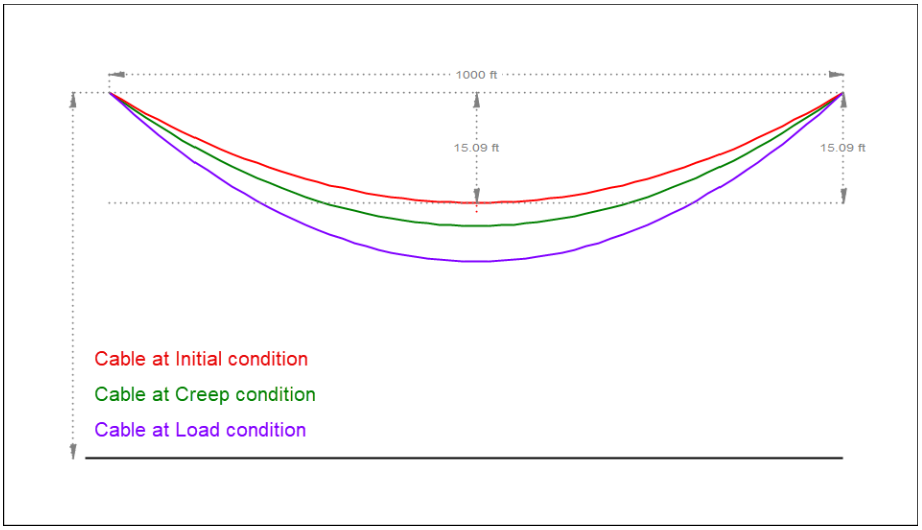


Figure 2: A wire displayed at Initial, Creep, and Load conditions

In that example, clearly the greatest sag will occur if the cable ever permanently elongates due to an extreme loading event. So, the sag and tension associated with the cable's **Load** condition should be considered the "Final" value, correct? No, not necessarily.

The nuance comes into play when we consider the *probability* of the **Load** or **Creep** "Final" cable states occurring. The fundamental concept of this Technical Note is that extreme loading events—and thus the **Load** condition—are not guaranteed to ever occur. Most heavy loading events considered in line design have 25, 50, or even 100-year return periods. There is a small chance the cable will experience a heavy loading event during these return periods, but there is an even greater chance the event will never occur at all. This doesn't mean the **Load** condition should be disregarded altogether, but a prudent engineer should make decisions with this concept in mind.

On the other hand, the **Creep** condition is simply a function of time and will *always* occur. Although there are now specialized wire types which creep either minimally or not at all, most cables are guaranteed to permanently elongate due to creep over time.

Let's consider the cable in Figure 2 again. If a heavy loading event occurs during the life of the line and the cable sags as shown by the **Load** condition, clearances must be maintained. In this case, the "Final" sag should be associated with the **Load** condition since it results in the minimum clearance buffer. The "Final" tension, however, should be associated with the **Creep** case. This ensures that maximum "Final" tensions considered during design are not lessened due to the *possibility* of a heavy loading event occurring, even if the larger sags associated with a heavy loading event govern in clearance checks.

To illustrate this idea with a more specific example, let's turn to NESC Rule 261H1c. This rule states that vibration mitigation devices must be installed when tension associated with a cable in its "Final" state exceeds 25% of that cable's rated breaking strength (RBS). Though newer editions of the NESC now specify this "Final" condition to be from creep rather than a loading event, let's assume in this example we are considering the **Load** condition to be

"Final." If PLS-CADD, PLS-CADD/LITE or PLS-CADD/ULTRALITE calculates a cable to be at 24% RBS when considering the **Load** condition, an engineer may decide vibration mitigation devices are not necessary. However, this is only true if the heavy loading event resulting in that 24% RBS actually occurs in the first few years after construction of the line. Otherwise, the cable will approach the **Creep** condition over time, and could maintain tensions at values significantly higher than 25% RBS. The cable is now at risk of experiencing fatigue failures due to Aeolian vibration since the decision to forego vibration mitigation devices was based on tensions that the cable never experienced.

The "Final" cable condition for the "worst" case scenario depends on the context, and the desired data. Cables must be designed based on *both* of these possible "Final" conditions to meet the applicable code clearances and ensure proper dampening. For this reason, PLS-CADD, PLS-CADD/LITE and PLS-CADD/ULTRALITE include both the **Creep** and **Load** conditions in sag-tension reports.

Case Study

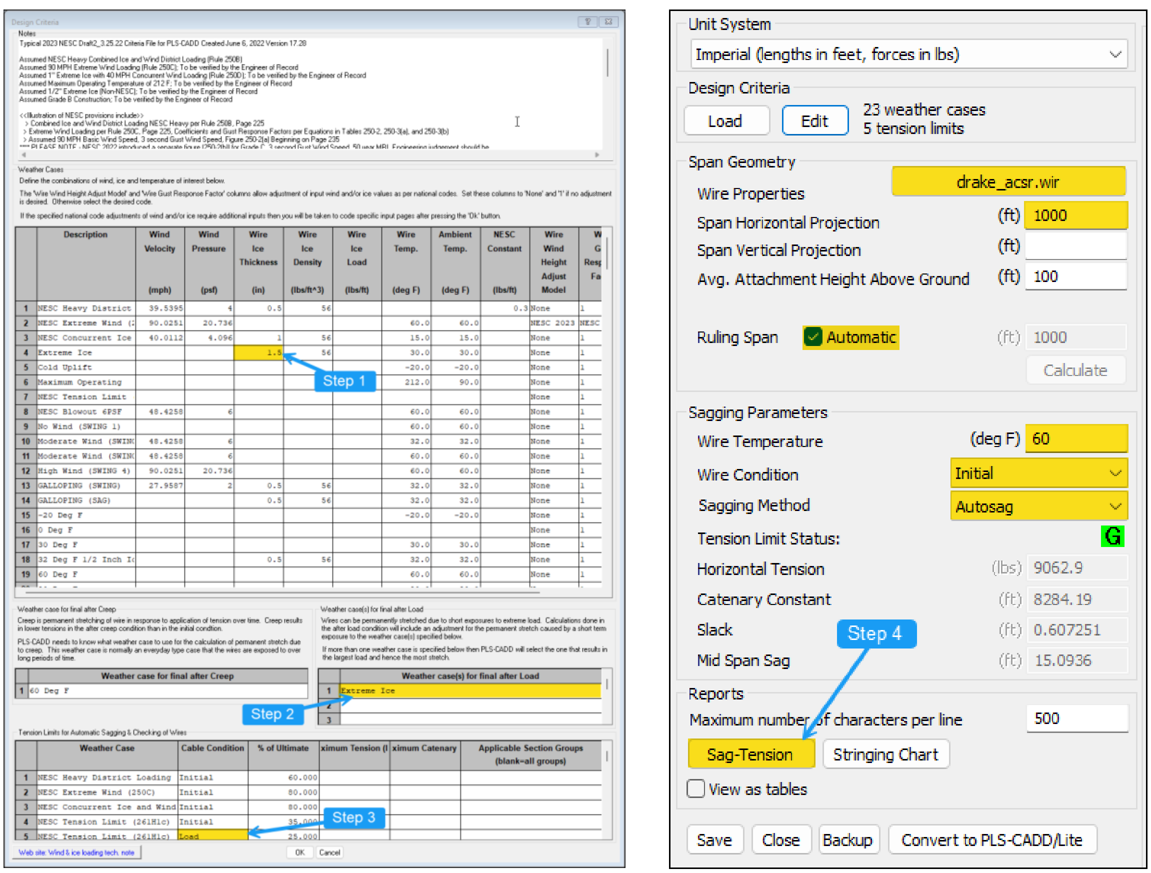
We conclude with a case study that can be easily recreated to reiterate the concepts covered in this Technical Note. This example was created in PLS-CADD/ULTRALITE so that it can be recreated even by users without full PLS-CADD or PLS-CADD/LITE licenses. The .bak file download link can be found on the first page of this document.

Case 1

- Drake ACSR
- 1000' Ruling Span
- 2023 NESC Heavy Loading (1/2" ice, 4 psf wind, 0°F)
- Additionally, a utility-specified Extreme Ice loading (1½" ice, no wind, 30°F)

Using PLS-CADD or PLS-CADD/LITE:

1. Modify the Weather Cases table in the 2023 NESC Heavy criteria file to reflect the Extreme Ice case.
2. Next, set the Extreme Ice weather case as the controlling case for the "final after Load" condition in the table shown in Figure 3a.
3. In this example, we will only consider the **Load** condition to represent the cable in its "Final" state. To reflect this assumption in the model, find the "Tension Limits for Automatic Sagging & Checking of Wires." Update the "Cable Condition" value in Row 5 to "Load."
4. Ensure all other inputs are as shown in Figure 3b, and create a Sag-Tension report by clicking the corresponding button.



Figures 3a and 3b: Inputs in PLS-CADD/ULTRALITE

The resulting sag-tension report is shown below:

Ruling Span Sag Tension Report

Weather Case		Cable Load (lbs/ft)			R.S. Initial Cond.					R.S. Final Cond. After Creep					R.S. Final Cond. After Load				
#	Description	Hor. Load	Vert Load	Res. Load	Max. Tens. (lbs)	Hori. Tens. (lbs)	Max Ten %UL	C (ft)	R.S. Sag (ft)	Max. Tens. (lbs)	Hori. Tens. (lbs)	Max Ten %UL	C (ft)	R.S. Sag (ft)	Max. Tens. (lbs)	Hori. Tens. (lbs)	Max Ten %UL	C (ft)	R.S. Sag (ft)
1	NESC Heavy District Loading (250B)	0.70	2.08	2.49	14755	14702	47	5900	21.20	14605	14552	46	5839	21.42	12469	12406	40	4978	25.13
2	NESC Extreme Wind (250C)	1.63	1.09	1.96	11861	11820	38	6020	20.77	10944	10900	35	5552	22.53	9299	9247	30	4710	26.57
3	NESC Concurrent Ice and Wind (250D)	1.06	3.67	3.82	17549	17445	56	4567	27.40	17549	17445	56	4567	27.40	16204	16091	51	4213	29.71
4	Extreme Ice	0.00	5.87	5.87	21375	21171	68	3605	34.73	21375	21171	68	3605	34.73	21375	21171	68	3605	34.73
5	Cold Uplift	0.00	1.09	1.09	11722	11709	37	10703	11.68	10494	10480	33	9579	13.05	7763	7744	25	7078	17.67
6	Maximum Operating	0.00	1.09	1.09	5808	5782	18	5285	23.67	5227	5198	17	4752	26.33	4898	4867	16	4449	28.13
7	NESC Tension Limit (261H1c)	0.00	1.09	1.09	11019	11006	35	10060	12.43	9605	9589	30	8765	14.26	7207	7187	23	6569	19.04
8	NESC Blowout 6PSF	0.55	1.09	1.23	9528	9508	30	7754	16.13	8089	8066	26	6578	19.01	6498	6468	21	5275	23.71
9	No Wind (SWING 1)	0.00	1.09	1.09	9080	9063	29	8284	15.09	7524	7504	24	6859	18.23	5946	5921	19	5412	23.11
10	Moderate Wind (SWING 2)	0.55	1.09	1.23	10363	10344	33	8436	14.82	8947	8926	28	7279	17.18	7034	7007	22	5714	21.89
11	Moderate Wind (SWING 3)	0.55	1.09	1.23	9528	9508	30	7754	16.13	8089	8066	26	6578	19.01	6498	6468	21	5275	23.71
12	High Wind (SWING 4)	1.91	1.09	2.21	12567	12518	40	5677	22.03	11796	11745	37	5326	23.49	10143	10083	32	4572	27.37
13	GALLOPING (SWING)	0.35	2.08	2.11	12955	12912	41	6132	20.40	12261	12216	39	5801	21.56	10380	10327	33	4904	25.51
14	GALLOPING (SAG)	0.00	2.08	2.08	12872	12830	41	6179	20.24	12157	12113	39	5834	21.44	10276	10224	33	4924	25.41
15	-20 Deg F	0.00	1.09	1.09	11722	11709	37	10703	11.68	10494	10480	33	9579	13.05	7763	7744	25	7078	17.67
16	0 Deg F	0.00	1.09	1.09	11019	11006	35	10060	12.43	9605	9589	30	8765	14.26	7207	7187	23	6569	19.04
17	30 Deg F	0.00	1.09	1.09	10011	9996	32	9137	13.68	8461	8443	27	7718	16.20	6512	6489	21	5932	21.09
18	32 Deg F 1/2 Inch Ice	0.00	2.08	2.08	12872	12830	41	6179	20.24	12157	12113	39	5834	21.44	10276	10224	33	4924	25.41
19	60 Deg F	0.00	1.09	1.09	9080	9063	29	8284	15.09	7524	7504	24	6859	18.23	5946	5921	19	5412	23.11
20	90 Deg F	0.00	1.09	1.09	8230	8212	26	7507	16.66	6765	6743	21	6164	20.29	5620	5593	18	5113	24.47
21	120 Deg F	0.00	1.09	1.09	7490	7470	24	6828	18.32	6153	6129	20	5602	22.33	5425	5397	17	4933	25.36
22	167 Deg F	0.00	1.09	1.09	6530	6507	21	5948	21.03	5507	5480	17	5009	24.98	5142	5113	16	4673	26.77
23	212 Deg F	0.00	1.09	1.09	5808	5782	18	5285	23.67	5227	5198	17	4752	26.33	4898	4867	16	4449	28.13

Figure 4: Example sag-tension report for Drake ACSR

As discussed previously, NESC Rule 261H1c specifies tension limitations for open supply conductors: 35% of ultimate tension at the "Initial" condition, and 25% of ultimate tension at the "Final" condition. In this example, the **Load** condition is assumed to be "Final."

If only the **Load** condition is considered, then the two tension limitations required by the NESC appear to be satisfied. In reality, the cable is exceeding the NESC limit by 5% at the **Creep** condition if a heavy loading event does not occur in the first 10 years after construction. *This is something that we simply cannot accurately predict and certainly cannot rely upon occurring.*

"Creep is ALWAYS a factor!"