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Prestressing conductors in PLS-CADD and PLS-CADD Lite

Prestress is a process used by some to eliminate some or all of the permanent stretch of a conductor during construction prior to final sagging and tensioning. Modern practice is to string conductors to the 'initial' state and then let time (creep) and weather events (load) naturally stretch the conductors. This additional stretch is accounted for on the design side so the 'final' sags do not create any encroachments. This is not only easier to construct but much safer. However, due to ACSS conductor having very little 'creep' (some manufacturers actually specify no creep at all in the steel core of their ACSS conductor properties), tensions can remain high for many years (decades) if the overhead line doesn't experience the weather events expected under 'load'; this can lead to aeolian vibration problems if not accounted for (see TechNote "Why is Creep ALWAYS a Factor?" at http://www.powline.com/products/creep.html). Thus, some ACSS manufacturers are unfortunately now recommending that ACSS conductors be prestressed to simulate long term loadings as an aeolian vibration mitigation method rather than simply reducing their installed tensions and designing the overall transmisison line accordingly based on the creep tensions.

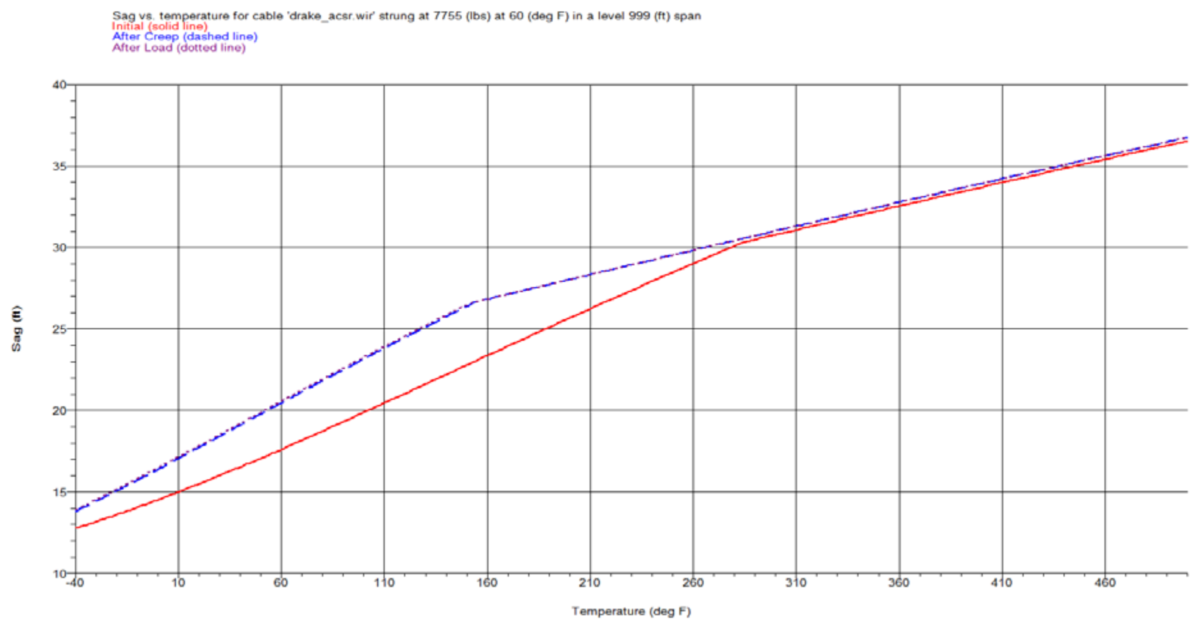
This paper will discuss how prestress is done in PLS-CADD and PLS-CADD LITE. For discussion purposes, a basic 1000' foot span of a typical 795 ACSR Drake is strung under 2012 National Electrical Safety Code for an arbitrarily selected location under NESC Medium (Rule 250B), 90 mph Extreme Wind (Rule 250C), and a Combined Wind and Ice of 30 mph with a 3/4" radial ice at 15°F (Rule 250D). Using the maximum tension limitations of Rule 261H1b, the maximum controlling design tension limit is 25% RTS, Final After Load. The resulting maximum tension then occurs under NESC Rule 250D of 14216 pounds horizontal tension. Note also that the maximum sag at 212°F is 28.4 feet. The Sag Tension report is given below;

Ruling Span Sag Tension Report

Weather Case		Cable Load			R.S. Initial Cond.					R.S. Final Cond. After Creep					R.S. Final Cond. After Load				
#	Description	Hor. Load (lbs/ft)	Vert Load (lbs/ft)	Res. Load (lbs/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)	Max. Tens. (lbs)	Hori. Tens. (lbs)	Max Ten %UL	C (ft)	R.S. Sag (ft)
1	NESC Medium District Loading (250B)	0.54	1.52	1.81	11300	11264	36	6230	20.04	10712	10674	34	5903	21.15	10664	10626	34	5877	21.25
2	NESC Extreme Wind (250C)	1.39	1.09	1.77	10154	10116	32	5712	21.86	9410	9368	30	5290	23.61	9371	9329	30	5268	23.71
3	NESC Concurrent Ice and Wind (250D)	0.50	2.83	2.87	14288	14216	45	4952	25.23	14285	14213	45	4951	25.23	14288	14216	45	4952	25.23
4	Extreme Ice	0.00	2.09	2.09	11813	11767	38	5620	22.22	11324	11275	36	5385	23.19	11285	11236	36	5366	23.27
5	Cold Uplift	0.00	1.09	1.09	9572	9557	30	8736	14.29	8528	8511	27	7780	16.05	8472	8454	27	7728	16.15
6	Maximum Operating	0.00	1.09	1.09	5214	5185	17	4739	26.36	4844	4812	15	4399	28.40	4844	4813	15	4400	28.40
7	NESC Tension Limit (261H1b)	0.00	1.09	1.09	8973	8956	28	8187	15.25	7869	7850	25	7176	17.40	7825	7805	25	7135	17.50
8	NESC Blowout 6PSF	0.55	1.09	1.23	8269	8246	26	6725	18.57	7263	7237	23	5901	21.16	7226	7200	23	5872	21.27
9	No Wind (SWING 1)	0.00	1.09	1.09	7770	7751	25	7085	17.62	6697	6675	21	6101	20.47	6664	6641	21	6071	20.57
10	Moderate Wind (SWING 2)	0.55	1.09	1.23	8966	8945	28	7295	17.12	7948	7924	25	6462	19.32	7909	7885	25	6430	19.42
11	Moderate Wind (SWING 3)	0.55	1.09	1.23	8269	8246	26	6725	18.57	7263	7237	23	5901	21.16	7226	7200	23	5872	21.27
12	High Wind (SWING 4)	1.91	1.09	2.21	11509	11456	37	5195	24.04	10965	10909	35	4947	25.25	10931	10876	35	4932	25.33
13	GALLOPING (SWING)	0.35	2.09	2.12	11855	11808	38	5562	22.45	11375	11325	36	5334	23.41	11333	11283	36	5315	23.50
14	GALLOPING (SAG)	0.00	2.09	2.09	11766	11719	37	5597	22.31	11274	11225	36	5361	23.30	11229	11180	36	5340	23.39
15	-20 Deg F	0.00	1.09	1.09	10048	10033	32	9171	13.61	9080	9064	29	8285	15.07	9018	9002	29	8228	15.17
16	0 Deg F	0.00	1.09	1.09	9423	9407	30	8599	14.52	8352	8334	27	7618	16.39	8302	8284	26	7572	16.49
17	30 Deg F	0.00	1.09	1.09	8549	8531	27	7798	16.01	7438	7418	24	6781	18.41	7394	7373	23	6740	18.53
18	32 Deg F 1/2 Inch Ice	0.00	2.09	2.09	11766	11719	37	5597	22.31	11274	11225	36	5361	23.30	11229	11180	36	5340	23.39
19	60 Deg F	0.00	1.09	1.09	7770	7751	25	7085	17.62	6697	6675	21	6101	20.47	6664	6641	21	6071	20.57
20	90 Deg F	0.00	1.09	1.09	7094	7073	23	6465	19.31	6097	6072	19	5550	22.50	6069	6044	19	5525	22.60
21	120 Deg F	0.00	1.09	1.09	6514	6491	21	5934	21.05	5608	5582	18	5102	24.48	5587	5560	18	5082	24.58
22	167 Deg F	0.00	1.09	1.09	5772	5746	18	5253	23.78	5083	5053	16	4619	27.05	5083	5054	16	4619	27.04
23	212 Deg F	0.00	1.09	1.09	5214	5185	17	4739	26.36	4844	4812	15	4399	28.40	4844	4813	15	4400	28.40

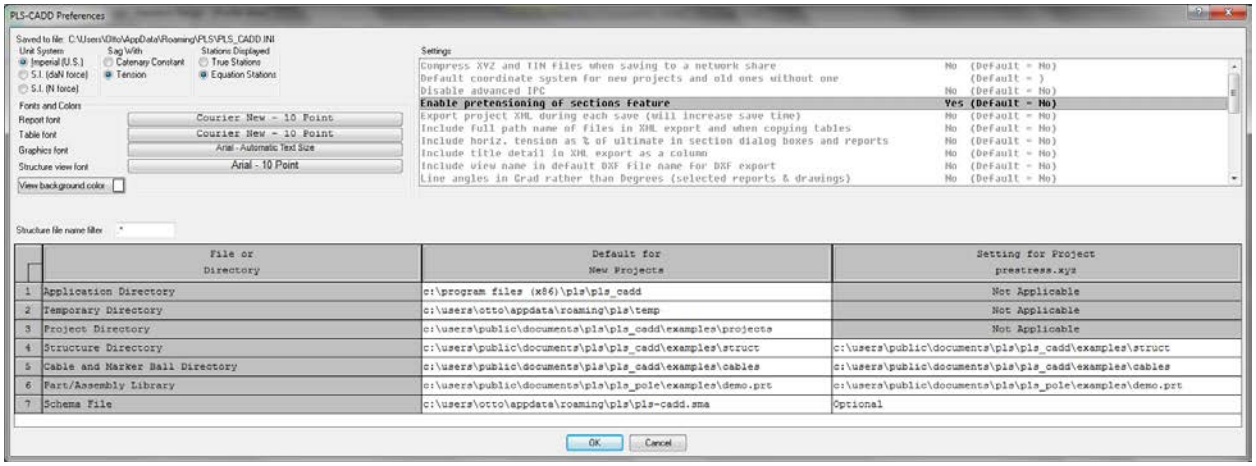
(Note that due to PLS-CADD accounting for the thickness of the poles for the actual cable attachment points, the span length of the conductor in all of the examples in this paper is 999.2 feet.)

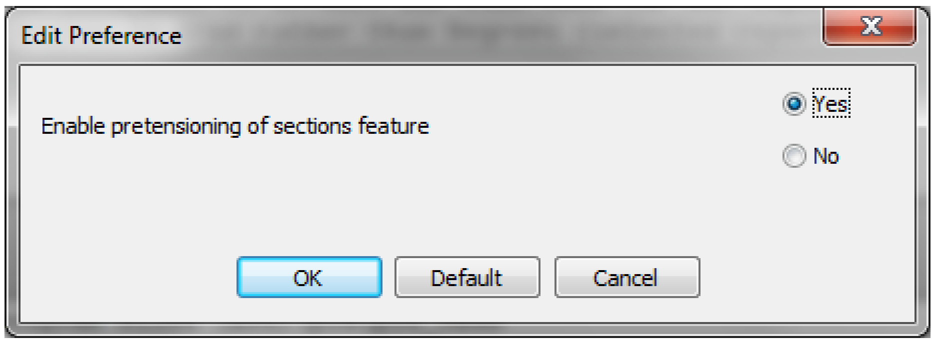
If a graph of Temperature versus Sag is generated (which can be done by selecting the "Graph" button under the Sections / Sag-Tensoin Report dialog), it can be seen that the conductor will experience additional sag, i.e. elongation, After Creep and After Load.



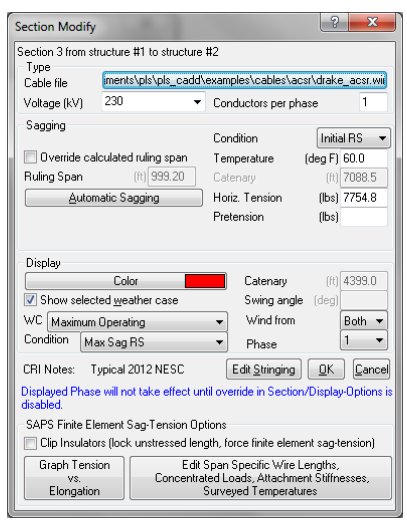
The concept of pretension is that if the conductor is pulled up to this maximum tension (and held for a specified time to be determined by the conductor manufacturer) it will then reach its maximum *design* load and thus its maximum *design* elongation. While some form of 'partial prestress' can certainly be accomplished at a lower tension – as will be dicussed later in this paper – the following example of prestress will consider the ultimate solution to eliminate all long-term stress due to creep and/or weather from the conductor. One of the most difficult problems in prestressing is that during the stringing operation, the conductor most likely will not be at the corresponding maximum tension temperature (15°F in this example) and thus a different tension must be calculated for the exact temperature of the conductor at stringing. Prestressing has always been able to be manually performed by the user in PLS-CADD if the user understood this very complex process and how to recreate it in PLS-CADD. Due to recent requests to make this process easier and automated, the automatic prestress feature has been added. However, there are some significant **dangers** involved in prestressing if the overall effect on a line is not understood and those will be discussed at the conclusion of this paper.

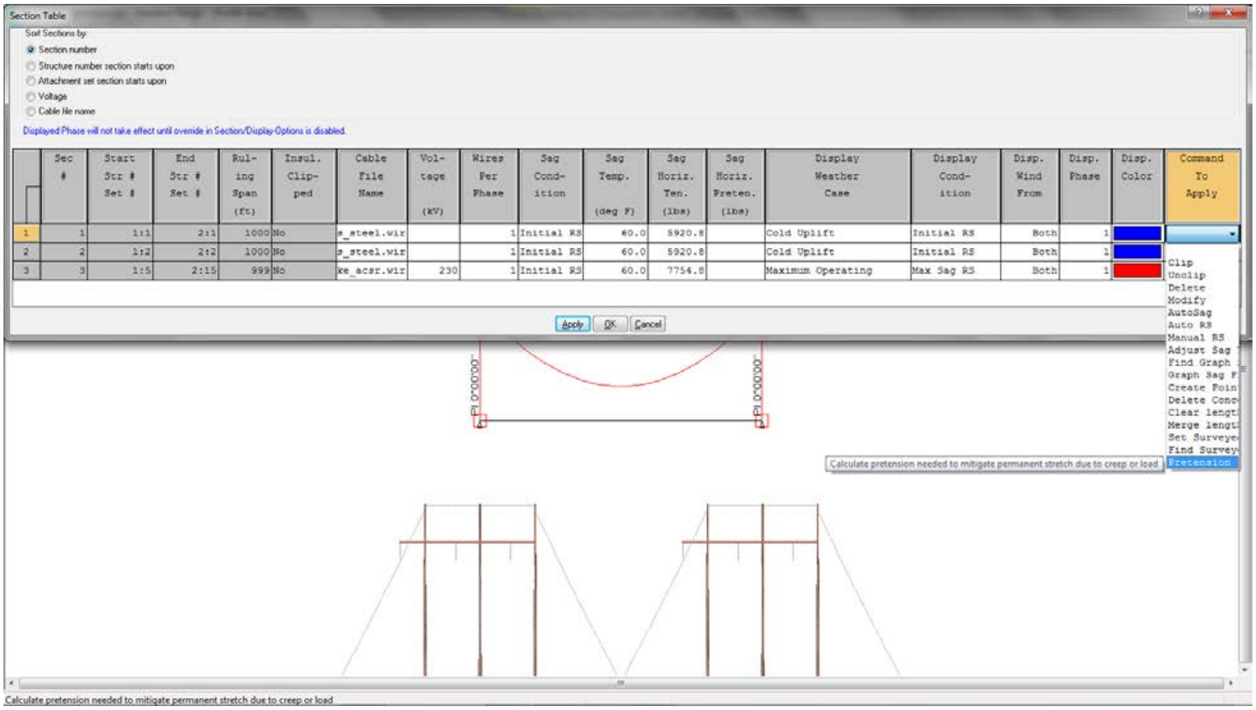
To use the prestress feature in PLS-CADD, it must first be enabled under *File / Preferences* by changing the 'Enable pretensioning of sections feature' to 'Yes':



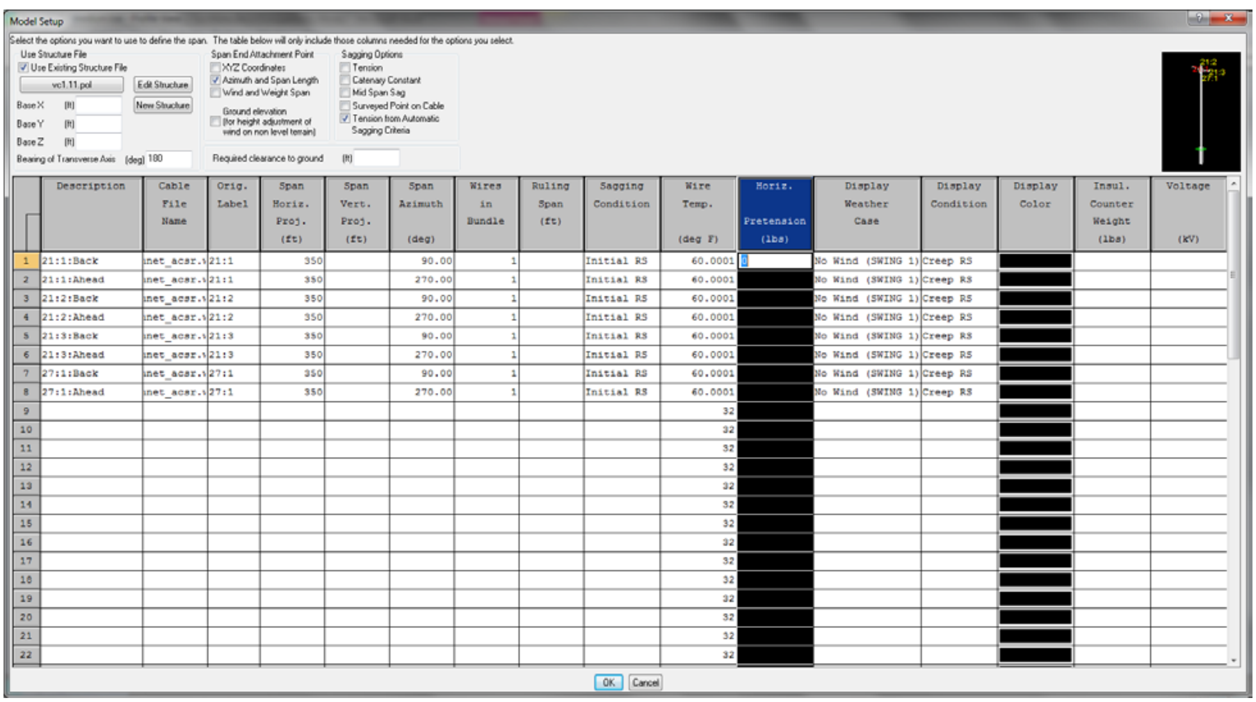


The conductor temperature at the time of prestressing is an important factor that should be evaluated. PLS-CADD will use the Sagging Temperature for this temperature (selected under *Sections / Modify* and also in *Sections / Table*). The default is 60° F / 15°C, but the default can be changed under Criteria / Default Wire Temperature and Condition. Once enabled, the Prestress function will be available under Sections / Modify and the Command to Apply column on the far right of the Sections/ Table.



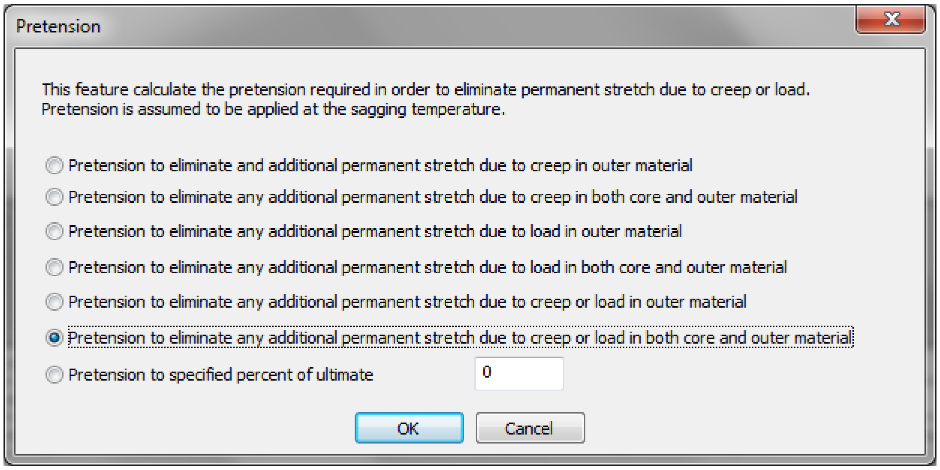


In PLS-CADD LITE, there will be an additional column in *Line / Setup* for inputting the Horizontal Pretension.

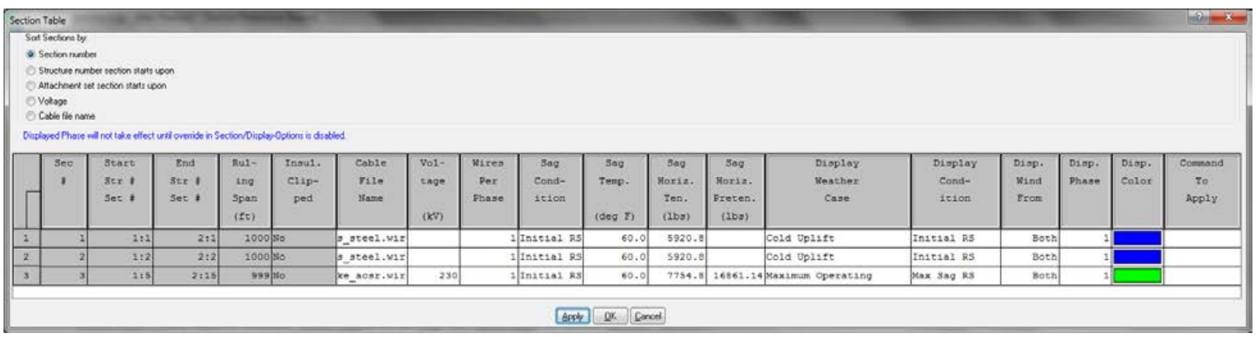


If using PLS-CADD LITE or the *Sections / Modify* option, the prestress value will have to be input manually.

Using the Pretension command in the *Sections / Table* will automatically calculate the prestress value and place it in the Pretension input for the *Sections / Modify* dialog box. This value will be calculated based on the selections in the Pretension dialog box below. It is suggested that a copy of your line be made using *Lines / Edit* to create a 'Standard Design' line and a 'After Prestress' line. Once the 'Pretension' option has been selected for the conductor(s) that you wish to pretension in the far right column, click the OK or Apply button and you will be presented with at first a warning (more on this later) and then the following dialog box;



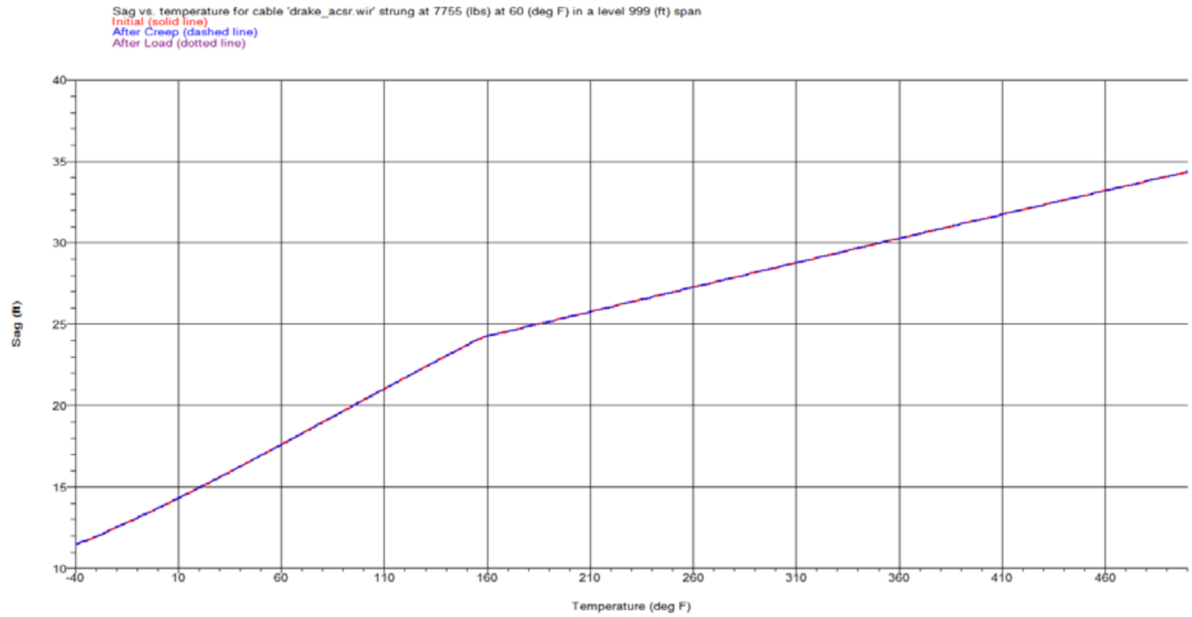
As discussed above, this first example will be to eliminate all stretch in the conductor; this means in both the steel core and the aluminum outer stranding of our example ACSR. As such, the 6th option is selected for this example. The other options are self-explanatory and with the exception of one, will all result in a lower pretension value but will correspondingly result in some additional elongation of the conductor at a later time as not all of the elongation will be removed. After selecting OK, the amount of tension at the sagging temperature will be automatically calculated for you.



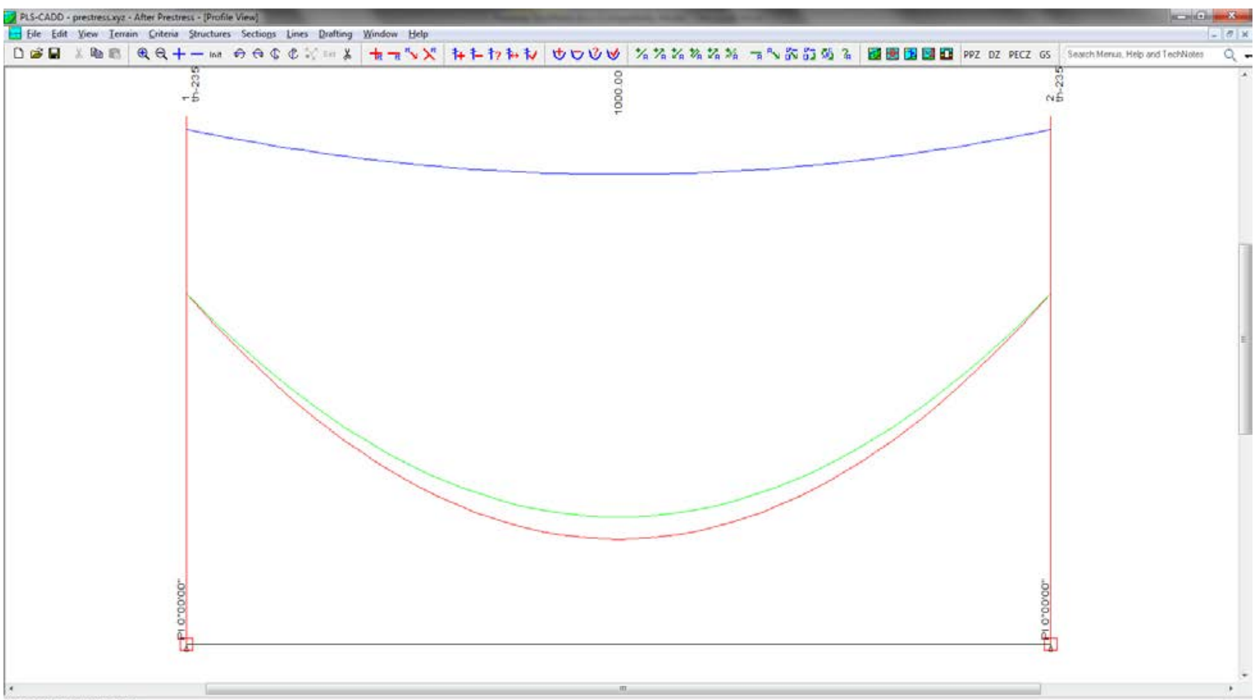
	Sec #	Start Str # Set #	End Str # Set #	Ruling Span (ft)	Insul. Clipped	Cable File Name	Voltage (kV)	Wires Per Phase	Sag Condition	Sag Temp. (deg F)	Sag Horiz. Ten. (lbs)	Sag Horiz. Preten. (lbs)	Display Weather Case	Display Condition	Disp. Wind From	Disp. Phase	Disp. Color	Command To Apply
1	1	1:1	2:1	1000	No	s_steel.wir		1	Initial RS	60.0	5920.8		Cold Uplift	Initial RS	Both	1		
2	2	1:2	2:2	1000	No	s_steel.wir		1	Initial RS	60.0	5920.8		Cold Uplift	Initial RS	Both	1		
3	3	1:5	2:15	999	No	xe_acsr.wir	230	1	Initial RS	60.0	7754.8	16861.14	Maximum Operating	Max Sag RS	Both	1		

It is very important to note that the tension is 16,861 pounds; this is significantly higher than the 14,216 pounds required to stretch the conductor by the same amount at 15°F. This is the first warning that you should be wary of prestressing conductors as you will need to check all the components on your structures such as the insulators, guys, anchors, etc. to make sure they can handle this higher tension during construction. If the line in our example was designed to the minimum requirements of the NESC, then no, they were not as the maximum tension used for their design was only 14,216 pounds.

Examining the graph of the temperature versus sag will show that all of the long-term elongation has now been removed from the conductor;



A quick look at the profile view of your project will show the apparent advantage of prestressing; in our example span, the red colored conductor is the 'Standard Design' and the green colored conductor is the 'After Prestress' design.



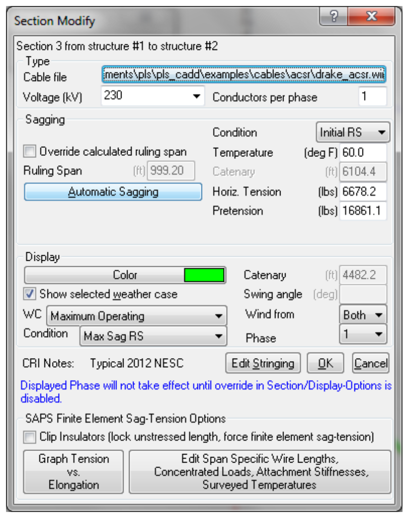
Generating the Sag-Tensions report will also show that the sag at 212°F is now 25.84 feet, nearly 3 feet less than the original design sag of 28.4 feet.

Ruling Span Sag Tension Report

#	Description (Weather Case)	Cable Load Hor. (lbs/ft)	Cable Load Vert (lbs/ft)	Cable Load Res. (lbs/ft)	R.S. Initial Cond. Max. Tens. (lbs)	R.S. Initial Cond. Hori. Tens. (lbs)	R.S. Initial Cond. Max Ten %UL	R.S. Initial Cond. C (ft)	R.S. Initial Cond. R.S. Sag (ft)	R.S. Final Cond. After Creep Max. Tens. (lbs)	R.S. Final Cond. After Creep Hori. Tens. (lbs)	R.S. Final Cond. After Creep Max Ten %UL	R.S. Final Cond. After Creep C (ft)	R.S. Final Cond. After Creep R.S. Sag (ft)	R.S. Final Cond. After Load Max. Tens. (lbs)	R.S. Final Cond. After Load Hori. Tens. (lbs)	R.S. Final Cond. After Load Max Ten %UL	R.S. Final Cond. After Load C (ft)	R.S. Final Cond. After Load R.S. Sag (ft)
1	NESC Medium District Loading (250B)	0.54	1.52	1.81	12057	12023	38	6649	18.78	12056	12022	38	6649	18.78	12057	12023	38	6649	18.78
2	NESC Extreme Wind (250C)	1.39	1.09	1.77	10476	10438	33	5894	21.19	10476	10438	33	5894	21.19	10476	10438	33	5894	21.19

3	NESC Concurrent Ice and Wind (250D)	0.50	2.83	2.87	15593	15527	50	5408	23.09	15593	15526	50	5408	23.09	15593	15527	50	5408	23.09
4	Extreme Ice	0.00	2.09	2.09	12550	12506	40	5973	20.91	12550	12506	40	5973	20.91	12550	12506	40	5973	20.91
5	Cold Uplift	0.00	1.09	1.09	10199	10184	32	9309	13.41	10198	10184	32	9309	13.41	10199	10184	32	9309	13.41
6	Maximum Operating	0.00	1.09	1.09	5317	5289	17	4835	25.84	5317	5289	17	4835	25.84	5317	5289	17	4835	25.84
7	NESC Tension Limit (261H1b)	0.00	1.09	1.09	9344	9328	30	8527	14.64	9344	9328	30	8526	14.64	9344	9328	30	8527	14.64
8	NESC Blowout 6PSF	0.55	1.09	1.23	8334	8312	26	6778	18.42	8334	8312	26	6778	18.42	8334	8312	26	6778	18.42
9	No Wind (SWING 1)	0.00	1.09	1.09	7775	7756	25	7089	17.61	7774	7755	25	7089	17.61	7775	7756	25	7089	17.61
10	Moderate Wind (SWING 2)	0.55	1.09	1.23	9239	9218	29	7517	16.61	9238	9218	29	7517	16.61	9239	9218	29	7517	16.61
11	Moderate Wind (SWING 3)	0.55	1.09	1.23	8334	8312	26	6778	18.42	8334	8312	26	6778	18.42	8334	8312	26	6778	18.42
12	High Wind (SWING 4)	1.91	1.09	2.21	12036	11985	38	5435	22.98	12035	11985	38	5435	22.98	12036	11985	38	5435	22.98
13	GALLOPING (SWING)	0.35	2.09	2.12	12587	12542	40	5908	21.14	12587	12542	40	5907	21.14	12587	12542	40	5908	21.14
14	GALLOPING (SAG)	0.00	2.09	2.09	12489	12445	40	5944	21.01	12489	12445	40	5944	21.01	12489	12445	40	5944	21.01
15	-20 Deg F	0.00	1.09	1.09	10912	10898	35	9962	12.53	10911	10898	35	9961	12.53	10912	10898	35	9962	12.53
16	0 Deg F	0.00	1.09	1.09	9976	9961	32	9106	13.71	9976	9961	32	9105	13.71	9976	9961	32	9106	13.71
17	30 Deg F	0.00	1.09	1.09	8769	8752	28	8000	15.60	8769	8752	28	8000	15.61	8769	8752	28	8000	15.60
18	32 Deg F 1/2 Inch Ice	0.00	2.09	2.09	12489	12445	40	5944	21.01	12489	12445	40	5944	21.01	12489	12445	40	5944	21.01
19	60 Deg F	0.00	1.09	1.09	7775	7756	25	7089	17.61	7774	7755	25	7089	17.61	7775	7756	25	7089	17.61
20	90 Deg F	0.00	1.09	1.09	6964	6943	22	6346	19.67	6964	6943	22	6346	19.68	6964	6943	22	6346	19.67
21	120 Deg F	0.00	1.09	1.09	6315	6292	20	5751	21.71	6315	6291	20	5751	21.72	6315	6292	20	5751	21.71
22	167 Deg F	0.00	1.09	1.09	5608	5581	18	5102	24.48	5608	5581	18	5102	24.48	5608	5581	18	5102	24.48
23	212 Deg F	0.00	1.09	1.09	5317	5289	17	4835	25.84	5317	5289	17	4835	25.84	5317	5289	17	4835	25.84

However, further examination of the Sag-Tension report or running the Sections / Check function will unfold the second warning you should be aware of if prestressing your conductors; the tension of the conductor under NESC Rule261H1b is now at **30%,** which is significantly higher than the allowable 25%! In order to keep from violating the NESC, the conductor must now be strung at a lower tension. This can be done automatically in PLS-CADD by using the Autosag function in *Sections / Modify* (or globally for many conductors in the *Sections / Table* on the far right column.)



After this retensioning, examining the Sag-Tension report will now show compliance to the NESC, but it will also show the maximum sag at 212°F is now 27.87 feet; only 6 inches less than the original design.

Ruling Span Sag Tension Report

#	Description	Cable Load Hor. (lbs/ft)	Cable Load Vert (lbs/ft)	Cable Load Res. (lbs/ft)	R.S. Initial Cond. Max. Tens. (lbs)	R.S. Initial Cond. Hori. Tens. (lbs)	R.S. Initial Cond. Max Ten %UL	R.S. Initial Cond. C (ft)	R.S. Initial Cond. R.S. Sag (ft)	R.S. Final Cond. After Creep Max. Tens. (lbs)	R.S. Final Cond. After Creep Hori. Tens. (lbs)	R.S. Final Cond. After Creep Max Ten %UL	R.S. Final Cond. After Creep C (ft)	R.S. Final Cond. After Creep R.S. Sag (ft)	R.S. Final Cond. After Load Max. Tens. (lbs)	R.S. Final Cond. After Load Hori. Tens. (lbs)	R.S. Final Cond. After Load Max Ten %UL	R.S. Final Cond. After Load C (ft)	R.S. Final Cond. After Load R.S. Sag (ft)
1	NESC Medium District Loading (250B)	0.54	1.52	1.81	10713	10674	34	5904	21.15	10713	10674	34	5904	21.15	10713	10674	34	5904	21.15
2	NESC Extreme Wind (250C)	1.39	1.09	1.77	9411	9369	30	5290	23.61	9411	9369	30	5290	23.61	9411	9369	30	5290	23.61
3	NESC Concurrent Ice and Wind (250D)	0.50	2.83	2.87	14336	14264	46	4969	25.14	14336	14264	46	4969	25.14	14336	14264	46	4969	25.14
4	Extreme Ice	0.00	2.09	2.09	11327	11279	36	5387	23.18	11327	11279	36	5387	23.18	11327	11279	36	5387	23.18
5	Cold Uplift	0.00	1.09	1.09	8532	8515	27	7783	16.04	8532	8515	27	7783	16.04	8532	8515	27	7783	16.04
6	Maximum Operating	0.00	1.09	1.09	4934	4904	16	4482	27.87	4934	4904	16	4482	27.87	4934	4904	16	4482	27.87
7	NESC Tension Limit (261H1b)	0.00	1.09	1.09	7873	7854	25	7179	17.39	7873	7854	25	7179	17.39	7873	7854	25	7179	17.39
8	NESC Blowout 6PSF	0.55	1.09	1.23	7263	7237	23	5902	21.16	7263	7237	23	5902	21.16	7263	7237	23	5902	21.16
9	No Wind (SWING 1)	0.00	1.09	1.09	6698	6675	21	6102	20.46	6698	6675	21	6102	20.46	6698	6675	21	6102	20.46
10	Moderate Wind (SWING 2)	0.55	1.09	1.23	7952	7928	25	6465	19.31	7952	7928	25	6465	19.31	7952	7928	25	6465	19.31
11	Moderate Wind (SWING 3)	0.55	1.09	1.23	7263	7237	23	5902	21.16	7263	7237	23	5902	21.16	7263	7237	23	5902	21.16
12	High Wind (SWING 4)	1.91	1.09	2.21	10968	10913	35	4949	25.24	10968	10913	35	4949	25.24	10968	10913	35	4949	25.24
13	GALLOPING (SWING)	0.35	2.09	2.12	11376	11326	36	5335	23.41	11376	11326	36	5335	23.41	11376	11326	36	5335	23.41
14	GALLOPING (SAG)	0.00	2.09	2.09	11275	11226	36	5362	23.29	11275	11226	36	5362	23.29	11275	11226	36	5362	23.29
15	-20 Deg F	0.00	1.09	1.09	9084	9067	29	8288	15.06	9084	9067	29	8288	15.06	9084	9067	29	8288	15.06
16	0 Deg F	0.00	1.09	1.09	8362	8344	27	7627	16.37	8362	8344	27	7627	16.37	8362	8344	27	7627	16.37
17	30 Deg F	0.00	1.09	1.09	7442	7422	24	6784	18.40	7442	7422	24	6784	18.40	7442	7422	24	6784	18.40
18	32 Deg F 1/2 Inch Ice	0.00	2.09	2.09	11275	11226	36	5362	23.29	11275	11226	36	5362	23.29	11275	11226	36	5362	23.29
19	60 Deg F	0.00	1.09	1.09	6698	6675	21	6102	20.46	6698	6675	21	6102	20.46	6698	6675	21	6102	20.46
20	90 Deg F	0.00	1.09	1.09	6097	6073	19	5551	22.50	6097	6073	19	5551	22.50	6097	6073	19	5551	22.50
21	120 Deg F	0.00	1.09	1.09	5609	5582	18	5103	24.48	5609	5582	18	5103	24.48	5609	5582	18	5103	24.48
22	167 Deg F	0.00	1.09	1.09	5182	5153	16	4710	26.52	5182	5153	16	4710	26.52	5182	5153	16	4710	26.52
23	212 Deg F	0.00	1.09	1.09	4934	4904	16	4482	27.87	4934	4904	16	4482	27.87	4934	4904	16	4482	27.87

Thus, for our ACSR example, the conductor was pulled 2,645 pounds higher than the structures were designed for, and only a 6 inch gain in sag was the result. However, since the conductor tension had to be reduced from the original tension, a lower pretension can be used. Repeating the pretension process in Sections / Table, the pretension now only has to be 15,074 pounds. Using this lower pretension means that the Automatic Sagging can be used again to tension the wire to the tightest possible tension. This process can be done for several iterations to finally find the perfect balance of prestress and stringing tension. The final Sag-Tension results for our example ACSR are as follows;

Ruling Span Sag Tension Report

#	Description	Cable Load Hor. (lbs/ft)	Cable Load Vert (lbs/ft)	Cable Load Res. (lbs/ft)	R.S. Initial Cond. Max. Tens. (lbs)	R.S. Initial Cond. Hori. Tens. (lbs)	R.S. Initial Cond. Max Ten %UL	R.S. Initial Cond. C (ft)	R.S. Initial Cond. R.S. Sag (ft)	R.S. Final Cond. After Creep Max. Tens. (lbs)	R.S. Final Cond. After Creep Hori. Tens. (lbs)	R.S. Final Cond. After Creep Max Ten %UL	R.S. Final Cond. After Creep C (ft)	R.S. Final Cond. After Creep R.S. Sag (ft)	R.S. Final Cond. After Load Max. Tens. (lbs)	R.S. Final Cond. After Load Hori. Tens. (lbs)	R.S. Final Cond. After Load Max Ten %UL	R.S. Final Cond. After Load C (ft)	R.S. Final Cond. After Load R.S. Sag (ft)
1	NESC Medium District Loading (250B)	0.54	1.52	1.81	10711	10672	34	5902	21.16	10711	10672	34	5902	21.16	10711	10672	34	5902	21.16
2	NESC Extreme Wind (250C)	1.39	1.09	1.77	9409	9367	30	5289	23.61	9409	9367	30	5289	23.61	9409	9367	30	5289	23.61
3	NESC Concurrent Ice and Wind (250D)	0.50	2.83	2.87	14334	14262	46	4968	25.14	14334	14262	46	4968	25.14	14334	14262	46	4968	25.14
4	Extreme Ice	0.00	2.09	2.09	11325	11277	36	5386	23.19	11325	11277	36	5386	23.19	11325	11277	36	5386	23.19
5	Cold Uplift	0.00	1.09	1.09	8530	8512	27	7781	16.04	8530	8512	27	7781	16.04	8530	8512	27	7781	16.04
6	Maximum Operating	0.00	1.09	1.09	4847	4816	15	4402	28.38	4847	4816	15	4402	28.38	4847	4816	15	4402	28.38
7	NESC Tension Limit (261H1b)	0.00	1.09	1.09	7871	7852	25	7177	17.40	7871	7852	25	7177	17.40	7871	7852	25	7177	17.40
8	NESC Blowout 6PSF	0.55	1.09	1.23	7261	7235	23	5900	21.16	7261	7235	23	5900	21.16	7261	7235	23	5900	21.16
9	No Wind (SWING 1)	0.00	1.09	1.09	6699	6676	21	6103	20.46	6699	6676	21	6103	20.46	6699	6676	21	6103	20.46
10	Moderate Wind (SWING 2)	0.55	1.09	1.23	7950	7926	25	6464	19.32	7950	7926	25	6464	19.32	7950	7926	25	6464	19.32
11	Moderate Wind (SWING 3)	0.55	1.09	1.23	7261	7235	23	5900	21.16	7261	7235	23	5900	21.16	7261	7235	23	5900	21.16
12	High Wind (SWING 4)	1.91	1.09	2.21	10966	10910	35	4948	25.25	10966	10910	35	4948	25.25	10966	10910	35	4948	25.25
13	GALLOPING (SWING)	0.35	2.09	2.12	11374	11324	36	5334	23.42	11374	11324	36	5334	23.42	11374	11324	36	5334	23.42
14	GALLOPING (SAG)	0.00	2.09	2.09	11273	11224	36	5361	23.30	11273	11224	36	5361	23.30	11273	11224	36	5361	23.30
15	-20 Deg F	0.00	1.09	1.09	9082	9065	29	8286	15.07	9082	9065	29	8286	15.07	9082	9065	29	8286	15.07
16	0 Deg F	0.00	1.09	1.09	8354	8336	27	7620	16.38	8354	8336	27	7620	16.38	8354	8336	27	7620	16.38
17	30 Deg F	0.00	1.09	1.09	7440	7420	24	6782	18.41	7440	7420	24	6782	18.41	7440	7420	24	6782	18.41
18	32 Deg F 1/2 Inch Ice	0.00	2.09	2.09	11273	11224	36	5361	23.30	11273	11224	36	5361	23.30	11273	11224	36	5361	23.30
19	60 Deg F	0.00	1.09	1.09	6699	6676	21	6103	20.46	6699	6676	21	6103	20.46	6699	6676	21	6103	20.46
20	90 Deg F	0.00	1.09	1.09	6098	6074	19	5552	22.49	6098	6074	19	5552	22.49	6098	6074	19	5552	22.49
21	120 Deg F	0.00	1.09	1.09	5610	5583	18	5104	24.47	5610	5583	18	5104	24.47	5610	5583	18	5104	24.47
22	167 Deg F	0.00	1.09	1.09	5087	5058	16	4623	27.02	5087	5058	16	4623	27.02	5087	5058	16	4623	27.02
23	212 Deg F	0.00	1.09	1.09	4847	4816	15	4402	28.38	4847	4816	15	4402	28.38	4847	4816	15	4402	28.38

In summary, the ACSR was pretensioned to 15,075 pounds which created the Initial state of the conductor being identical in sags and tensions to the Final state. Of course this pretension would have to be calculated for the actual conductor temperature at the time of prestress and would be different for the wide range of temperatures that could be experienced during the prestressing. The end result would be stringing in a wire at the same state as the Final condition is expected to be. This is all dependent upon the actual maximum design weather condition of ice and/or wind being experienced on the line; if a higher loading does occur the conductor will stretch more and additional permanent elongation will occur. It is for this reason that as stated above, modern construction method does not use prestressing, but strings the conductor to the natural prestressed condition and lets time and weather do the stretching according to the design.

This same example will now be repeated for an equivalent ACSS conductor. Due to the 25% Final tension under NESC Rule 261H1b, the maximum sag is 33 feet at 212°F.

Ruling Span Sag Tension Report

#	Weather Case: Description	Cable Load (lbs/ft): Hor.	Cable Load (lbs/ft): Vert	Cable Load (lbs/ft): Res.	R.S. Initial Cond.: Max. Tens. (lbs)	R.S. Initial Cond.: Hori. Tens. (lbs)	R.S. Initial Cond.: Max Ten %UL	R.S. Initial Cond.: C (ft)	R.S. Initial Cond.: R.S. Sag (ft)	R.S. Final Cond. After Creep: Max. Tens. (lbs)	R.S. Final Cond. After Creep: Hori. Tens. (lbs)	R.S. Final Cond. After Creep: Max Ten %UL	R.S. Final Cond. After Creep: C (ft)	R.S. Final Cond. After Creep: R.S. Sag (ft)	R.S. Final Cond. After Load: Max. Tens. (lbs)	R.S. Final Cond. After Load: Hori. Tens. (lbs)	R.S. Final Cond. After Load: Max Ten %UL	R.S. Final Cond. After Load: C (ft)	R.S. Final Cond. After Load: R.S. Sag (ft)
1	NESC Medium District Loading (250B)	0.54	1.52	1.81	8603	8555	33	4733	26.39	8603	8555	33	4733	26.39	7694	7641	30	4227	29.56
2	NESC Extreme Wind (250C)	1.39	1.09	1.77	8077	8028	31	4534	27.55	8077	8028	31	4534	27.55	6991	6934	27	3916	31.91
3	NESC Concurrent Ice and Wind (250D)	0.50	2.83	2.87	11203	11110	43	3871	32.29	11203	11110	43	3871	32.29	11203	11110	43	3871	32.29
4	Extreme Ice	0.00	2.09	2.09	9219	9159	36	4376	28.55	9219	9159	36	4376	28.55	8464	8399	33	4012	31.14
5	Cold Uplift	0.00	1.09	1.09	6719	6697	26	6125	20.39	6719	6697	26	6125	20.39	5273	5245	20	4797	26.04
6	Maximum Operating	0.00	1.09	1.09	4509	4475	17	4093	30.53	4240	4205	16	3846	32.50	4175	4139	16	3786	33.02
7	NESC Tension Limit (261H1b)	0.00	1.09	1.09	6475	6451	25	5900	21.16	6475	6451	25	5900	21.16	5066	5036	20	4606	27.12
8	NESC Blowout 6PSF	0.55	1.09	1.23	6402	6373	25	5199	24.02	6402	6373	25	5199	24.02	5237	5201	20	4243	29.45
9	No Wind (SWING 1)	0.00	1.09	1.09	5946	5921	23	5415	23.06	5946	5921	23	5415	23.06	4826	4795	19	4386	28.49
10	Moderate Wind (SWING 2)	0.55	1.09	1.23	6712	6684	26	5453	22.90	6712	6684	26	5453	22.90	5385	5350	21	4364	28.63
11	Moderate Wind (SWING 3)	0.55	1.09	1.23	6402	6373	25	5199	24.02	6402	6373	25	5199	24.02	5237	5201	20	4243	29.45
12	High Wind (SWING 4)	1.91	1.09	2.20	9246	9179	36	4163	30.01	9246	9179	36	4163	30.01	8429	8357	33	3790	32.98
13	GALLOPING (SWING)	0.35	2.09	2.12	9275	9214	36	4341	28.78	9275	9214	36	4341	28.78	8533	8466	33	3989	31.33
14	GALLOPING (SAG)	0.00	2.09	2.09	9202	9142	36	4367	28.61	9202	9142	36	4367	28.61	8434	8369	33	3998	31.26
15	-20 Deg F	0.00	1.09	1.09	6902	6880	27	6293	19.84	6902	6880	27	6293	19.84	5475	5448	21	4983	25.07
16	0 Deg F	0.00	1.09	1.09	6657	6634	26	6068	20.58	6657	6634	26	6068	20.58	5210	5181	20	4738	26.36
17	30 Deg F	0.00	1.09	1.09	6295	6271	24	5735	21.77	6295	6271	24	5735	21.77	4982	4952	19	4529	27.58
18	32 Deg F 1/2 Inch Ice	0.00	2.09	2.09	9202	9142	36	4367	28.61	9202	9142	36	4367	28.61	8434	8369	33	3998	31.26
19	60 Deg F	0.00	1.09	1.09	5946	5921	23	5415	23.06	5946	5921	23	5415	23.06	4826	4795	19	4386	28.49
20	90 Deg F	0.00	1.09	1.09	5613	5587	22	5109	24.44	5474	5447	21	4982	25.07	4680	4648	18	4251	29.39
21	120 Deg F	0.00	1.09	1.09	5303	5275	20	4824	25.89	5086	5056	20	4624	27.01	4543	4510	18	4124	30.30
22	167 Deg F	0.00	1.09	1.09	4870	4839	19	4425	28.23	4603	4571	18	4180	29.89	4346	4311	17	3943	31.69
23	212 Deg F	0.00	1.09	1.09	4509	4475	17	4093	30.53	4240	4205	16	3846	32.50	4175	4139	16	3786	33.02

This is a little more than 4.5 feet more than the equivalent ACSR sag. This confuses many people at first as the concept of ACSS is that it is supposed to sag less, but since it has a lower initial strength to begin with (the aluminum is annealed and has very little, if any, strength) and therefore it must be sagged in at a lower tension; at least to meet the requirements of the NESC.

Using the Sections / Table to Pretension and then AutoSag the ACSS, it can be seen that the ACSS can actually be tightened up more after the pretensioning and then the resulting Sag-Tension run shows significantly less sag than the original ACSS installation;

Ruling Span Sag Tension Report

#	Weather Case: Description	Cable Load (lbs/ft): Hor.	Cable Load (lbs/ft): Vert	Cable Load (lbs/ft): Res.	R.S. Initial Cond.: Max. Tens. (lbs)	R.S. Initial Cond.: Hori. Tens. (lbs)	R.S. Initial Cond.: Max Ten %UL	R.S. Initial Cond.: C (ft)	R.S. Initial Cond.: R.S. Sag (ft)	R.S. Final Cond. After Creep: Max. Tens. (lbs)	R.S. Final Cond. After Creep: Hori. Tens. (lbs)	R.S. Final Cond. After Creep: Max Ten %UL	R.S. Final Cond. After Creep: C (ft)	R.S. Final Cond. After Creep: R.S. Sag (ft)	R.S. Final Cond. After Load: Max. Tens. (lbs)	R.S. Final Cond. After Load: Hori. Tens. (lbs)	R.S. Final Cond. After Load: Max Ten %UL	R.S. Final Cond. After Load: C (ft)	R.S. Final Cond. After Load: R.S. Sag (ft)
1	NESC Medium District Loading (250B)	0.54	1.52	1.81	9335	9291	36	5140	24.30	9335	9291	36	5140	24.30	9253	9209	36	5095	24.52
2	NESC Extreme Wind (250C)	1.39	1.09	1.77	8298	8250	32	4659	26.81	8298	8250	32	4659	26.81	8235	8187	32	4624	27.02
3	NESC Concurrent Ice and Wind (250D)	0.50	2.83	2.87	12937	12857	50	4479	27.89	12937	12857	50	4479	27.89	12937	12857	50	4479	27.89
4	Extreme Ice	0.00	2.09	2.09	10052	9997	39	4776	26.16	10052	9997	39	4776	26.16	9973	9918	39	4738	26.36
5	Cold Uplift	0.00	1.09	1.09	6898	6876	27	6289	19.85	6898	6876	27	6289	19.85	6811	6789	26	6209	20.11
6	Maximum Operating	0.00	1.09	1.09	5074	5044	20	4614	27.08	5074	5044	20	4614	27.08	5074	5044	20	4614	27.08
7	NESC Tension Limit (261H1b)	0.00	1.09	1.09	6473	6450	25	5899	21.17	6473	6450	25	5899	21.17	6473	6450	25	5899	21.17
8	NESC Blowout 6PSF	0.55	1.09	1.23	6499	6470	25	5279	23.66	6499	6470	25	5279	23.66	6499	6470	25	5279	23.66
9	No Wind (SWING 1)	0.00	1.09	1.09	6099	6074	24	5555	22.48	6099	6074	24	5555	22.48	6099	6074	24	5555	22.48
10	Moderate Wind (SWING 2)	0.55	1.09	1.23	6724	6696	26	5463	22.86	6724	6696	26	5463	22.86	6724	6696	26	5463	22.86
11	Moderate Wind (SWING 3)	0.55	1.09	1.23	6499	6470	25	5279	23.66	6499	6470	25	5279	23.66	6499	6470	25	5279	23.66
12	High Wind (SWING 4)	1.91	1.09	2.20	9843	9780	38	4436	28.16	9843	9780	38	4436	28.16	9777	9714	38	4406	28.36
13	GALLOPING (SWING)	0.35	2.09	2.12	10111	10055	39	4738	26.37	10111	10055	39	4738	26.37	10036	9980	39	4702	26.57
14	GALLOPING (SAG)	0.00	2.09	2.09	10007	9952	39	4754	26.27	10007	9952	39	4754	26.27	9932	9876	38	4718	26.48
15	-20 Deg F	0.00	1.09	1.09	7279	7259	28	6639	18.81	7279	7259	28	6639	18.81	7186	7165	28	6553	19.05
16	0 Deg F	0.00	1.09	1.09	6778	6756	26	6179	20.21	6778	6756	26	6179	20.21	6694	6671	26	6101	20.47
17	30 Deg F	0.00	1.09	1.09	6344	6320	24	5780	21.60	6344	6320	24	5780	21.60	6344	6320	24	5780	21.60
18	32 Deg F 1/2 Inch Ice	0.00	2.09	2.09	10007	9952	39	4754	26.27	10007	9952	39	4754	26.27	9932	9876	38	4718	26.48
19	60 Deg F	0.00	1.09	1.09	6099	6074	24	5555	22.48	6099	6074	24	5555	22.48	6099	6074	24	5555	22.48
20	90 Deg F	0.00	1.09	1.09	5866	5841	23	5342	23.38	5866	5841	23	5342	23.38	5866	5841	23	5342	23.38
21	120 Deg F	0.00	1.09	1.09	5652	5625	22	5145	24.28	5652	5625	22	5145	24.28	5652	5625	22	5145	24.28
22	167 Deg F	0.00	1.09	1.09	5342	5314	21	4860	25.70	5342	5314	21	4860	25.70	5342	5314	21	4860	25.70
23	212 Deg F	0.00	1.09	1.09	5074	5044	20	4614	27.08	5074	5044	20	4614	27.08	5074	5044	20	4614	27.08

However, when comparing that to the original ACSR sag of 28.4 feet, this is only slightly more than a 1.3 foot gain in ground clearance.

Finally, an equivalent High Strength ACSS conductor was used for a third review of the effects of prestressing. To summarize without showing all of the reports, the maximum installed sag of a Drake ACSS HS285 installed to the maximum tension limits allowed by the NESC is 28.81 feet under 212°F Final After Load. After pretensioning to fully prestress the core and outer strandings of 15,464 pounds and retensioning the conductor to the NESC maximum tension limits, the maximum sag is 22.15 feet at 212°F, or a 6.25 feet gain in ground clearance over the standard ACSR equivalent. But to state once again, unless a specific pretension load case is developed, the structure most likely was only designed to handle 14,216 pounds of tension and thus the structure would theoretically fail if the 15,464 pounds was applied during this pretension effort. If the pretension were limited to the maximum 14,216 pounds that the structure was designed for, the final sag would be 23.24 feet at 212°F, or a 5.56 feet gain in ground clearance over the ACSR.

It would be easy to conclude this paper at this point and leave the reader with the understanding that pretensioning ACSR and normal ACSS conductors does not change the final results very much and that pretensioning a High Strength ACSS can yield significant gains in ground clearances. However, several words of caution must be made here about pretensioning in actual practice; the prestressing operation during stringing of conductors not only requires specialized equipment, training, and is quite time consuming, but it also very dangerous work. It is not advisable to pull structures to their full design tensions while people are in the immediate path of destruction should a structure fail. Common construction procedures provide for a 'Factor of Safety' for the linemen. Hoists, shackles, and other equipment may be overdesigned by a Factor of Safety of 3. Cranes may use a Factor of Safety of 2 for any lifts. Do we really expect that a Factor of Safety of 1.0 be used for the structures that are supporting potentially the most dangerous part of line construction? What would the linemen think if they knew that the structure they were tied off to during this operation had a Factor of Safety of 1.0 (or less as illustrated above)? These are obviously answers that the Engineer of Record on the project must decide and be responsible for. If the pretensioning capabilities as requested by users of PLS-CADD are utilized, these factors must be considered and addressed before just merely following the recommendations of a cable manufacturer who may not understand the overall impact on a transmission line design. Could the structures be designed for a 'pretensioning' load case with an adequate Factor of Safety for construction? Yes, but the cost for such structures could be well above the cost of simply selecting slightly taller structures for the design.

It is for the reasons outlined in this paper that pretensioning methods are rarely used in modern times and strong consideration should be given before electing to use it on your project.