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Thermal Rating in PLS-CADD

Introduction

Thermal rating calculations let you determine steady-state or transient relationships between conductor temperature and electrical current based on ambient weather. These calculations, coupled with PLS-CADD's ability to display and check line clearances at various temperatures, provide you with all the necessary tools to rate your lines. This can be done for the more common static or seasonal ratings or for a more complicated Ambient Adjusted Rating (AAR). Thermal rating calculations are accessed through the ***Sections/ Thermal Calculations (IEEE, CIGRE and TNSP)...*** menus.

If you are interested in the behavior of conductors subjected to periods of high temperature operation which can cause additional permanent elongation beyond that of typical creep elongation then you should refer rather to the Technical Note that covers Elevated Temperature Creep of AAC, AAAC, ACAR, AACSR and ACSR Conductors.

Supported Standards

All thermal rating calculations performed by PLS-CADD are based on the following standards:

- IEEE Standard 738-2006, -2012 & -2023: Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors
- CIGRE Brochure 207 August 2002: Thermal Behaviour of Overhead Conductors
- CIGRE Brochure 601 December 2014: Guide for Thermal Rating Calculations of Overhead Lines
- TNSP 2009: Operational Line Ratings

You should refer to these documents for all underlying assumptions.

Properties needed for Cables

Prior to conducting any rating calculation, you should make sure that the conductors used in your PLS-CADD model have proper thermal properties defined.

This section details the units for the various properties that can be entered into the Thermal Rating Properties section of the **Electrical** tab in the Cable Data window (accessible via ***Sections/ Cable Files/ Create New Cable File...*** or ***Sections/ Cable Files/ Edit Existing Cable File...***). Formulas for derived properties are also provided as a guide to creating custom cables.

In addition, Appendix A provides an overview of the various cable properties and what standard/calculation uses the various properties to guide the input accordingly.

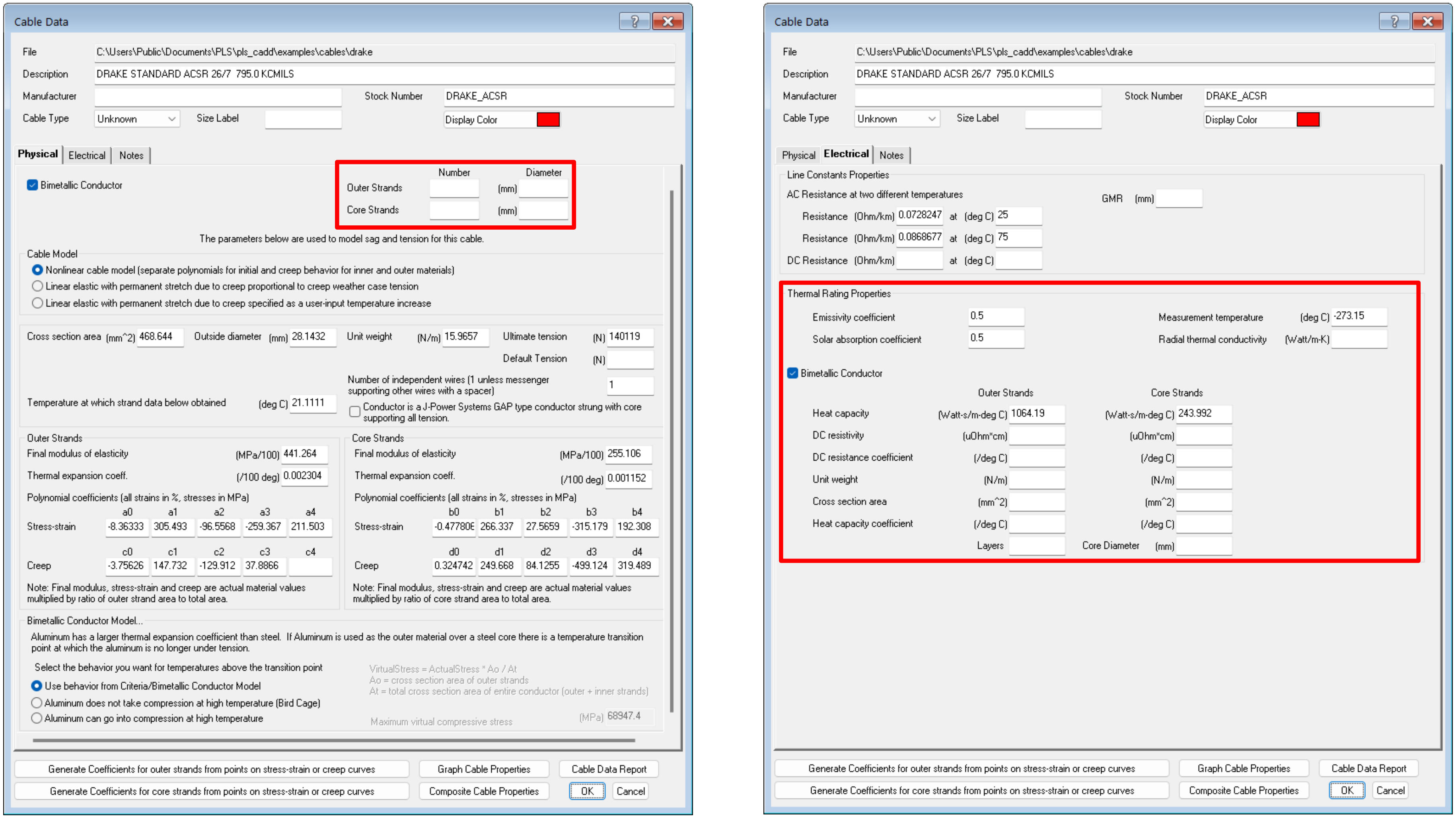


Figure 1 - Cable Data Dialog highlighting the data entry fields needed to perform Thermal Rating calculations for cable/wire files in the Physical and Electrical tabs

Thermal bimetallic properties for a cable are enabled by checking the Bimetallic check box in the Thermal Rating Properties section on the Electrical tab. The properties for the outer strands are always visible and represent all the cable's strands when bimetallic properties are disabled. The properties for the core strands are only visible when the bimetallic properties are enabled, this is shown in Figure 2.

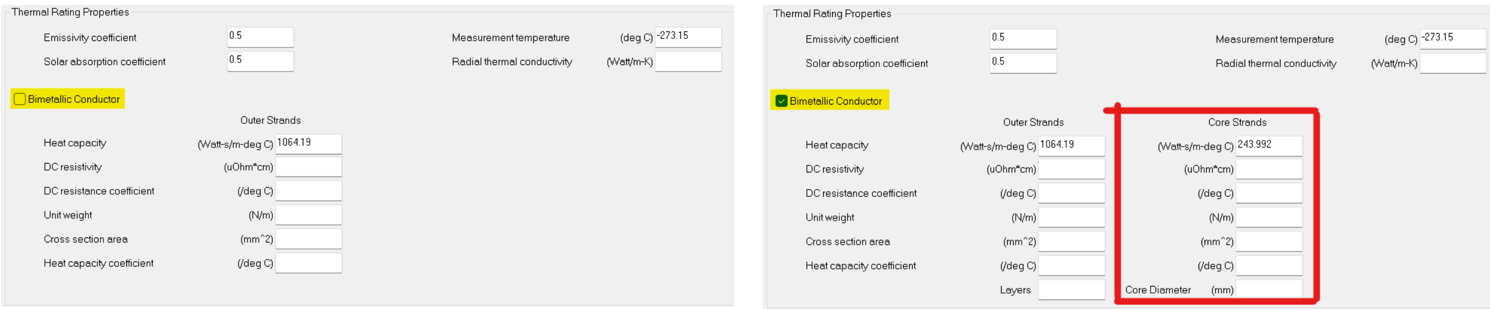


Figure 2 - Indication of how to allow for bimetallic thermal property input for composite wires

Most thermal properties will have two inputs when modeling bimetallic conductors – one value for the outer strands and another value for the core strands. Be sure to properly differentiate between outer and core strand material/geometric properties to ensure that the final composite cable properties are correct.

Note that the use of °C and °K temperature units are interchangeable for thermal properties because the rate of change for Celsius and Kelvin are the same. PLS-CADD typically uses °C while some properties may traditionally be provided using °K.

Cable files also allow the bimetallic modeling of stress/strain via a similar, but independent, check box under the **Physical** tab of the Cable Data window. The two independent bimetallic settings allow a cable to be modeled as monometallic for the stress/strain relationship and as bimetallic for thermal calculations if so desired.

Input Properties

See the IEEE Standard 738, CIGRE Brochure 207, or CIGRE Brochure 601 for the definition of the input properties as they relate to thermal rating functions.

Property	**SI Units**	**Imperial Units**	**Comments**
Emissivity Coefficient	dimensionless	dimensionless	See applicable standard.
Solar Absorption Coefficient	dimensionless	dimensionless	See applicable standard.
Measurement Temperature	°C	°F	
Radial Thermal Conductivity	W/(m·°K)	W/(m·°K)	The units for this property are typically provided in SI so Imperial units are the same.
Heat Capacity	(W·s)/(m·°C)	(W·s)/(ft·°F)	Calculate using (**c·γ·A**) from the physical properties table below.
DC Resistivity	uΩ·cm	uΩ·inch	
DC Resistance Coefficient	1/°C	1/°F	
Unit Weight	N/m	lb/ft	Calculate using (**g·γ·A**) from the physical properties table below.
Cross Section Area	mm^2	in^2	Same as **A** in physical properties table below but with different units.
Heat Capacity Coefficient	1/°C	1/°F	
Layers	dimensionless	dimensionless	
Core Diameter	mm	in	

Physical Properties

The above formulas for heat capacity and unit weight require different units for some properties compared to what is used in the PLS-CADD cable file editor. Refer to the following table for the correct units to use with those formulas.

Symbol	Property	SI Units	Imperial Units	Comments
A	cross section area	m^2	ft^2	Same as input area but different units for formulas above.
c	specific heat capacity	(W·s)/(kg·°C)	(W·s)/(lb·°F)	
γ	density	kg/m^3	lb/ft^3	SI requires mass density and Imperial requires weight density.
g	gravitational acceleration or conversion factor	$9.807\ m/s^2$	1	Imperial value is dimensionless.

Types of calculations available in PLS-CADD

The types of calculations that can be performed are described in more detail in the PLS-CADD User's Manual (Section 11.2.6. Thermal Ratings).

Broadly speaking there are three types of calculators, these are Steady-state thermal ratings, Transient Thermal Ratings and then the Batch Thermal Calculator (which also performs Steady-state calculations, but for multiple wires/sections at a time).

Steady-state Thermal Rating

Steady-state Thermal Rating is defined as the constant electrical current which yields the maximum allowable conductor temperature for specified weather conditions and conductor characteristics under the assumption that the conductor is in thermal equilibrium (steady state).

For given conductor properties and ambient weather conditions, you can use:

1) ***Sections/ Thermal Calculations (IEEE, CIGRE and TNSP)/ Steady-State Conductor Temperature…*** to determine the conductor temperature for a given electric current,
2) ***Sections/ Thermal Calculations (IEEE, CIGRE and TNSP)/ Steady-State Thermal Rating…*** to determine the current that causes a given conductor temperature, or
3) ***Sections/ Thermal Calculations (IEEE, CIGRE and TNSP)/ Steady-State Temperature vs Current Graph…*** to display the relationship between the two.

To extend the capability of these calculators, PLS-CADD enables you to determine the maximum operating temperature that all conductors in a span (or the full line) can achieve using the ***Lines/ Reports/ Thermal Rating Report…***

The maximum temperature is that for which the required clearance under a wire just becomes insufficient. This clearance is to the TIN model of the ground, if such a TIN is available, and/or to surveyed points within a certain horizontal offset of the wires. If a TIN is not available, the program generates internally a ground profile under each wire by connecting points in a manner similar to that used for generating the centerline ground profile and the side profiles.

The line connecting points on a TIN under a wire is colored purple. The survey points above which the clearance is checked are colored blue. The profiles which are generated under the wires are shown in yellow. The shortest clearance to all these items is that determining the maximum allowed conductor temperature.

Profiles generated under the wires can be removed with ***View/ Markers/ Clear Markers***. Maximum conductor temperatures are included in a text report and are displayed with a marker at the controlling location. If you were to display the conductor at the exact controlling temperature, it would touch the top of the marker. This maximum temperature can then be used to back-calculate the line's Thermal Rating using the ***Sections/ Thermal Calculations (IEEE, CIGRE and TNSP)/ Steady-State Thermal Rating…***

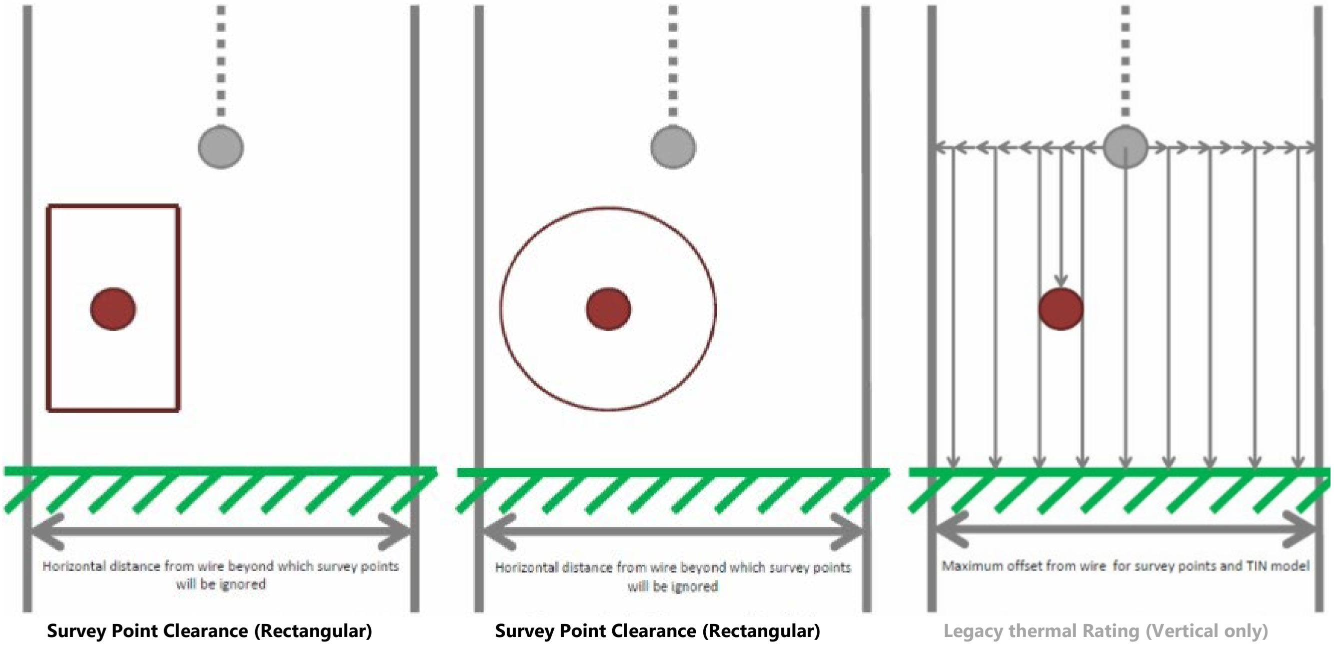


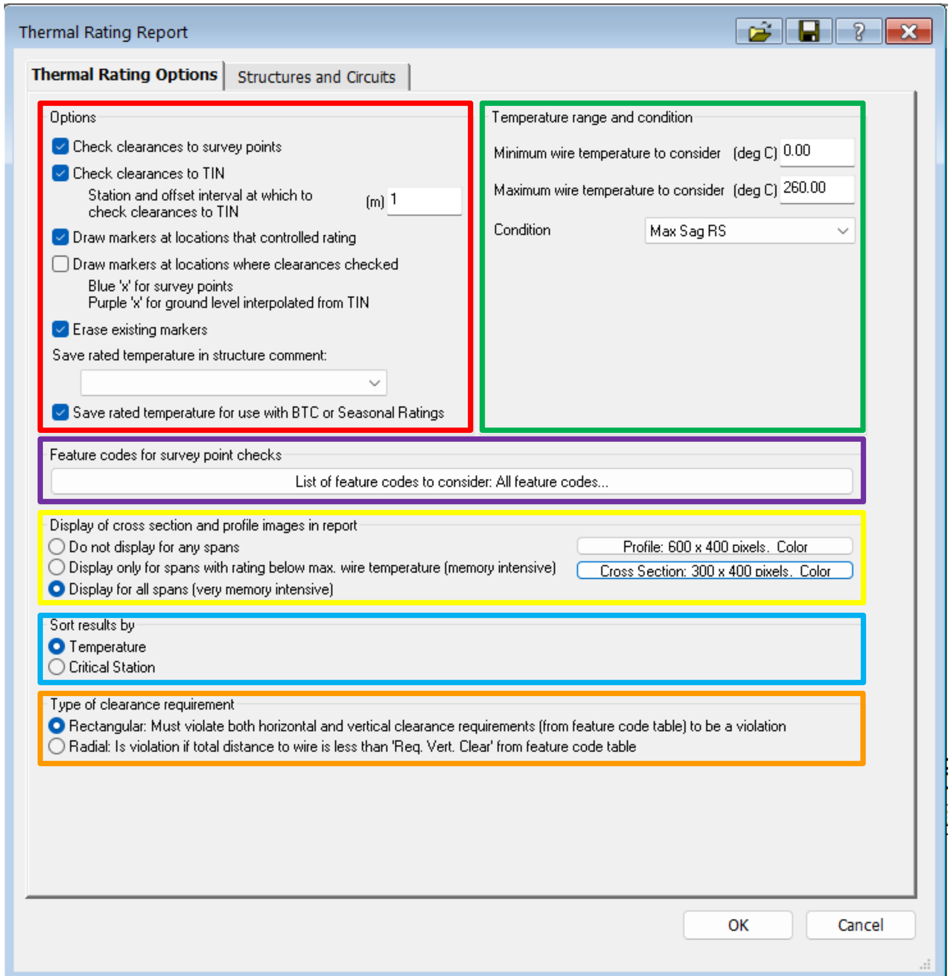
Figure 3 - Illustration of how various clearance checks are performed

NOTE: The clearance types of rectangular and radial that are now supported by the Thermal Rating tool do differ from our legacy thermal line rating report. There is the deprecated menu command ***F1/ Custom/ Under Development/ Legacy Lines/ Reports/ Thermal Rating Report…*** to get a report dialog with the original behavior. If you do elect to use the Legacy approach using the vertical only checks you should consider the following:

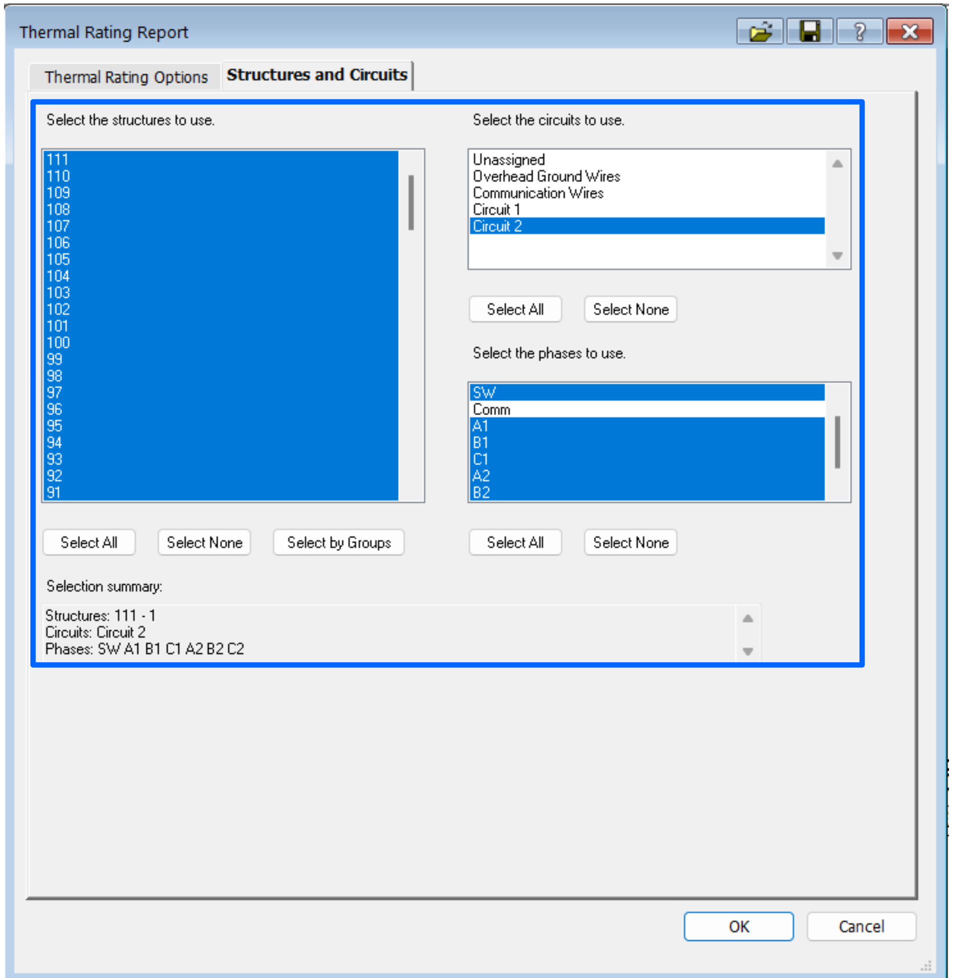
> You can encounter survey points that have a vertical clearance violation, but which are horizontally far enough away from the conductor to not actually be a violation. Thus, one suggested way to use legacy thermal rating report is an iterative approach.
>
> Start by using a large horizontal offset that matches the largest horizontal clearance requirement in your feature code table. Then, if a span has a vertical thermal violation on a feature code with a horizontal clearance requirement that is less than initially specified, run the thermal rating report again with a horizontal offset that matches the horizontal clearance requirement for that feature code.
>
> A few iterations of this approach may be necessary to identify controlling points.

The new method using Rectangular or Radial clearance checks for Thermal rating does not need this iterative approach.

The inputs and options for the Thermal Rating report are as follows:



Options	Option to check clearances to survey points. If this option is not selected the report will not check clearances to survey points.
	Option to define the station and offset interval when checking clearances to the TIN. If this option is not selected the report will not check clearances to the ground surface.
	Option to draw markers at locations that control rating. This draws a red marker listing the maximum conductor temperature per span displayed at the controlling station.
	Option to draw markers at locations where clearances are checked.
	Option to erase markers before running the report.
	Option to save rated temperature in a structure comment for use elsewhere.
	Option to save thermal rated temperature for use with the Batch Thermal Calculator or Seasonal Ratings.
Set and Temperature Range	Input to set the minimum wire temperature for the spans being analyzed. Input to set the maximum wire temperature for the spans being analyzed. The Condition drop down menu allows the user to select the cable condition to use for the report.
Feature Codes for Survey Point Checks	Select from a list the feature codes that clearances should be used to determine the maximum temperature rating and reported within the Thermal Rating report.
Display of Cross Section and Profile Images in Report	Options to display cross section and profile graphics within the thermal rating report.
Sort Results by	Option to sort and display results per span displayed in the Thermal Rating Summary report by *(maximum wire) Temperature* or *Critical Station*.
Type of clearance requirement	Rectangular - Clearance must violate **both** the required horizontal and vertical clearance.
	Radial - Clearance is checked radially from the wire and must violate the distance defined in the required vertical clearance.



Select the structures to use	This dialog allows the user to define specific structures or a range of structures to run the report on.
Select the circuits to use	This dialog allows the user to define specific circuit to analyze. The circuits are defined within **Sections/ Electric/ Define Circuits and Phases**.
Select the phases to use	This menu allows for the selections of electrical phases to include into the report. The phases are defined within **Sections/ Electric/ Define Circuits and Phases**.
Selection summary	Summary of structures, circuits and phases that thermal rating report will analyze.

Once the report is run (by clicking OK in the dialog's displayed above), the software:

- Produces a report showing the maximum operating temperature for the selected spans, phases and circuits, with any graphics selected. The report includes:
    - A section on the required clearances for the selected feature codes,
    - A list of the sections that have been evaluated,
    - A Thermal Rating Summary, which lists the critical point for each span and notifies you what feature code that point is. This section also includes any graphical views (Profile and/or Cross section views)
    - A Thermal Rating Detail table listing the critical point for each wire in each span.
    - A Thermal Rating by Span Graph (included in the report and as a stand-alone window.
- In addition, any Markers that are chosen will be placed in the model views for you to scrutinize and study.

Thermal Rating Summary

Note: Spans sorted in order of temperature causing vertical clearance violations

Circuit	Phase	Back Structure Number	Ahead Structure Number	Maximum Wire Temp. (deg C)	Critical Station (m)	Critical Offset (m)	Critical X (m)	Critical Y (m)	Critical Z (m)	Offset From Wire (m)	Notes
69kV Circuit 1	B1	10	11	47	756.69	0.98	638860.29	108165.95	313.89	1.05	Point TINPTXY TREE
69kV Circuit 1	C1	4	5	167	148.03	1.17	639468.79	108170.94	325.36	-0.03	Point GROUND
69kV Circuit 1	C1	2	3	500	26.80	-1.35	639589.19	108167.90	320.22	-0.74	No violations found at max temp. of 500.00
69kV Circuit 1	C1	3	4	500	96.14	2.62	639520.61	108173.99	321.90	2.24	No violations found at max temp. of 500.00
69kV Circuit 1	C1	5	6	500	250.28	-1.76	639366.69	108164.85	321.73	-2.96	No violations found at max temp. of 500.00
69kV Circuit 1	C1	6	7	500	315.68	3.32	639301.15	108167.90	321.57	2.12	No violations found at max temp. of 500.00
69kV Circuit 1	C1	7	8	500	410.28	-1.74	639206.67	108161.80	314.01	-2.94	No violations found at max temp. of 500.00
69kV Circuit 1	C1	8	9	500	509.35	-1.51	639107.61	108163.32	312.48	-2.72	No violations found at max temp. of 500.00
69kV Circuit 1	C1	9	10	500	591.74	5.03	639025.31	108170.94	311.58	2.29	No violations found at max temp. of 500.00
69kV Circuit 1	C1	11	12	500	835.40	3.99	638781.47	108166.37	302.55	1.92	No violations found at max temp. of 500.00
69kV Circuit 1	C1	12	13	500	3741.95	-1.29	638706.79	108157.23	300.69	-2.95	No violations found at max temp. of 500.00
69kV Circuit 1	C1	13	14	500	986.60	-0.99	638630.59	108155.70	299.17	-2.20	No violations found at max temp. of 500.00
69kV Circuit 1	C1	14	15	500	1100.90	-0.38	638516.29	108154.18	299.90	-1.58	No violations found at max temp. of 500.00
69kV Circuit 1	C1	15	16	500	1192.30	2.85	638424.85	108155.70	301.99	1.65	No violations found at max temp. of 500.00

Circuit: '69kV Circuit 1' Span from structure 10 to 11 and cross section at station 756.69 (m) X=638860.31 Y=108164.90 (m)
Maximum wire temperature 47 (deg C), Point TINPTXY TREE
Red line goes from controlling point to required height above it.
Thick dotted blue line is wire position at maximum temperature.

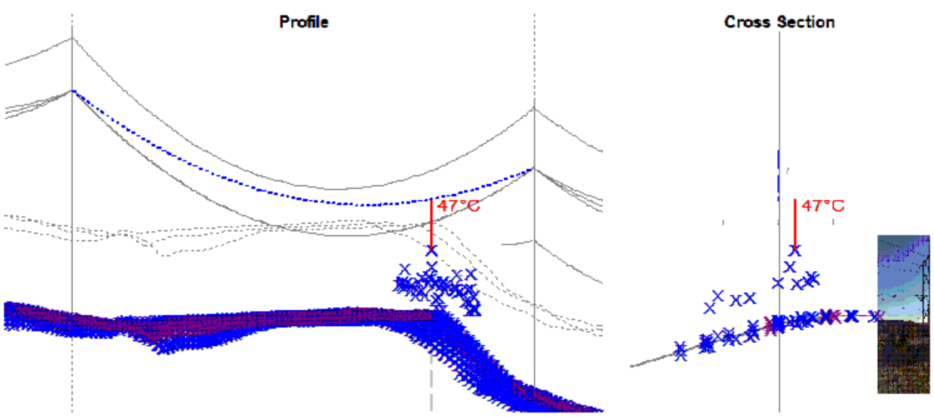


Figure 4 - Excerpt from the Thermal Rating Report

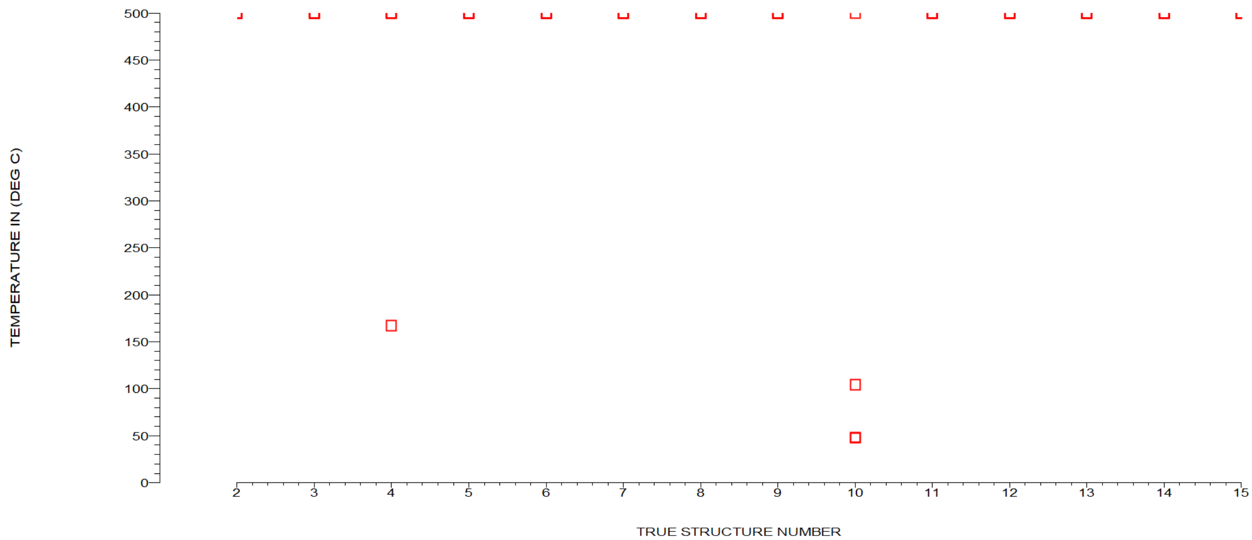


Figure 5 - Thermal Rating by Span Graph

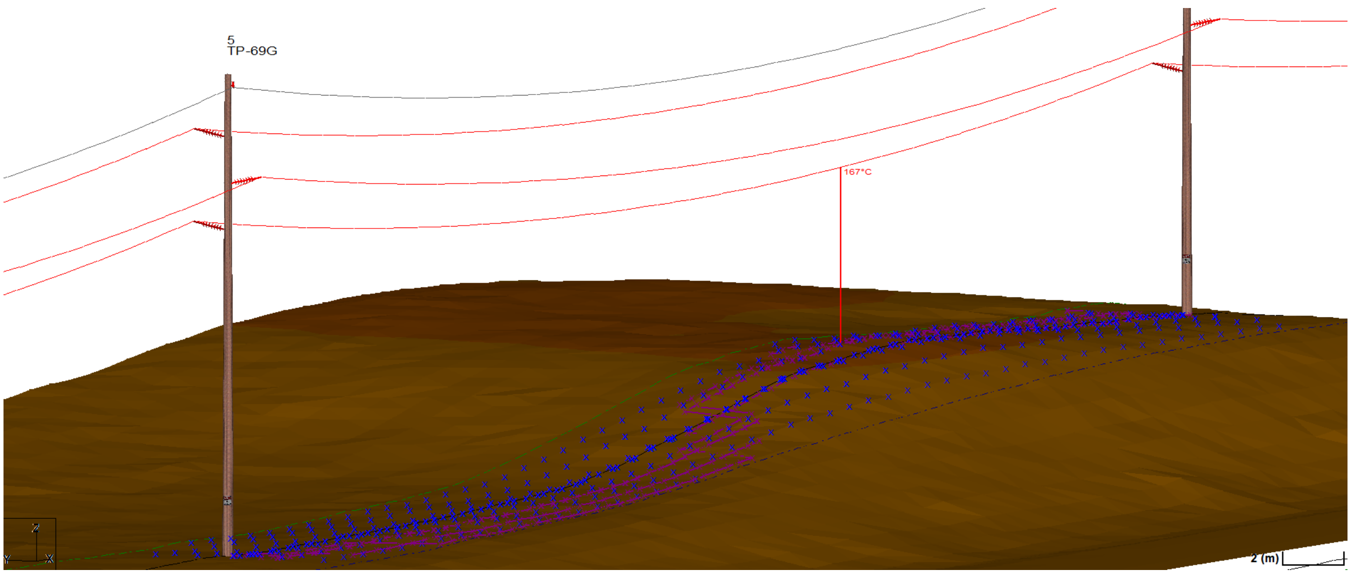


Figure 6 - Markers left behind after running a Thermal Rating Report in the 3D view

Transient Thermal Rating

When the line current suddenly changes, or to consider the line's rating under emergency conditions you need to consider the transient behavior of the wires.

The two options in PLS-CADD here are:

1) ***Sections/ Thermal Calculations (IEEE 738 and CIGRE)/ Conductor Temp. for Current Change…***, which determines the conductor temperature for a specified step increase in current. You could use this information to find out how much time you would have in an emergency situation until your required clearance is violated.
2) ***Sections/ Thermal Calculations (IEEE 738 and CIGRE)/ Transient Thermal or Fault Rating…*** determines the electrical current step increase that will cause the conductor to reach a specified temperature in a specified amount of time. This is useful to determine the maximum emergency current capacity of a line.

Batch Thermal Calculator

Possibly the most useful of the calculators for Steady-state Thermal Ratings is the Batch Thermal Calculator. This is accessed through the ***Sections/ Thermal Calculations (IEEE 738 and CIGRE)/ Batch Thermal Calculator…*** command. This calculator allows you to perform multiple Steady State Conductor Temperature and Steady State Thermal Rating Calculations at once and provides a link to import the required data for the spans from a current design. It can also export the results back into the current design as the Display Weather Case for the sections. Figure 7 shows the Batch Thermal Calculator table that you can fill out manually or you can choose to import data from your project.

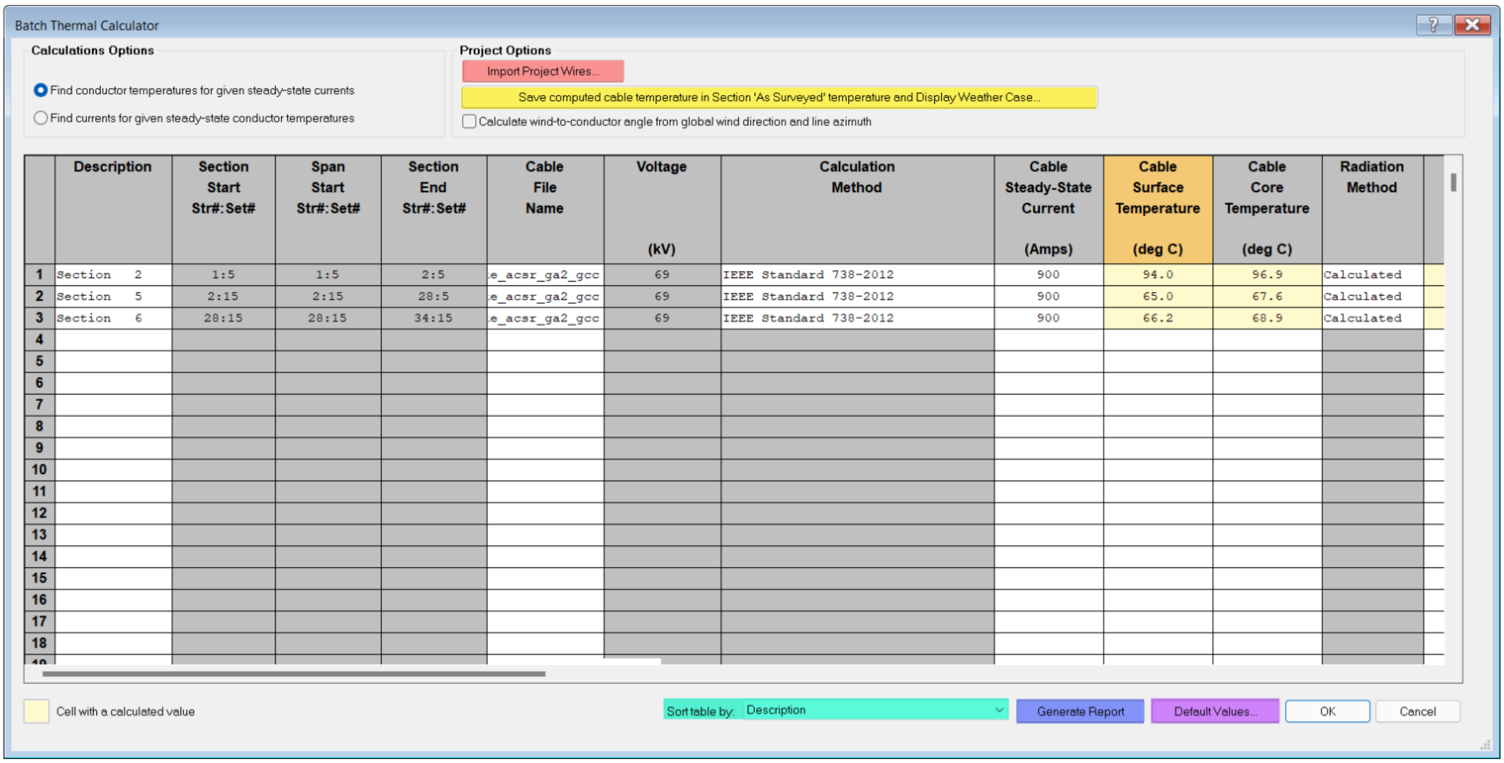


Figure 7 - Batch Thermal Calculator

Each row in the table represents a calculation and the user can enter a description for each of these rows and input the necessary data in the table dependent on the calculation type selected by the radio buttons in the upper left corner of the dialog box (either determining the conductor temperature for a given current or finding the currents for given conductor temperatures). Several of the inputs in the table such as the day of the year and global wind direction may be the same for all the calculations in the table. You can select the '*Default Values*' button at the bottom of the table and nominate values for these items. The *Sort table by* option at the bottom of the table gives you control on how the table is sorted.

You can import conductor data from an existing design into the table using the '*Import Project Wires*' button at the top of the dialog box. This will bring up the ***Import from Project*** dialog box where you can choose which voltages you wish to import as well as set default values for these sections.

If the project has a coordinate system defined in ***Terrain/ Coordinate System/ Define***…, you can check the box at the top of the table and have the program calculate the wind to conductor angle automatically from the global wind direction and line azimuth if you use the '*Import Project Wires*' command.

The '*Generate Report*' button will create a Batch Thermal Calculator Report that documents your results. It will record all variables you have selected in the table for each calculation.

If you used the '*Import Project Wires*' button and performed the calculations in the table, you can choose to click on the *Save computed cable temperature in Section 'As Surveyed' temperature and Display Weather Case…* button at the top of the table that automatically takes the calculated cable temperature from the table for each section and populates the **Display Weather Case** for each of the sections with this calculated temperature (you can see the results clearly if you navigate to ***Sections/ Table…***).

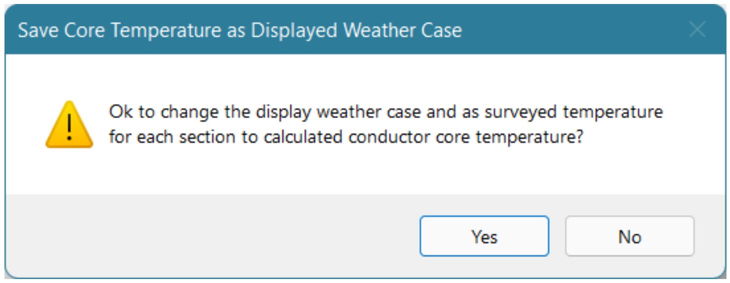


Figure 8 – Warning given when saving core temperatures from the Batch Thermal Calculator in PLS-CADD

This calculated temperature for each span is also placed in the **Ahead Span Surveyed Wire Temp** column of the **Wire Lengths and Attachment Stiffness** table. Doing this allows you to leverage the built in display condition/weather case called *****Surveyed Wire Temp.***** which allows for each span to be displayed at its calculated surveyed temperature without forcing you to create multiple weather cases in your ***Criteria/ Weather…*** table.

If you imported wires for each individual span of a section, you will be prompted for what temperature you wish to export to the model for each section as the Display Weather Case Temperature. You can choose between the minimum, maximum, or average temperature of all the spans in the section. This will automatically change the display of the section to the selected option. If you want to display each of the spans with their as-surveyed temperature, then you can select the option *** Surveyed Wire Temp *** for the Display Weather Case.

NOTE:

1. The Cable Steady-State Current input for the table is for the individual wire based on the cable file. It is not for the bundled phase so the engineer would need to decide how to split the amperage on a phase for input in the table for the wire.
2. If you close the Batch Thermal Calculator table and then come back to it, it is recommended to click on the '*Import Project Wires*' button again. The Batch Thermal Calculator does not update automatically if you have made any changes to your wire model since the last time you were in the table.
3. The use of CIGRE Brochure 207 requires strand and core material information when calculating some results.
4. The use of CIGRE Brochure 601 requires the radial thermal conductivity property in the cable file.

The Batch Thermal Calculator can be used to create seasonal, day/night or Ambient Adjusted Ratings (AAR) by varying input parameters such as Ambient temperature and calculated Global Solar Radiation (by changing the Day of Year and Sun Time).

Ambient Adjusted Ratings (AAR) & Seasonal Ratings

Ambient Adjusted Ratings and Seasonal Ratings require that the evaluation of the current carrying capacity of a transmission line reflect the fact that ambient temperature and weather conditions change with time and seasons. Amongst other requirements, FERC 881 mandates that transmission providers use ambient adjusted ratings to evaluate transmission service requests that are more than 10 days in the future. Also, the transmission provider must calculate a Seasonal Rating for at least four seasons in a year and each season must reflect average ambient conditions. Seasonal Ratings must be recalculated at least annually with the latest weather statistics. Utilities are allowed to define their own seasons but they must be less than or equal to 6 months and there must be at least 4 seasons.

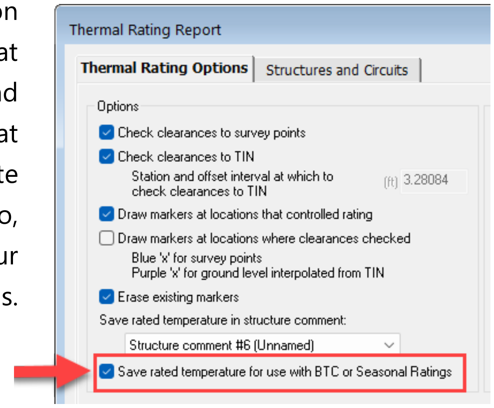


Figure 9 - Option to save the rated temperature

To calculate Seasonal Ratings, the first step is to run a Thermal Rating Report for the project. When running this Thermal Rating Report the option to '*Save rated temperature for use with BTC or Seasonal Ratings*' must be selected, as shown in Figure 9. When this option is selected the thermal rating temperatures are saved on a span and section basis.

You can see this by:

1. Clicking on the *Section Modify* button to activate the ***Section/ Modify*** tool.
2. Click on the section you wish to modify/inspect.
3. Clicking *OK* when the correct Section is highlighted.
4. Clicking on the button '*Edit Span Specific Wire Lengths, Concentrated Loads, Attachment Stiffnesses, Surveyed Temperatures*'

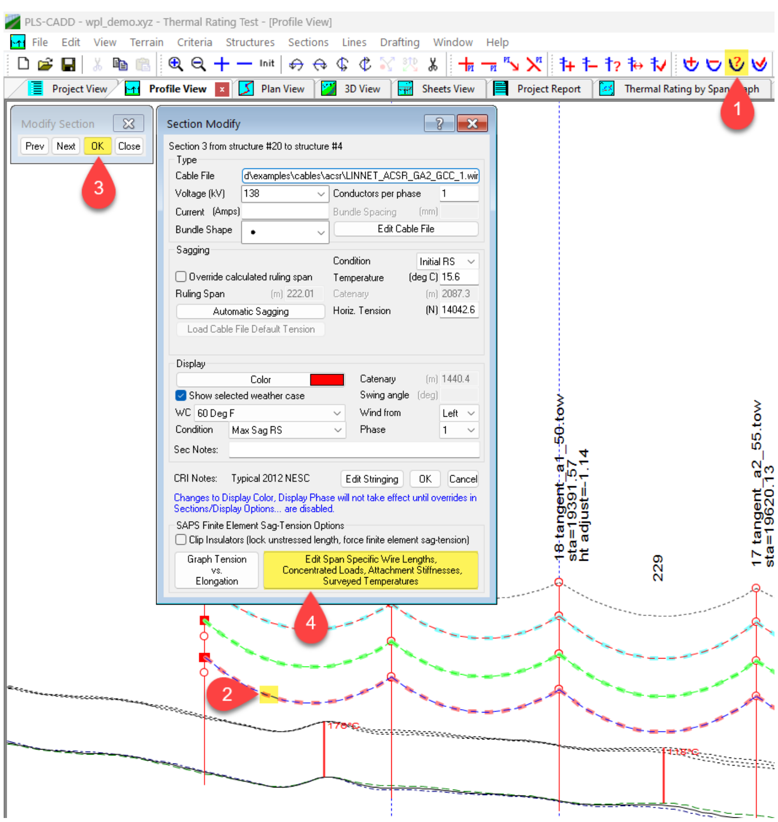
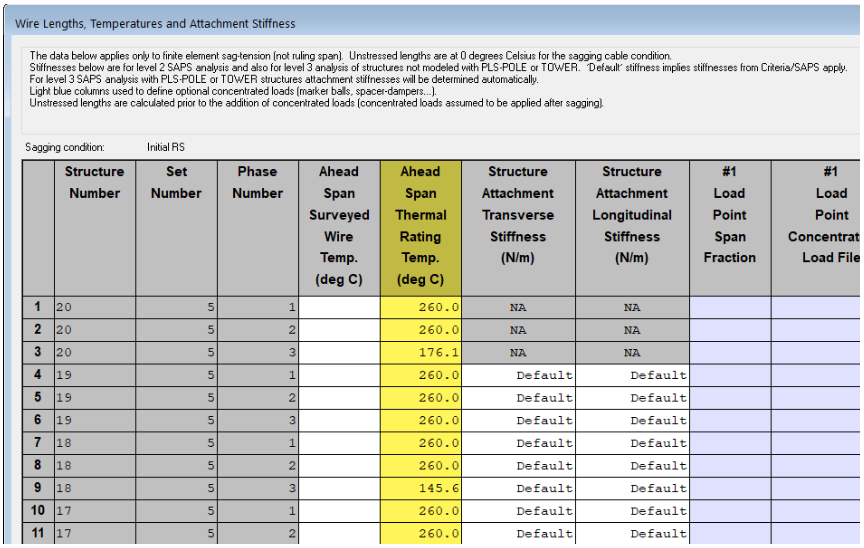


Figure 10 – Access to the Thermal Rating temperatures in the Section Modify dialog

This will open the *Wire Lengths, Temperatures and Attachment Stiffness* Dialog. The fifth column in this table holds the calculated Thermal Rating Temperature for each Ahead Span.

You will note that if you have not yet run a Thermal Rating Report this value is set to absolute zero (-273 °C or -459.4 °F), any other temperature will be assumed to be a valid input for the thermal rating.



Wire Lengths, Temperatures and Attachment Stiffness

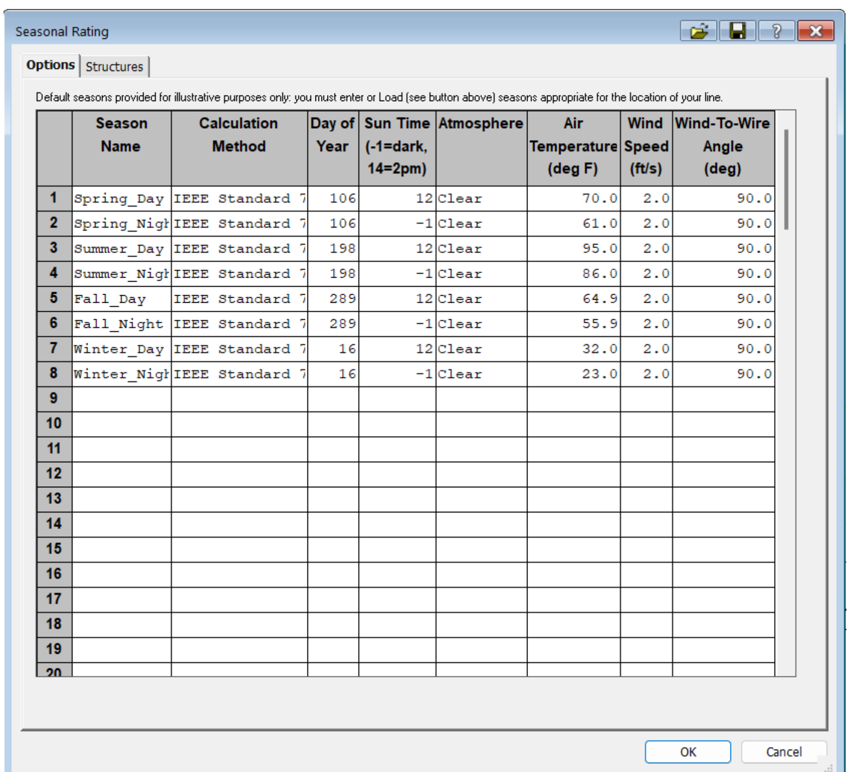
The data below applies only to finite element sag-tension (not ruling span). Unstressed lengths are at 0 degrees Celsius for the sagging cable condition.
Stiffnesses below are for level 2 SAPS analysis and also for level 3 analysis of structures not modeled with PLS-POLE or TOWER. 'Default' stiffness implies stiffnesses from Criteria/SAPS apply.
For level 3 SAPS analysis with PLS-POLE or TOWER structures attachment stiffnesses will be determined automatically.
Light blue columns used to define optional concentrated loads (marker balls, spacer-dampers...).
Unstressed lengths are calculated prior to the addition of concentrated loads (concentrated loads assumed to be applied after sagging).

Sagging condition: Initial RS

	Structure Number	Set Number	Phase Number	Ahead Span Surveyed Wire Temp. (deg C)	Ahead Span Thermal Rating Temp. (deg C)	Structure Attachment Transverse Stiffness (N/m)	Structure Attachment Longitudinal Stiffness (N/m)	#1 Load Point Span Fraction	#1 Load Point Concentrat Load File
1	20	5	1		260.0	NA	NA		
2	20	5	2		260.0	NA	NA		
3	20	5	3		176.1	NA	NA		
4	19	5	1		260.0	Default	Default		
5	19	5	2		260.0	Default	Default		
6	19	5	3		260.0	Default	Default		
7	18	5	1		260.0	Default	Default		
8	18	5	2		260.0	Default	Default		
9	18	5	3		145.6	Default	Default		
10	17	5	1		260.0	Default	Default		
11	17	5	2		260.0	Default	Default		

Figure 11 – Wire Lengths, Temperatures and Attachment Stiffness Dialog showing the saved Thermal Rating Temperature

The menu command ***Lines/ Reports/ Seasonal Rating***… is where a user can define all the scenarios for the seasonal rating calculations, or it can be used for ambient adjusted ratings for short term transmission service requests. Figure 12 displays the Seasonal Rating table which is contained in the *Options* tab of the dialog. In this table a user can select the name of a season, calculation method, day of year, sun time, atmosphere, wind speed and wind to wire angle. These are the typical inputs required for the calculation method specified in the table.



Seasonal Rating

Options | Structures

Default seasons provided for illustrative purposes only: you must enter or Load (see button above) seasons appropriate for the location of your line.

	Season Name	Calculation Method	Day of Year	Sun Time (-1=dark, 14=2pm)	Atmosphere	Air Temperature (deg F)	Wind Speed (ft/s)	Wind-To-Wire Angle (deg)
1	Spring_Day	IEEE Standard 7	106	12	Clear	70.0	2.0	90.0
2	Spring_Nigh	IEEE Standard 7	106	-1	Clear	61.0	2.0	90.0
3	Summer_Day	IEEE Standard 7	198	12	Clear	95.0	2.0	90.0
4	Summer_Nigh	IEEE Standard 7	198	-1	Clear	86.0	2.0	90.0
5	Fall_Day	IEEE Standard 7	289	12	Clear	64.9	2.0	90.0
6	Fall_Night	IEEE Standard 7	289	-1	Clear	55.9	2.0	90.0
7	Winter_Day	IEEE Standard 7	16	12	Clear	32.0	2.0	90.0
8	Winter_Nigh	IEEE Standard 7	16	-1	Clear	23.0	2.0	90.0
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OK Cancel

Figure 12 - Seasonal Rating Dialog inputs

The structures tab of this dialog allows a user to pick a selection of structures or circuits to run the Seasonal Rating Report on. If a range of structures is selected then the seasonal rating calculation will be done for the section and span with the limiting maximum operating temperature derived from the previously run thermal rating report.

Once the input parameters are defined a user can then click *OK* to run the report. A ***Seasonal Rating Summary*** will open in a report window and provide the user with a steady-state thermal rating in Amps for the limiting span in each season, i.e. the lowest rated or critical span. Figure 13 shows the Seasonal Rating Summary report. For more insight you will also be presented with a separate ***Detailed Seasonal Ratings Report*** which has the full set of data for the calculations performed for each span that you selected to run the report on.

```
Seasonal Rating Summary

      Season   Circuit   Control    Wire  Steady-State
                      Span Start Surface       Thermal
                       Str#:Set#   Temp.        Rating
                                 (deg F)        (Amps)
-------------------------------------------------------
   Spring_Day Circuit 2       20:5   206.6         644.5
 Spring_Night Circuit 2       20:5   206.6         699.8
   Summer_Day Circuit 2       20:5   206.6         582.9
 Summer_Night Circuit 2       20:5   206.6         644.9
     Fall_Day Circuit 2       20:5   206.6         669.7
   Fall_Night Circuit 2       20:5   206.6         719.9
   Winter_Day Circuit 2       20:5   206.6         736.0
 Winter Night Circuit 2       20:5   206.6         778.4
```

Figure 13 - Seasonal Rating Summary

Appendix A

Matrix showing how cable data is used in the Thermal Rating reports:

		IEEE 738:			Cigre		TNSP 2009	P1283/D8 (ETC) [1]	Comments
Cable Property	**Tab**	2006	2012	2023	207	601			
Bimetallic conductor	Physical							●	
Cable type	Physical							●	Only AAC, AAAC, ACSR & AACSR supported
Cast rod strands								●	Manual input – not stored in cable file
Core cross section area	Electrical				●	●			
Core DC resistivity	Electrical								Only used for reporting
Core DC resistance coeff.	Electrical								Only used for reporting
Core diameter	Electrical		●	●	●	●			
Core heat capacity	Electrical	●	●	●	●	●	●		
Core heat capacity coeff.	Electrical				●	●			
Core strand diameter	Physical							●	
Core strand number	Physical							●	
Core thermal expansion coeff.	Physical							●	
Core unit weight	Electrical				●	●			
Cross section area [2]	Calculated				●			●	
Emissivity coeff.	Electrical	●	●	●	●	●	●		
Measurement temperature	Electrical				●	●			
Outer cross section area	Electrical				●	●			
Outer DC resistivity	Electrical				●	●			
Outer DC resistance coeff.	Electrical				●	●			
Outer heat capacity	Electrical	●	●	●	●	●	●		
Outer heat capacity coeff.	Electrical				●	●			
Outer strand diameter	Physical				●	●	●	●	
Outer strand layers	Electrical				●				
Outer strand number	Physical							●	
Outer thermal expansion coeff.	Physical							●	
Outer unit weight	Electrical				●	●			
Outside diameter	Physical	●	●	●	●	●	●		
Radial thermal conductivity	Electrical		●	●	●	●			
Resistances at temperatures	Electrical	●	●	●	●	●	●		
Sag-tension related								●	
Solar absorption coeff.	Electrical	●	●	●	●	●	●		
Temperatures for resistances	Electrical	●	●	●	●	●	●		
Thermal bimetallic	Electrical		●	●	●	●	●		
Ultimate tension	Physical							●	

Notes:

1. ETC - Elevated Temperature Creep refer to https://www.powline.com/technotes/Elevated_Temperature_Creep.pdf.
2. Total area should equal the sum of areas for outer and core strands based on strand quantity and diameter.