June 3, 2014

CLEAN LINE ENERGY

PLAINS & EASTERN HVDC LINE

PRELIMINARY DESIGN CRITERIA
Revision E

PROJECT NUMBER:
132836

PROJECT CONTACT:
BRIAN BERKEBILE
CURTIS SYMANK
EMAIL:
BRIAN.BERKEBILE@POWERENG.COM
CURTIS.SYMANK@POWERENG.COM
PHONE:
803-835-5902 (Brian)
512-963-8103 (Curtis)

POWER ENGINEERS

PRELIMINARY DESIGN CRITERIA

PREPARED FOR: CLEAN LINE ENERGY
PREPARED BY: BRIAN BERKEBILE
PHONE 803-835-5902
EMAIL BRIAN.BERKEBILE@POWERENG.COM

REVISED & UPDATED JUNE 2014
PREPARED FOR: CLEAN LINE ENERGY
PREPARED BY: CURTIS SYMANK
PHONE 512-963-8103
EMAIL CURTIS.SYMANK@POWERENG.COM

REVISION HISTORY		
DATE	REVISED BY	REVISION
A	BHB	DRAFT for Review
B (9-9-10)	BHB	DRAFT for Review
C (1-27-11)	CIM	Added more clearances
D (6-1-11)	CIM	Added Metal Return Conductor
E(6-3-14)	CIM	Final for Preliminary Design Updates: Power, Ampacity, MOT, Sag & Tension, Loading Criteria (added NESC Medium, updated Construction Snub-Off, Stringing/Breaking Case), Insulator Data, updated Appendices A, E, F, P, Q, added Appendices AA,AB, AC, AD, AE, AF.

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ABBREVIATIONS

ACSR:	Aluminum Conductor, Steel Reinforced
ACSS:	Aluminum Conductor, Steel Supported
ACCR:	Aluminum Conductor Composite Reinforced
AGS:	Armor Grip Support
ASCE:	American Society of Civil Engineers
CTZFS:	Cable Tension For Zero Fiber Strain
CSZFS:	Cable Strian For Zero Fiber Strain
FC:	Sag Tension Limit, Final After Creep Condition
FL:	Sag Tension Limit, Final After Load Condition
Hz:	Hertz
I:	Sag Tension Limit, Initial Condition
kcmil:	1000 Circular Mills
kips:	1000 pounds
kV:	kilovolts
Manual No. 74	ASCE Manual and Report on Engineering Practice No. 74 “Guidelines for Electrical Transmission Line Structural Loading
N/A	Not Applicable
NESC:	National Electrical Safety Code, 2007
OHSW:	Overhead Shield Wire
OPGW:	Fiber Optic Ground Wire
ROW:	Right-of-Way
RUS:	Rural Utilities Service
TBD:	To Be Determined
TW:	Trapezoidal Shaped Conductor
MRC:	Metallic Return Conductor
PC:	Pole Conductor
MAD:	Minimum Approach Distance
WS:	Working Space

GENERAL

Project Information

Owner's Name:	Clean Line Energy Partners ("Clean Line")
Project Name:	Plains and Eastern HVDC transmission line
Length:	Approximately 700 miles
Voltage:	+/- 600 kV DC (Bi-Pole)
Planned Energization Date:	Approximately 2015 or 2016

Correspondence/Project Personnel

POWER Engineers, Inc.

Project Manager		Curtis Symank
	Email:	curtis.symank@powereng.com
	Phone:	512-795-3700
	Fax:	512-795-3999
	Address:	POWER Engineers, Inc.
		7600B North Capital of Texas Hwy, Suite 320
		Austin, Texas 78731

Project Management Support		Brian Berkebile
	Email:	Brian.berkebile@powereng.com
	Phone:	803-835-5902
	Fax:	803-835-5999
	Address:	POWER Engineers, Inc.
		1041 521 Corporate Center Drive Suite 105
		Fort Mill, South Carolina 29707

Project Engineer T-Line Design		Cristian Militaru
	Email:	cmilitaru@powereng.com
	Phone:	803-835-5906
	Fax:	803-835- 5999
	Address:	POWER Engineers, Inc.
		1041 521 Corporate Center Drive Suite 105
		Fort Mill, South Carolina 29707

Project Engineer		Brian Furumasu
Electrical Studies	Email:	Brian.furumasu@powereng.com
	Phone:	503-293-7124
	Fax:	503-293-7199
	Address:	POWER Engineers, Inc.
		9320 SW Barbur Boulevard Suite 200
		Portland, OR 97219
Project Consultant		Dave Wedell
	Email:	dwedell@powereng.com
	Phone:	314-851-4024
	Fax:	314-8514099
	Address:	POWER Engineers, Inc.
		12755 Olive Blvd, Suite 100
		St. Louis, MO 63141

Client

Project Manager		Wayne Galli, Ph.D., P.E.
		Vice President, Transmission and Technical Services
	Email:	wgalli@cleanlineenergy.com
	Phone:	(832) 319-6337
	Fax:	(832) 310-6311
	Address:	Clean Line Energy Partners, LLC
		1001 McKinney, Suite 700
		Houston, TX 77002

Project Description

This project involves developing Preliminary Design and other supporting information for the purpose of developing a revised budgetary cost estimate by Clean Line Energy Partner's ("Clean Line") and its EPC team for the proposed Plains and Eastern HVDC transmission line. This project is currently moving from the conceptual stage to a preliminary design and estimate stage. The purpose of the Preliminary Design is to advance the project definition from the current conceptual level to a preliminary design level, which will serve as the basis for developing budgetary cost estimates for the transmission line. These estimates will, in turn, be used by Clean Line in their on-going project economic analyses.

Clean Line has stated that the desired nominal operating voltage for the project is +/- 600 kV.

The preliminary design effort currently underway generally reflects updates to the conceptual design performed by POWER. As such, the revisions and updates to this Design Criteria document reflect a combination of revised or updated studies reflecting the information know at this stage of the project. The format and approach taken by POWER is to update the conceptual design information, revising where appropriate. In some cases, primarily in appendices, prior content has not been updated since the conclusions are known to be unchanged. In such cases, a clarifying note has been added to the appendix.

CODE(S) AND LOADING CONDITIONS

Controlling Code(s)

NESC:	NESC Rule 250 B Heavy District (for the portion of the line in Oklahoma state) NESC Rule 250 B Medium District (for the portions of the line in Arkansas and Tennessee states) NESC Rule 250C Extreme Wind, adjusted for 50-year return period NESC Rule 250D Extreme Ice with Concurrent Wind, adjusted for 50-year return period
Location or State Specific:	Oklahoma, Arkansas, and Tennessee
Client Specific:	Clean Line Energy

Loading Conditions For Non-Deadend Structures

Case	Description	Weather Case	Ref	Cable Condition	Vert. Load Factor	Wind Load Factor	Tension Load Factor	Strength Reduction Factor
1	NESC HEAVY ALL WIRES INTACT (STEEL & CONCRETE) **OKLAHOMA STATE ONLY**	0°F, 0.5" ICE, 4 PSF	NESC 250B, 253-1 / 261-1A	Initial	1.5	2.5	1.65	1
2	NESC MEDIUM ALL WIRES INTACT (STEEL & CONCRETE) **ARKANSAS & TENNESSEE STATES ONLY**	15°F, 0.25" ICE, 4 PSF	NESC 250B, 253-1 / 261-1A	Initial	1.5	2.5	1.65	1
3	EXTREME WIND ALL WIRES INTACT (STEEL & CONCRETE)	60°F 90 MPH (50 YR RP) ASSUMED 230' MAX STR HEIGHT, WITH 820' SPAN; Kz,c=1.57, Kz,s=1.35; Gf,c=0.66; Gf, s=0.80 Results: 20.74 PSF ON WIRE 23.00 PSF ON STR	NESC 250C, 253-1 / 261-1A Table 250-2 Table 250-3	Initial	1.0	1.0	1.0	1
4	NESC EXTREME ICE WITH CONCURRENT WIND ALL WIRES INTACT (STEEL & CONCRETE)	15°F 1.00" ICE (50 YR RP) 4.1 PSF WIND	NESC 250D, 253-1 / 261-1A	Initial	1.0	1.0	1.0	1
5	F2 TORNADIC WIND <u>ON STRUCTURE WITH NO WIRES</u>	60°F, 157 MPH (63.1 PSF)	ASCE #74 2.7.1	Not Applicable	1.0	1.0	1.0	1
6	EVERYDAY LOADS	60°F		Initial	1.0	1.0	1.0	1
7	CONSTRUCTION, SNUB-OFF, 3:1	0°F	IEEE524 Annex D	Initial	1.5	1.5	1.5	1
8	STRINGING/BROKEN SHIELD WIRE LOAD	0°F, 4 PSF	ASCE #74 3.3.2 Failure Containment	Initial	1.5	1.5	1.5	1
9	STRINGING/BROKEN METAL RETURN CONDUCTOR LOAD	0°F, 4 PSF	ASCE #74 3.3.2 Failure Containment	Initial	1.5	1.5	1.5	1
10	STRINGING/BROKEN POLE CONDUCTOR LOAD	0°F, 4 PSF	ASCE #74 3.3.2 Failure Containment	Initial	1.5	1.5	1.5	1

Notes:

1. Load cases 1 through 5 shall be analyzed assuming a foundation rotation of 1.72° (3%) when used with pole structures.

2. Load case 3 is a maximum deflection case when used with pole structures. Deflection at the pole tip shall be limited to 9% of the above ground structure height under this load condition. The total of 9% includes 1.72° (3%) due to foundation rotation.

3. Load case 6 is for deflection control of pole structures under every day conditions. The maximum deflection for tangent structures is one pole tip diameter. The maximum deflection for angle structures at the pole tip is 1 ½ % of the above ground height. Angle structures not meeting this requirement shall be cambered.

4. For structure load calculations (ruling spans, wind spans, weight spans, etc. for each type of structure), see attached Appendix AA-Design Assumptions.

5. Load Case 3 shall be analyzed with the wind in a transverse direction, at a 45° yawed angle, and in a longitudinal direction.

6. Load Case 7, snub-off, is applied with wires snubbed off at three horizontal to one vertical. All wires (shieldwires, MRCs, pole conductors) should be assumed that will snub-off simultaneously (worst case). See attached Appendix AB, for Snub-Off Case Loadings example of calculations (based on IEEE 524, Annex D).

7. Load Case 8, stringing/broken shield wire, accounts for a stringing block getting hung up at one of the shieldwires or for breaking one of the shieldwires. The longitudinal load applied to the structure at that broken shield wire position: back span: 0% of tension, 100% of weight span, ahead span: 100% of tension, 100% of weight span (assumed the shield wire breaks in the middle of back span, which is the worst case, that means its vertical load remains intact, assumed leveled spans). All other wire loads should be assumed intact. See ASCE Manual 74-2010, Section 3.3.2. Longitudinal Loads and Failure Containment for detailed calculations and attached Appendix AE-Stringing /Broken Case Example of Calculation.

8. Load Case 9, stringing/broken MRC (metal return conductor), accounts for a stringing block getting hung up at one of the MRCs or for breaking one of the MRCs. The longitudinal load applied to the structure at that broken MRC position: back span: 0% of tension, 100% of weight span; ahead span: 70% of tension (the broken MRC insulator string is assumed to swing longitudinally at a 45 deg angle towards ahead span), 100% of weight span (assumed the MRC breaks in the middle of back span, that means its vertical load remains intact, which is the worst case, assumed levels spans). All other wire loads should be assumed intact. See ASCE Manual 74-2010, Section 3.3.2. Longitudinal Loads and Failure Containment for detailed calculations and attached Appendix AE-Stringing /Broken Case Example of Calculation.

9. Load Case 9, stringing/broken pole conductor, accounts for a stringing block getting hung up at one sub-conductor out of three in the bundle, of only one pole (positive or negative) or for breaking of one sub-conductor out of three in the bundle, of only one pole (positive or negative). The longitudinal load applied to the structure at that broken sub-conductor: back span: 0% of tension, 100% of weight span; ahead span: 70% of tension (the broken pole conductor insulator string is assumed to swing longitudinally at a 45 deg angle towards the ahead span), 100% of weight span (assumed that sub-conductor breaks in the middle of back span, which is the worst case, that means its vertical load remains intact, assumed levels spans). The other two sub-conductors, from the pole where we broke one sub-conductor, and all the other pole three sub-conductors, both shield wires, and both MRCs locations should be assumed intact. See ASCE Manual 74-2010, Section 3.3.2. Longitudinal Loads and Failure Containment for detailed calculations and attached Appendix AE-Stringing /Broken Case Example of Calculation.

10. The structure should be designed for an additional load case, for loads anticipated due to rigging for wire clip in during construction. Loads shall be applied as follows: at one pole conductor location, apply load: W_{CL} directly above the work point (WP). Each location should be analyzed separately. The values should be:
    - Tangent Suspension 0-2 deg:
        - Basic: W_{CL}=26,650 lbs; Medium: W_{CL}=31750 lbs; Heavy: W_{CL}=43600 lbs.
    - Small Angle Suspension 2-10 deg:
        - W_{CL}=31750 lbs
    - Medium Angle Suspension 10-30 deg:
        - W_{CL}=31750 lbs

    Apply load case 6 to all other attachment points.

11. All load cases shall include the weight of the clamp and hardware (shieldwires) and the weight of insulators and hardware (for MRC and pole conductors) provided in attached Appendix AC-Clamps and Insulator Parameters and attached Appendix AD- Insulator Assembly Types. The wind load on clamps (shieldwire) and insulators (MRC, pole conductor) will use the Area Exposed to Wind [ft^2] provided in attached Appendix AC-Clamps and Insulator Parameters.

12. Load case 6 will also include 800 lb. additional vertical load at the tip of each arm to account for two maintenance men and equipment.

13. Load Case 5 shall be for wind on structure only with no wires attached. Structure shall be analyzed with the wind in a transverse direction, at a 45° yawed angle, and with a longitudinal wind.

14. Insulators will be designed for the following overload factors and strength reduction factors (reference RUS Bulletin 1724E-200 Paragraph 8.9.1)
    a. Case 1 and 2: Overload Factor = 1.0, Strength Reduction Factor = 0.4
    b. All the other cases: Overload Factor = 1.0, Strength Reduction Factor = 0.5 for non-ceramic, 0.65 for ceramic and glass.

15. All lattice structural members shall be able to hold a 350 lb load, applied vertically at their midpoint, conventionally combined with the stresses derived from Load Case 6.

Loading Conditions For Deadend Structures

Case	Description	Weather Case	Ref	Cable Condition	Vert. Load Factor	Wind Load Factor	Tension Load Factor	Strength Reduction Factor
1	NESC HEAVY ALL WIRES INTACT (STEEL & CONCRETE) **OKLAHOMA STATE ONLY**	0°F, 0.5" ICE, 4 PSF	NESC 250 B, 253-1 / 261-1A	Initial	1.5	2.5	1.65	1
2	NESC MEDIUM ALL WIRES INTACT (STEEL & CONCRETE) **ARKANSAS & TENNESSEE STATES ONLY**	15°F, 0.25" ICE, 4 PSF	NESC 250 B, 253-1 / 261-1A	Initial	1.5	2.5	1.65	1
3	EXTREME WIND ALL WIRES INTACT (STEEL & CONCRETE)	60°F 90 MPH (50 YR RP) ASSUMED 230' MAX STR HEIGHT, WITH 820' SPAN; Kz,c=1.57, Kz,s=1.35; Gf,c=0.66; Gf, s=0.80 Results: 20.74 PSF ON WIRE 23.00 PSF ON STR	NESC 250C, 253-1 / 261-1A Table 250-2 Table 250-3	Initial	1.0	1.0	1.0	1
4	NESC EXTREME ICE WITH CONCURRENT WIND ALL WIRES INTACT (STEEL & CONCRETE)	15°F 1.00" ICE (50 YR RP) 4.1 PSF WIND	NESC 250D, 253-1 / 261-1A	Initial	1.0	1.0	1.0	1
5	F2 TORNADIC WIND <u>ON STRUCTURE WITH NO WIRES</u>	60°F, 157 MPH (63.1 PSF)	ASCE #74 2.7.1	Not Applicable	1.0	1.0	1.0	1
6	EVERYDAY LOADS	60°F		Initial	1.0	1.0	1.0	1
7	NESC HEAVY DEADEND ALL WIRES REMOVED FROM ONE SPAN (STEEL & CONCRETE) **OKLAHOMA STATE ONLY**	0°F, 0.5" ICE, 4 PSF	NESC 250B, 253-1 / 261-1A	Initial	1.5	2.5	1.65	1
8	NESC MEDIUM DEADEND ALL WIRES REMOVED FROM ONE SPAN (STEEL & CONCRETE) **ARKANSAS & TENNESSEE STATES ONLY**	15°F, 0.25" ICE, 4 PSF	NESC 250B, 253-1 / 261-1A	Initial	1.5	2.5	1.65	1
9	EXTREME WIND DEADEND ALL WIRES REMOVED FROM ONE SPAN (STEEL & CONCRETE)	60°F 90 MPH (100 YR RP) ASSUMED 230' MAX STR HEIGHT, WITH 820' SPAN; Kz,c=1.57, Kz,s=1.35; Gf,c=0.66; Gf, s=0.80 Results: 22.74 PSF ON WIRE 23.00 PSF ON STR	NESC 250C, 253-1 / 261-1A	Initial	1.0	1.0	1.0	1
10	NESC EXTREME ICE WITH CONCURRENT WIND; DEADEND; ALL WIRES REMOVED FROM ONE SPAN; (STEEL & CONCRETE)	15°F 1.25" ICE (100 YR) 4.1 PSF WIND	NESC 250D, 253-1 / 261-1A	Initial	1.0	1.0	1.0	1

Notes:

1. Load cases 1 through 5 shall be analyzed assuming a foundation rotation of 1.72° (3%) when used with pole structures.

2. Load case 3 is a maximum deflection case when used with pole structures. Deflection at the pole tip shall be limited to 9% of the above ground structure height under this load condition. The total of 9% includes 1.72° (3%) due to foundation rotation.

3. Load case 6 is for deflection control of pole structures under every day conditions. The maximum deflection for tangent structures is one pole tip diameter. The maximum deflection for angle structures at the pole tip is 1 ½ % of the above ground height. Angle structures not meeting this requirement shall be cambered.

4. For structure load calculations (ruling spans, wind spans, weight spans, etc. for each type of structure), see attached Appendix AA-Design Assumptions.

5. Load Cases 7, 8, 9, and 10 shall be used to verify all deadend structures are designed to carry all wires deadended on <u>one side</u> of the structure.

6. Load Case 3 shall be analyzed with the wind in a transverse direction, at a 45° yawed angle, and with a longitudinal wind.

7. All load cases shall include the weight of the clamp and hardware (shieldwires) and the weight of insulators and hardware (for MRC and pole conductors) provided in attached Appendix AC-Clamps and Insulator Parameters and attached Appendix AD- Insulator Assembly Types. The wind load on clamps (shieldwire) and insulators (MRC, pole conductor) will use the Area Exposed to Wind [ft2] provided in attached Appendix AC-Clamps and Insulator Parameters.

8. Load case 6 will also include 800 lb. additional vertical load at the tip of each arm to account for two maintenance men and equipment.

9. Load Case 5 shall be for wind on <u>structure only</u> with no wires attached. Load Case 5 shall be analyzed with the wind in a transverse direction, at a 45° yawed angle, and with a longitudinal wind.

10. Insulators will be designed for the following overload factors and strength reduction factors (reference RUS Bulletin 1724E-200 Paragraph 8.9.1):
    a. Case 1, 2,7, and 8: Overload Factor = 1.0, Strength Reduction Factor = 0.4
    b. All the other cases: Overload Factor = 1.0, Strength Reduction Factor = 0.5 for non-ceramic, 0.65 for ceramic and glass.

11. All lattice structural members shall be able to hold a 350 lb load, applied vertically at their midpoint, conventionally combined with the stresses derived from Load Case 6.

WIRES FOR THE MAIN LINE

Transmission Conductor

Size (kcmil/AWG):	2156 kcmil
Composition (ACSR, AAC, etc.):	ACSR
Code Word:	Bluebird
Diameter:	1.762 inches
Weight:	2.511 lbs/ft
Rated Breaking Strength:	60,300 lbs
Design Voltage:	600 kV HVDC
Typical Operating Voltage:	600 kV HVDC
Maximum Operating Voltage:	632 KV HVDC
Maximum Conductor Temperature (Temperatures calculated using IEEE 738 methodology for predicted line loadings under normal and emergency conditions):	Normal Regime: I_{PC} =I pole/3=3600/3=1200 A: 71 Deg C (160 Deg F) Emergency Regime: I_{PC} =I pole/3=4320/3=1440 A: 81 Deg C (177 Deg F)

Appendix J provides comparison between the possible conductors which could be selected for this contract and ends with a recommendation of the selection. Sag and Tension calculations for the Pole Conductor (PC): ACSR Bluebird, Metal Return Conductor (MRC): ACSR Chukar, and OPGW are shown in Appendix E, while Appendix F reports Ampacity calculation.

OPGW

There will be two OPGW, one to protect each pole conductor. Detailed Specification for the OPGW is presented in Appendix B. POWER requested quotations from several vendors and all of them came back with a “stranding stainless steel tube” type of OPGW design, trying to match the Power’s specification. POWER chose the vendor with the design providing the highest CTZFS (Cable Tension for Zero Fiber Strain), and highest CSFZFS (Cable Strain for Zero Fiber Strain), also called “Strain Margin”, and which had also the lowest cost for OPGW and its hardware. Details of the chosen OPGW are listed below.

Size (kcmil/AWG):	49AY85ACS-2C
Composition (EHS, AW, etc.):	12 Aluminum Clad Steel Wires ACS20.3% IACS 2 Aluminum Alloy Wires AY6201-T81 2 Stainless Steel Tubes 304 containing 6-24 fibers each and gel
Diameter:	0.591 inches
Weight:	0.473 lbs/ft
Rated Breaking Strength:	25,369 lbs
Number of Fibers:	12-48, depending on final project requirements

Appendix C lists the Lightning Algorithm used to check the OPGW while Appendix D shows the outer layer’s wire required diameter calculation based on expected lighting charge at line location.

Metal Return Conductor (MRC)

Size (kcmil/AWG):	1780 kcmil
Composition (ACSR, AAC, etc.):	ACSR
Code Word:	Chukar
Diameter:	1.602 inches
Weight:	2.075 lbs/ft
Rated Breaking Strength:	51,000 lbs
Design Voltage:	53 kV HVDC
Typical Operating Voltage:	53 kV HVDC
Maximum Operating Voltage:	56 KV HVDC
Maximum Conductor Temperature (Temperatures calculated using IEEE 738 methodology for predicted line loadings under normal and emergency conditions):	Normal Regime: I_{MRC} =I pole/2=3600/2=1800 A: 113 Deg C (235 Deg F) Emergency Regime: I_{MRC} =I pole/2=4320/2=2160 A: 143 Deg C (289 Deg F)

Appendix P lists the required Metal Return Conductor clearances while appendix Q presents the Metal Return Conductor selection analysis.

WIRES FOR MISSISSIPPI RIVER CROSSING SPANS

Transmission Conductor- FOR MISSISSIPPI RIVER CROSSING SPANS

Size (kcmil/AWG):	1622 kcmil
Composition (ACSR, AAC, etc.):	ACCR-TW_1622-T13
Code Word:	Pecos (this trap wire is diameter equivalent to round wire Martin)
Diameter:	1.417 inches
Weight:	1.774 lbs/ft
Rated Breaking Strength:	55500 lbs
Design Voltage:	600 kV HVDC
Typical Operating Voltage:	600 kV HVDC
Maximum Operating Voltage:	632 KV HVDC
Maximum Conductor Temperature (Temperatures calculated using IEEE 738 methodology for predicted line loadings under normal and emergency conditions):	Normal Regime: I PC =I pole/3=3600/3=1200 A: 82 Deg C (179 Deg F) Emergency Regime: I PC =I pole/3=4320/3=1440 A: 97 Deg C (206 Deg F)

The ampacity calculations and corresponding MOTs are presented in attached Appendix F - Ampacity calculations.
The comparison leading to the selection of the ACCR/TW Pecos wire is shown in Appendix G, titled Mississippi River Crossing-Conductor Comparison and Selection.

OPGW - FOR MISSISSIPPI RIVER CROSSING SPANS

Like the main line, there will be two OPGW, one to protect each pole. But the OPGE design for the Mississippi River Crossing, is different than the OPGW for the rest of the line, due to the fact the OPGW for the river crossing has to go over a very long span (about 4000'), so it is needed a special OPGW design, with high CTZFS (over 80%) and CSFZFS (over 0.55%), even for a span of 4000'.

Size (kcmil/AWG):	161 ACS-2C
Composition (EHS, AW, etc.):	17 Aluminum Clad Steel Wires ACS20.3% IACS 2 Stainless Steel Tubes 304 containing 6-24 fibers each and gel
Diameter:	0.646 inches
Weight:	0.678 lbs/ft
Rated Breaking Strength:	38,079 lbs
Number of Fibers:	12-48, depending on final project requirements

Metal Return Conductor (MRC)- FOR MISSISSIPPI RIVER CROSSING SPANS

Size (kcmil/AWG):	1622 kcmil
Composition (ACSR, AAC, etc.):	ACCR/TW_1622-T13
Code Word:	Pecos
Diameter:	1.417 inches
Weight:	1.774 lbs/ft
Rated Breaking Strength:	55,500 lbs
Design Voltage:	59 kV HVDC
Typical Operating Voltage:	59 kV HVDC
Maximum Operating Voltage:	62 KV HVDC
Maximum Conductor Temperature (Temperatures calculated using IEEE 738 methodology for predicted line loadings under normal and emergency conditions):	Normal Regime: 102 Deg C (216 Deg F) Emergency Regime: 128 Deg C (263 Deg F)

Information pertaining to the type of MRC selected for Mississippi river crossing is in appendix G1-Mississippi river crossing-metal return conductor comparison and selection and appendix P1-Mississippi river crossing-metal return conductor clearances tables.

Notes:
1) The ACCR/TW Pecos conductor has a different conductor temperature when it is used as pole conductor vs. when it is used as metal return conductor, due to the different ampacity for each case.

- Pole Conductor:
    - Normal Regime: I conductor=I pole/3=3600/3=1200 A, with MOT=82 C (179 F)
    - Emergency Regime: I conductor=I pole/3=4320/3=1440 A, with MOT=97 C (206 F)

- Metal Return Conductor:
    - Normal Regime: I conductor=I pole/2=3600/2=1800 A, with MOT=126 C (259 F)
    - Emergency Regime: I conductor=I pole/2=4320/2=2160 A, with MOT=164 C (328 F)

2) The Metal Return Conductor ACSR Chukar used on the entire line (except Mississippi River Crossing) will be energized at +/- 53 KV, while the Metal Return Conductor ACCR/TW Pecos used on the Mississippi River Crossing will be energized at +/-59 kV.

CONDUCTOR RATING CRITERIA

The following table summarizes conductor ampacity calculated using IEEE 738 methodology under normal and emergency loading conditions, using the following assumptions:

Ambient air temperature = 40 deg C (104 deg F), Wind Speed=2 ft/s, Emissivity factor = 0.5; and Solar absorptivity factor = 0.5.

See Appendix F-Ampacity Calculations, for other parameters used in these calculations, and the resulting maximum operating temperatures for the conductors analyzed.

Circuit	Conductor	Voltage (kV)	Normal Ratings				Emergency Ratings (20% over Normal Ratings)			
			Winter		Summer		Winter		Summer	
			MW	Amps	MW	Amps	MW	Amps	MW	Amps
Plains & Eastern	ACSR Bluebird 3 sub-conductors per pole	Nominal: 600 Maximum: 632	4320 At rectifier	3600 Per pole 1200 Per sub-conductor	4320 At rectifier	3600 Per pole 1200 Per sub-conductor	5184 At rectifier	4320 Per pole 1440 Per sub-conductor	5184 At rectifier	4320 Per pole 1440 Per sub-conductor
Plains & Eastern Mississippi River Crossing Span	ACCR-TW Pecos 3 sub-conductors per pole	Nominal: 600 Maximum: 632	4320 At rectifier	3600 Per pole 1200 Per sub-conductor	4320 At rectifier	3600 Per pole 1200 Per sub-conductor	5184 At rectifier	4320 Per pole 1440 Per sub-conductor	5184 At rectifier	4320 Per pole 1440 Per sub-conductor

WIRE SAG/TENSION LIMITS

Conductor and Metal Return Conductor Sag-Tension Limits for main line
The following table summarizes all sag-tension limits considered. The most stringent limit will be utilized to control the sag-tension in each span, or an agreed upon control tension will be used that will also meet the requirements below. See Appendix E-Sag & Tension Files.

Weather Case				Sag or Tension Limit		
Wind (psf)	**Ice (inches)**	**Temp (°F)**	**Cond.**	**NESC Limit**	**South wire Sag10 Program Limit**	**Project Specific Limit**
4	0.5	0	I	60% RBS	50% RBS	50% RBS
4	0.25	15	I	60% RBS	50% RBS	50% RBS
20.74	0	60	I	--	--	75% RBS
4.1	1	15	I			75% RBS
0	0	60	I	35% RBS	--	--
0	0	60	F	25% RBS	--	-
0	0	0	I	--	33.3% RBS	33.3% RBS
0	0	0	F	--	25% RBS	25% RBS
0	0	-20	I	--	--	Uplift Condition
4	0.5	0	I	--	--	Slack Tension Into Substation D.E. Frame. 5000 lbs maximum per sub-conductor. Max per HVDC pole = 5000 lbs x no. of sub-conductors.
4	0.25	15	I	--	---	
20.72	0	60	I	--	--	
4.1	1	15	I	--	--	

Conductor and Metal Return Conductor Sag-Tension Limits- for river crossing spans.
The following table summarizes all sag-tension limits considered. The Mississippi River Crossing Span is about 4000 ft. The most stringent limit will be utilized to control the sag-tension in each span, or an agreed upon control tension that will also meet the requirements below. See Appendix E-Sag & Tension Files.

Weather Case				Sag or Tension Limit		
Wind (psf)	**Ice (inches)**	**Temp (°F)**	**Cond.**	**NESC Limit**	**Southwire Sag10 Program Limit**	**Project Specific Limit**
4	0.5	0	I	60% RBS	50% RBS	50% RBS
4	0.25	15	I	60% RBS	50% RBS	50% RBS
20.74	0	60	I	--	--	75% RBS
4.1	1	15	I			75% RBS
0	0	60	I	35% RBS	--	--
0	0	60	F	25% RBS	--	-
0	0	0	I	--	33.3% RBS	33.3% RBS
0	0	0	F	--	25% RBS	25% RBS
0	0	-20	I	--	--	Uplift Condition

OPGW Sag-Tension Limits

The following table summarizes all sag-tension limits considered. The most stringent limit will be utilized to control the sag-tension in each span, or an agreed upon control tension will be used that will also meet the requirements below. See Appendix E-Sag & Tension Files.

Weather Case				Sag or Tension Limit		
Wind (psf)	**Ice (inches)**	**Temp (°F)**	**Cond.**	**NESC Limit**	**South wire Sag10 Program Limit**	**Project Specific Limit**
4	0.5	0	I	60% RBS	50% RBS	50% RBS
4	0.25	15	I	60% RBS	50% RBS	50% RBS
20.74	0	60	I	--	--	60% RBS
4.1	1	15	I			60% RBS
0	0	60	I	35% RBS	--	--
0	0	60	F	25% RBS	--	<= 85% of the Conductor Sag at the Same Loading Condition
0	0	0	I	--	33.3% RBS	33.3% RBS
0	0	0	F	--	25% RBS	25% RBS
0	0	-20	I	--	--	Uplift Condition
4	0.5	0	I	--	--	Slack Tension Into Substation D.E. Frame. 3000 lbs maximum per OPGW
4	0.25	15	I			
20.74	0	60	I	--	--	
4.1	1	15	I	--	--	

<u>OPGW to Conductor Sag Ratios Requirements </u>(to ensure shielding angles are maintained):

OPGW Sag @ 60 F, No Wind, No Ice, Final <= 85% Conductor Sag @ 60 F, No Wind, No Ice, Final

OPGW Sag @ 32 F, No Wind, **0.5" Ice**, Final <= **95%** Conductor Sag @ 32 F, No Wind**, No Ice**, Final

The second ratio at 32 F with Ice vs. 32 F without ice (95%) controls the sag and tension of OPGW. See Appendix E-Sag and Tension Files.

OPGW Sag-Tension Limits – FOR RIVER CROSSING SPANS

The following table summarizes all sag-tension limits considered. The Mississippi River Crossing Span is about 4000 ft. The most stringent limit will be utilized to control the sag-tension in each span, or an agreed upon control tension that will also meet the requirements below. See Appendix E-Sag & Tension Files.

Weather Case				**Sag or Tension Limit**		
Wind (psf)	**Ice (inches)**	**Temp (°F)**	**Cond.**	**NESC Limit**	**Alcoa Sag10 Program Limit**	**Project Specific Limit**
4	0.5	0	I	60% RBS	50% RBS	50% RBS
4	0.25	15	I	60% RBS	50% RBS	50% RBS
20.74	0	60	I	--	--	75% RBS
4.1	1	15	I			75% RBS
0	0	60	I	35% RBS	--	--
0	0	60	F	25% RBS	--	<= 85% of the Conductor Sag at the Same Loading Condition
0	0	0	I	--	33.3% RBS	33.3% RBS
0	0	0	F	--	25% RBS	25% RBS
0	0	-20	I	--	--	Uplift Condition

OPGW to Conductor Sag Ratios Requirements (to ensure shielding angles are maintained):

OPGW Sag @ 60 F, No Wind, No Ice, Final <= 85% Conductor Sag @ 60 F, No Wind, No Ice, Final

OPGW Sag @ 32 F, No Wind**, 0.5” Ice**, Final <= 95% Conductor Sag @ 32 F, No Wind, **No Ice**, Final

The second ratio at 32 F with ice vs 32 F without ice (95%) controls the sag and tension of OPGW.
See Appendix E-Sag and Tension Files.

Creep-Stretch Criteria

Condition for Final Sag after Load (Common Point):	NESC Heavy Rule 250 B: 0 Deg F, 4 PSF Wind, 0.5” Ice; k=0.3 (for Oklahoma State only)
	NESC Medium Rule 250 B: 15 Deg F, 4 PSF Wind, 0.25” Ice; k=0.2 (for Arkansas and Tennessee States only)
Condition for Final Sag after Creep:	60 Deg F, No Wind, No ice

Galloping

Double-loop galloping will be assumed for spans greater than 600 feet. Single-loop galloping will be assumed for spans less than 600 feet. Galloping ellipses will be allowed to overlap up to 10% of the elliptical major axis.

The weather case used to calculate swing angle used during galloping analyses will be 2 psf wind, 1/2” ice, 32°F final. The weather case used to calculate the ellipse size will be 0 psf wind, 1/2” ice, 32°F final.

Aluminum in Compression

It will be assumed that outer aluminum strands can go into compression under high temperature.

For ACSR and ACCR conductors, that is over 100 C (212 F).

The ACSR Bluebird (used as a pole conductor, for entire line, except for Mississippi River Crossing), does not follow “aluminum can go into compression” model, because its MOT (Maximum Operating Temperature), under both normal and emergency regime, does not go over 100 C (212 F).

The ACSR Chukar (used as metal return conductor for entire line, except Mississippi River Crossings), does follow “aluminum can go into compression” model, because its MOT (Maximum Operating Temperature), under both normal and emergency regime, does go over 100 C (212 F).

Note: The MRC will reach such high temperatures, over 100 C (212 F), only if one entire pole (positive or negative) is lost, in normal regime or emergency regime, with all its 3 sub-conductors, in which case, the current that was supposed to go through the 3 sub-conductors of that pole, will be split between the 2 MRCS. The probability of this to happen is very low, and even if it will ever happen, it will be just for a short period of time, up until the lost pole (positive or negative) will be repaired.

The ACCR/TW Pecos (used as both pole conductor and metal return conductor in Mississippi River Crossing Spans)), does follow “aluminum can go into compression” model, because its MOT (Maximum Operating Temperature), under emergency regime, because it does go over 100 C (212 F).

The ACCR/TW Pecos does not follow aluminum can go into compression” model under the normal regime, because in normal regime it does not go over 100 C (212 C).

Note: The ACCCR/TW Pecos, will still have its MOT, under both normal and emergency regime, under its limits imposed by the manufacturer (3 M) : 210 C (410 F), under normal regime, and 240 C (464 F), under emergency regime.

The maximum virtual compressive stress for ACSR Chukar, to be used in aluminum can go into compression” model is: 1.5 kpsi*($A_{AL\ outer}$/ A_{total})=1.5*1.3986/1.5126=1.387 kpsi

The maximum virtual compressive stress for ACSSR/TW Pecos, to be used in aluminum can go into compression” model is: 1.5 kpsi*($A_{AL\ outer}$/ A_{total})=1.5*1.274/1.437=1.329 kpsi

STRUCTURES

Circuits

No. Circuits (Single or Double):	2-Pole Horizontal HVDC with 2 Dedicated Metallic Return Conductors (MRC)
Bundled:	3 conductors per bundle (positive pole and negative pole)
Guyed or Self-Supporting:	Potential both guyed and self-supporting structures

Material

Wood (DF, WRC, preservative):	Do not consider wood
Steel (self-weathering, painted, galv.):	Potential weathering steel and galvanized steel
Concrete:	Potential concrete
Other:	

Configuration

Single Pole:	Potential single pole structure types: • Self-supporting Steel Tubular • Self-supporting Concrete
H-Frame	No
3-Pole:	No
Lattice:	Consider the following lattice tower types • Self-supporting Steel Lattice, • Guyed Single Mast or Vee
Other:	Consider the following additional structure types: • Cross Rope Suspension, Guyed Steel Lattice (with two foundations) • Cross Rope Suspension, Guyed Steel Lattice (Vee Configuration with a single foundation) • Guyed Single Mast or Vee Tubular Steel

Are Transposition Structures Required: YES ☐ NO ☑

Foundations

Type:	Drilled Pier
Geotechnical Data Available:	YES ☐ NO ☑
Geotechnical Study Required:	YES ☑ NO ☐ Desktop geotechnical study will be performed to determine soil types that may be encountered along the line and to classify them into several primary groups with typical soil design parameters to allow for estimated designs for budgetary purposes.
Design Criteria for Foundations subject to Lateral Loads	Drilled piers and direct embed poles subject to lateral loads will be designed per POWER standard as shown in Appendix K.
Design Criteria for Foundations subject to Uplift/Compression Loads	Drilled piers and direct embed poles subject to uplift/compression loads will be designed per POWER standard as shown in Appendix K.

Calculated Lightning Outages

Calculated outages from lightning will not exceed 1 outage per 100 miles per year per HVDC pole.

Appendix C lists the Lightning Algorithm used to check the OPGW while Appendix D shows the outer layer's wire required diameter calculation based on expected lighting charge at line location.

Distance between Deadends

A deadend structure will be placed approximately every 10 miles.

But a dead end structure will be used anyway for any line angle over 30 degrees.

The suspension structures will be used only for line angles under or equal with 30 degrees.

Other

Shield Angle (If Required): Inside: Maximum 15 degrees Outside: Maximum 15 degrees

Raptor Protection: YES ☐ NO ☐ Distance: APLIC (40" ht x 60" span)

Maximum or Minimum Pole Height Limitations (specify): TBD

Anodes Required: YES ☐ NO ☐ TBD

GUYS AND ANCHORS

Guys

Guy Strand (size, material): TBD

Guy to Pole Attachment:

- Pole Eye Plate: TBD
- Pole Band: TBD
- Guy Hook: TBD
- Other:

Guy Connection

Pole Attachment:

- Preformed: TBD
- 3-Bolt: TBD
- Automatic: TBD
- Other:

@ Anchor:

- Preformed: TBD
- 3-Bolt: TBD
- Automatic: TBD
- Other:

Guy Strain Insulators

Type: TBD

Guy Guards

Locations Required: TBD

Plastic: TBD Metal: TBD

Color: TBD Cattle Stub: TBD

Other (describe):

Anchors

Type:

- Plate: N/A Size: N/A
- Screw: TBD Size: TBD

Log: N/A Size: N/A
Concrete (describe): TBD
Other (describe): TBD
Rod: Length: TBD Diameter: TBD
Anodes Required: YES ☐ NO ☐ TBD

HARDWARE

Deadend Attachment

Description	Bolted	Compression	Other (describe)
Transmission Conductor (1)		X	
Shield Wire		N/A	
OPGW	X		Preformed

(1)Corona free hardware required: YES ☑ NO ☐

Suspension Attachment

Description	Formed Tie	Trunion Clamp	Suspension Clamp	Armor Rod	Line Guard	AGS	Other (Describe
Transmission Conductor (1)	N/A	N/A	TBD	TBD	N/A	TBD	
Shield Wire	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OPGW	N/A	N/A	TBD	TBD	N/A	TBD	

(1)Corona free hardware required: YES ☑ NO ☐

Bracing
Transmission:
Wood: N/A Steel: TBD
Other (describe):

Vibration Analysis
For preliminary cost estimating, vibration analysis will be performed using Vibrec software (AFL) or Vortex (PLP). For final design, vibration analysis would be performed by the damper supplier.

Spacer Requirements
Spacer dampers will be utilized on conductors and will be installed such that:

- The spacer dampers will be spaced symmetrically in each span with a maximum spacing of 200 ft, or asymmetrically, with 10-15% detuning, with maximum spacing of 272 ft, per CIGRE rules.
- Number of spacer dampers that will be installed in jumper strings: three (if 2 jumper strings are used-rectangle cross arm) or two (if 1 jumper string is used-triangle cross arm); two spacer dampers will be used in the jumper loop. The spacer dampers will be equally spaced between the deadends.

INSULATION

Type-Transmission

I-String:	Considered, but Not Chosen.
V-String:	Considered; Currently Preferred Configuration.
Horizontal Post:	N/A
Horizontal Vee:	N/A
Horizontal Jumper Post:	N/A
Vertical Jumper Post:	N/A

Material Transmission

Porcelain:	Considered, but Not Chosen
Glass:	Considered; Currently Preferred Material
Polymer:	Considered, but Not Chosen.
Other (fog, etc.):	To Be Considered
Corona Rings:	To Be Considered
End Fittings:	To Be Considered

Ratings-Transmission

Electrical Characteristics *			
DC Withstand Voltage*		Dry lightning impulse withstand (kV)	Structure Type
Dry one minute (kV)	Wet One minute (kV)		
150	65	140	225
170	75	150	255

Data based on toughened glass, ball & socket coupling, Sediver's DC fog type:

- 50 kips (N220P/C-171DR)
- 66 kips (F300PU/C-195DR).

*Electrical characteristics in accordance with IEC 61325.

Additional required parameters regarding the insulators are presented in attached Appendix AC-Clamp and Insulator Parameters and Appendix AD- Insulator Assembly Types.

RIGHT-OF-WAY

Description

Location of Line in ROW:	Assumed center
ROW Width:	Assumed 175' based on 1500' typical spans.

Right-of-Way Width Calculations for Blowout

Load Case 1:	0 PSF, No Ice, All Temperatures, Final (NESC 234 A.1)
Load Case 2:	6 PSF, No Ice, 60°F, Final (NESC 234 A.2)
Load Case 3:	Extreme Wind 20.74 psf, No Ice, 60°F, Final

Minimum clearances to be maintained from the blown out conductor to the edge of right-of way shall be as follows. Load Cases 1 and 2 are based on maintaining NESC clearance to buildings. See NESC 234 B. Clearances for Load Case 3 are not governed by NESC. This case is a criteria designed to keep the conductors on the right-of-way under an extreme wind. These clearances include a 3' buffer to accommodate survey and construction tolerances.

For required clearances to the ROW, see also Appendix A- Clearances Calculation Tables.

	Clearance for ±600 kV nominal & ±632 kV maximum
Load Case 1	25 ft*
Load Case 2	22 ft*
Load Case 3	0 ft – May vary by location

*See Appendix A- Clearances Calculation Tables.

The maximum structure deflection, including foundation rotation, for single shaft steel structures will be assumed at 9% of structure above ground height for Load Case 3 and 5% for Load Case 2. For lattice towers the maximum structure deflection will be assumed at 1% of the structure above ground height.

Electric Field Affects

Electric field calculations will be prepared using the Corona and Field Affects Program (CAFEP) developed by the Bonneville Power Administration. The calculations will be based on a maximum line to line voltage of the nominal 600 kV plus 5% (or 632 kV) at the sending end. Typical approximate structure configurations will be used along with a sample of the possible conductor bundling scenarios. Calculated values will be compared to the limits listed below as a reference. Note that Oklahoma, Arkansas, and Tennessee do not have any published limits.

IEEE Standard C95.6-2002 Limits

- Maximum E-field at edge of right-of-way: 5 kV/m
- Maximum E-field on the right-of-way: 20 kV/m

Corona

POWER will prepare corona effects calculations using the CAFEP software and the same scenarios as the electric field calculations. Clean Line Energy will provide the audible noise (AN) and AM radio interference (RI) limits to be maintained at the edge of right-of-way. If no values are provided, the typical industry guidance of 40 dB μV/m will be used for RI and the EPA recommendation of no greater than 55 dBA will be used for AN. All values are calculated at the edge of the right-of-way.

In addition, the corona losses along the line will be calculated manually for the same scenarios as above. The calculations will assume a line length of 700 miles as the specific line length is yet to be determined.

CLEARANCES

All clearances will be determined using 600 kV DC, nominal, pole-to-ground, and 632 kV DC, maximum, pole-to-ground.

Also, for comparison purposes, clearances were calculated using an “AC equivalent” voltage : 600 kV DC, peak, nominal, pole-to-ground is equivalent to: 600*sqrt(3)/sqrt(2)= 735 kV DC, rms, phase-to-phase.

See Appendix A-Clearances Calculation Tables.

Voltage System

All systems are considered effectively grounded or systems where ground faults are cleared by promptly de-energizing the faulted section, both initially and following subsequent breaker operations. The maximum operating voltage is the normal voltage plus 5%.

Clearance to Structure/Insulator Swing

The maximum and minimum insulator swings will be limited by minimum clearances required to the structure. This clearance will be to the arm, tower body, or to the pole. The load cases considered for insulator swing as it relates to clearance to structure will be as follows:

Load Case 1:	0 PSF Wind, No Ice, All Temperatures, Final
Load Case 2:	6 PSF, No Ice, 60°F, Final (NESC 235 E.2)
Load Case 3:	Extreme Wind, No Ice, 60°F, Final

Minimum clearances to be maintained from the closest line conductor or other hot element to the face of the metal structures shall be as follows:

	Clearance for ±600 kV nominal & ±632 kV maximum to Own Structure
Load Case 1	13.5 ft
Load Case 2	13.5 ft
Load Case 3	5 ft

Load Case 1, Load Case 2, Load Case 3 required clearance is based on necessary air gap equivalent (dry arc distance) under to following combination of mechanical and electrical parameters:

- Case 1: best mechanical: no wind, with worst electrical: lighting impulse withstand voltage.
- Case 2: medium mechanical: medium wind, with medium electrical: switching impulse withstand voltage.
- Case 3: worst mechanical: extreme wind, with best electrical: steady state, normal regime.

Load Case 1 and Load Case 2 clearance based on NESC Rule 235 E.

Important Note:

Load Case 1 and 2 minimum clearances were NOT increased to 17.33’ to meet IEEE 516-2009 MAD (Minimum Approach Distance) for tools (12.33’) and the Working Space (4.5’). Live Line Maintenance was considered at the conceptual design stage, and the clearance requirements are noted in this document. However, Live Line Maintenance clearance requirements are no longer included in the structure geometry and design calculations. If maintenance work is necessary on a pole, that pole must be de-energized.

The line will still function in mono-pole regime (the other pole will still be energized).

Load Case 3 based on EPRI T/L Reference Book +/ -600 KV HVDC Lines where the mechanical case Extreme Wind corresponds to the electrical case Steady State , normal regime, Figure 10-3 page 145 and Fig.10-4, Page 146: 4.1’, to which it was added a buffer of 0.9’.

See also for detailed clearance calculations attached Appendix A-Clearances Calculation Tables.

Ground Clearance

NESC:	34’ (w/3’ buffer) (See Appendix A-Clearances Calculation Tables).
REA:	N/A
Other:	N/A

Water Clearance for River Crossing Spans

NESC:	55’ (w/3’ buffer) (See Appendix A- Water Clearances Calculation Tables).
REA:	N/A
Other:	N/A

The water clearance was determined based on NESC Rule 232D, Table 232-3, f (DC Calculation) and NESC Rule 232, Table 232-1, 7 (AC Equivalent Calculation). It might change, based future requirements from the Corps of Engineers, or other regulators.

5 miliAmp Rule

This rule, NESC Rule 232.C.1.c, does not apply to HVDC lines because a DC line will not create a steady-state current as occurs with AC lines.

Clearance Between Wires on Different Supporting Structures

NESC:	Horizontal: 35 ft (w/3 ft buffer); Vertical: 28 ft(w/ 3 ft buffer) (Reference NESC Rule 233)
REA:	N/A
Other:	N/A

Clearance to Structures of Another Line

NESC:	22 ft (w/3 ft buffer) (Reference NESC Rule 234B)
REA:	N/A
Other:	N/A

Horizontal Clearance Between Line Conductors at Fixed Supports

CASE 1: The Horizontal clearance at the structure, of the same or different circuits, shall be per NESC 235B.3.a Alternate Clearance: Pole-to-Pole (horizontal configuration): 34.8' (w/3' buffer).

CASE 2: The Horizontal clearance at the supports, of the same or different circuits, shall also meet requirements according to sags per NESC 235B.1.b(2) :Pole-to-Pole (horizontal configuration): 27' (w/3' buffer).

CASE 3: Galloping

Refer to section titled "Galloping".

Vertical Clearance Between Line Conductors
Note: the poles (conductors) of the DC lines will be located horizontally, so these vertical clearances are just theoretical. Only the distance pole (conductor) to OPGW will be a vertical clearance.

CASE 1: Pole-to-Pole (if they are located in vertical configuration): 30 ft (w/3' buffer).
Pole-to-OPGW: 19 ft (w/3' buffer).The Vertical clearance at the structure shall be per NESC 235C. Reference NESC Table 235-5.

CASE 2: Pole-to-Pole (if they are located in vertical configuration): 30 ft (w/3' buffer).
Pole-to-OPGW: 19 ft (w/ 3' buffer). Vertical clearances at the structure shall be adjusted to provide sag-related clearances at any point in the span per NESC 235C.2.b. The sag-related clearances in the span are considered as diagonal clearances.

CASE 3: Galloping

Refer to section titled "Galloping".

Radial Clearance from Line Conductors to Supports, and to Vertical or Lateral Conductors, Span or Guy Wires Attached to the Same Support

NESC: To supports: 13.5' per NESC Rule 235 E, under both no wind and 6 psf wind (see for details Appendix A-Clearances Calculation Tables)

The "Live Line Maintenance values are no longer a design requirement, but are provided below for reference:
17.33' (MAD for Tools"12.33 per IEEE 516-2009+Working Space: 4.5' per NESC Rule 236&237)

To anchor guys: 16.9' per NESC235E, 4 b., where 600 kV, dc equivalent to 735 kV ac.

REA:	N/A
Other:	N/A

Clearances of the Metal Return Conductors

For Clearances of the Metal Return Conductor , see Appendix P (for entire line, except Mississippi River Crossings; used ACSR Chukar energized at +/- 53 kV) and Appendix P1 (for Mississippi River Crossings; used ACCR/TW Pecos energized at +/-59 kV).

MISCELLANEOUS

Grounding Requirements (type and frequency of grounding required)

Ground Type:

Butt Plate:	N/A
Butt Wrap:	N/A
Ground Rod:	To be used.
Other:	

Frequency of Grounding:

All Structures:	Yes
No. Per Mile:	TBD
Maximum Resistance per Structure (ohms):	10
Other:	

Special Equipment

Describe any special equipment requirements (switches, fiber optic materials, distribution underbuild, reclosers, etc.):

Splice boxes for the OPGW fibers will be used at the splice structures where an OPGW reel will finish, and at certain dead-end structures. Underground loose tube (LT) type fiber optic cable will be used from the last structure to the substation. The fibers from this underground fiber optic cable will be spliced to the fibers from the OPGW inside the splice box located on the last structure before the substation.

Material

Describe Owner supplied material (attach additional sheets if necessary):

Does the utility have a standard material list it uses: YES ☐ NO ☐

Describe Contractor supplied material (attach additional sheets if necessary) :

Environmental Protection

State any measures required or agencies to be contacted for wildlife protection requirements:

Describe any known industrial, salt-water contamination or other environment that may impact or has been known to impact electrical insulation:

State any measures required for airborne contamination protection (dust control):

Describe any known caustic or corrosive soil conditions:

DRAWINGS AND MAPS

Maps

Existing facility maps, P&P's available: YES ☐ NO ☐

List foreign utilities to be considered for project, if maps are available:

Power: ______ Gas: ______
Phone: ______ TV: ______
Sewer: ______ Water: ______
Highways: ______ Railroad: ______
Other: ______

Separate access road maps required: YES ☐ NO ☐
Describe ROW/Environmental or Easement Maps required, if any:

Drawing Requirements
Map and Plan and Profile Scales:

Key Map Scale: ______ **horiz.**
Plan Scale: ______ horiz.
Profile Scale: ______ vert. Size: ______ horiz.

Plan Type:
Planimetric: ______
Topographic: ______
Other: ______

Title Block:
POWER Standard: ______
Other: ______

Drawing Numbers:

POWER Generated: ______________________________

Owner Generated (describe): ______________________________

Final Drawings: ______________________________

Describe structure numbering sequence:

____

____

____

Describe any controlling mapping specifications:

All coordinates will be based on various State Plane systems, as required. Vertical datum is based on NAVD 88.

____

____

SUBSTATION/SWITCHYARD INTERFACE

Terminate at existing substation entry structure: YES ☐ NO

Comments: ______________________________

Maximum allowable tensions for substation deadend:

Conductor:	5000 lbs (assumed, no station data available)
OPGW/OHGW:	3000 lbs (assumed, no station data available)

Attachment height above ground substation deadend:

Conductor:	TBD (no station data available)
OPGW/OHGW:	TBD (no station data available)

Are substation drawings available? YES ☐ NO ☐, (if so, include)

OTHER

Describe any other items the engineer/designer may need to know to complete this project (attach additional sheets if necessary):

____

____

____

APPENDIX A- POLE CONDUCTOR CLEARANCES TABLES

Comparison of Clearances for Clean Line +/- 600 kV Project Plains & Eastern

Case	**NESC- DC** V nom=600 KV peak, pole-ground V max=632 KV (5% over V nom)	**NESC- AC Equivalent** V nom=735 KV rms, phase-to-phase 735=600*sqrt(3)/sqrt(2) Rule 230 H V max=772 KV (5% over V nom)	**EPRI** T/L Reference Book HVDC Lines	**MAD* for Tools** (IEEE 516-2009) **+ Working Space** (NESC Rule 236& 237)	**Conclusion**: Minimum possible value that can be used
Conductor to Ground:	Rule 232 D.3:	Rule 232 B and 232 C:	Not addressed.	N/A	
a. Track rails of railroads	38.68’ (bare) 39’ (rounded) 42’ (w/3’ buffer)	40.6’ (bare) 41’ (rounded) 44’ (w/3’ buffer)			**42’**
b. Streets, Alleys, roads, driveways, and parking lots	30.68’ (bare) 31’ (rounded) 34’ (w/3’ buffer)	32.6’ (bare) 33’ (rounded) 36’ (w/3’ buffer)			**34’**
c. Spaces and ways subject to pedestrians or restricted traffic:	26.68’ (bare) 27’ (rounded) 30’ (w/3’ buffer)	28.6’ (bare) 29’ (rounded) 32’ (w/3’ buffer)			**30’**
d. Vehicular areas	30.68’ (bare) 31’ (rounded) 34’ (w/3’ buffer)	32.6’ (bare) 33’ (rounded) 36’ (w/3’ buffer)			**34’**
Conductor to Water:	Rule 232 D, Table 232-3:	Rule 232, Table 232-1:	Not addressed.	N/A	
e. Water areas not suitable for sail boating or where sail boating is prohibited	28.46’ (bare) 29’ (rounded) 32’ (w/3’ buffer)	31.1’ (bare) 32’ (rounded) 35’ (w/3’ buffer)			**32’**
f. Water areas suitable for sail boating, including rivers, lakes, ponds, canals with unobstructed surface area:					
1) less than 0.08 km^2 (20 acres)	31.96’ (bare) 32’ (rounded) 35’ (w/3’ buffer)	34.6’ (bare) 35’ (rounded) 38’ (w/3’ buffer)			**35’**
(2) over 0.08 to 0.8 km^2 (20 to 200 acres)	39.96’ (bare) 40’ (rounded) 43’ (w/3’ buffer)	42.6’ (bare) 43’ (rounded) 46’ (w/3’ buffer)			**43’**
3) over 0.8 to 8 km^2 (200 to 2000 acres)	45.96’ (bare) 46’ (rounded) 49’ (w/3’ buffer)	48.6’ (bare) 49’ (rounded) 52’ (w/3’ buffer)			**49’**
(4) over 8 km^2 (2000 acres) Mississippi River Crossing	51.96’ (bare) 52’ (rounded) 55’ (w/3’ buffer)	54.6’ (bare) 55’ (rounded) 58’ (w/3’ buffer)			**55’**

Case	**NESC- DC** V nom=600 KV peak, pole-ground V max=632 KV (5% over V nom)	**NESC- AC Equivalent** V nom=735 KV rms, phase-to-phase 735=600*sqrt(3)/sqrt(2) Rule 230 H V max=772 KV (5% over V nom)	**EPRI** T/L Reference Book HVDC Lines	**MAD* for Tools** (IEEE 516-2009) **+ Working Space** (NESC Rule 236& 237)	**Conclusion**: Minimum possible value that can be used
Conductor to Own Structure No Wind	12.96' (bare) 13' (rounded) 13.5' (w/ 0.5 ' buffer) Rule 235 E.3b	12.95' (bare) 13' (rounded) 13.5' (w/0.5' buffer) Rule 235E, Table 235-6, item 4b	16.4' No Wind Case corresponds to Lightning Impulse, required clearance from Figure 10-13, page 150. Lightning Surge will be at least 30% higher than Switching Surge: 1080*1.3=1404 kV Surge Factor: Ti=1.8	12.83'+4.5'=17.33' MAD+WS	**13.5'**
Conductor to Own Structure Medium Wind 6 psf	12.96' (bare) 13' (rounded) 13.5' (w/0.5' buffer) Rule 235 E.3b	12.95' (bare) 13' (rounded) 13.5' (w/0.5' buffer) Rule 235E, Table 235-6, item 4b	9.8 ' Medium Wind Case corresponds to Switching Impulse, required clearance from Figure 10-13, page 150 Switching Surge=1.8*600 =1080 kV Surge Factor: Ti=1.8	12.83'+4.5'=17.33' MAD+WS	**13.5'**
Conductor to Own Structure Extreme Wind 24.3 psf	Not addressed	Not addressed	4.1' (no buffer) 5' (w/0.9' buffer) Extreme Wind corresponds to Steady State required clearance from Fig.10-3 , Page 145 and Fig.10-4, Page 146.	Not addressed	**5'**

*MAD=Minimum Approach Distance.

NESC-Clearance Conductor to Ground calculation:

NESC- DC: V nom=600 KV peak, pole-ground V max=632 KV (5% over V nom)	**NESC- AC Equiv** V nom=735 KV rms, phase-to-phase 735=600*sqrt(3)/sqrt(2) Rule 230 H V max=772 KV (5% over V nom)
Rule 232D, table 232-3: a. Track rails of railroads: H ref=22’ b. Streets, Alleys, roads, driveways, and parking lots: H ref=14’ c. Spaces and ways subject to pedestrians or restricted traffic: H ref=10’ d. Vehicular areas: H ref=14’ For Ref Altitude < 1500 ft: V max=1.05*V nom=632 kV C ref=3.28*(632*1.8*1.15/(500*1.15)^1.667*1.03*1.2=15.96’ For assumed maximum altitude for this line (worst case scenario): 3000 ft: Altitude Adder: (3000’-1500’)/1000’*3%=4.5% C alt=C ref*1.045=15.96’*1.045=16.68’ a. Track rails of railroads: C total=H ref + C alt=22’ + 16.68’=**38.68’ (bare)** **39’ (rounded)** **42’ (w/3’ buffer)** **CHOSEN** b. Streets, Alleys, roads, driveways, and parking lots: C total=H ref + C alt=14’ + 16.68’=**30.68’ (bare)** **31’ (rounded)** **34’ (w/3’ buffer)** **CHOSEN** c. Spaces and ways subject to pedestrians or restricted traffic: C total=H ref + C alt=10’ + 16.68’=**26.68’ (bare)** **27’ (rounded)** **30’ (w/3’ buffer)** **CHOSEN** d. Vehicular Areas: C total=H ref + C alt=14’ + 16.68’=**30.68’ (bare)** **31’ (rounded)** **34’ (w/3’ buffer)** **CHOSEN**	Equivalent max ac system voltage=735*1.05=772 KV Equivalent max ac system voltage, phase-to-ground=772/sqrt(3)=446 kV NESC Rule 232, Table 232-1, open supply conductor up to 22 kv: a. Track rails of railroads: H basic=26.5’ b. Streets, Alleys, roads, driveways, and parking lots: H basic=18.5’ c. Spaces and ways subject to pedestrians or restricted traffic: H basic=14.5’ d. Vehicular areas: H basic=18.5’ Voltage Adder: C adder=(446-22)*0.4”/12=14.1’ Altitude adder : zero a. Track rails of railroads: C total=H basic + C adder= 26.5’ + 14.1’=**40.6’ (bare)** **41’ (rounded)** **44’ (w/3’ buffer)** b. Streets, Alleys, roads, driveways, and parking lots: C total=H basic + C adder= 18.5’ + 14.1’=**32.6’ (bare)** **33’ (rounded)** **36’ (w/3’ buffer)** c. Spaces and ways subject to pedestrians or restricted traffic : C total=H basic + C adder= 14.5’ + 14.1’=**28.6’ (bare)** **29’ (rounded)** **32’ (w/3’ buffer)** d. Vehicular Areas: C total=H basic + C adder= 18.5’ + 14.1’=**32.6’ (bare)** **33’ (rounded)** **36’ (w/3’ buffer)**

NESC- Clearance Conductor-to-Own Structure calculation

for Cases: Medium Wind (6 psf) and No Wind:

NESC- DC: V nom=600 KV peak, pole-ground V max=632 KV (5% over V nom)	**NESC- AC Equiv** V nom=735 KV rms, phase-to-phase 735=600*sqrt(3)/sqrt(2) Rule 230H V max=772 KV (5% over V nom)
Rule 235E3b For Ref Altitude < 1500 ft: V max=1.05*V nom=632 kV C ref=39.37*(632*1.8*1.15/(500*1.2)^1.667*1.03=148.7”=12.4’ For assumed maximum altitude for this line (worst case scenario): 3000 ft: Altitude Adder: (3000’-1500’)/1000’*3%=4.5% C alt=C ref*1.045=12.4’*1.045=12.96’ C alt=**12.96’ (bare)** **13’ (rounded)** **13.5’ (w/0.5’ buffer)** **CHOSEN**	Equivalent max ac system voltage=735*1.05=772 KV Equivalent max ac system voltage, phase-to-ground=772/sqrt(3)=446 kV NESC Rule 235 E, 4b, open supply conductor up to 50 kv: H basic=11”=0.917’ Voltage Adder: C adder=(772-50)*0.2”/12=12.033’ Altitude adder : zero C total=H basic + C adder= 0.917’ + 12.033’=**12.95’ (bare)** **13’ (rounded)** **13.5’ (w/0.5’ buffer)**

NESC- Clearance to Anchor Guys calculation:

for Cases: Medium Wind (6 psf) and No Wind:

NESC- DC: V nom=500 KV peak, pole-ground V max=525 KV (5% over V nom)	**NESC- AC Equiv** V nom=735 KV rms, phase-to-phase 735=600*sqrt(3)/sqrt(2) Rule 230H V max=772 KV (5% over V nom)
Rule 235E3b For Ref Altitude < 1500 ft: V max=1.05*V nom=525 kV Cref=39.37*(525*1.8*1.15/(500*1.2))^1.667*1.03=109.2”=9.096’ For assumed maximum altitude for this line (worst case scenario): 3000 ft: Altitude Adder: (3000’-1500’)/1000’*3%=4.5% C alt=C ref*1.045=9.096’*1.045=9.506’ C alt=**9.506’ (bare)** **10’ (rounded)** **10.5’ (w/0.5’ buffer)**	Equivalent max ac system voltage=735*1.05=772 KV Equivalent max ac system voltage, phase-to-ground=772/sqrt(3)=446 kV NESC Rule 235 E, 4b, open supply conductor up to 50 kv: H basic=16”=1.333’ Voltage Adder: C adder=(772-50)*0.25”/12=15.041’ Altitude adder : zero C total=H basic + C adder= 1.333’ + 15.041’=**16.374’ (bare)** **16.4’ (rounded)** **16.9 ’ (w/0.5 ’ buffer)** **CHOSEN**

NESC-Clearance to Right –of-Way (Blowout):

for Cases: Medium Wind (6 psf) and No Wind:

NESC- DC:	NESC- AC Equiv
V nom=500 KV peak, pole-ground V max=525 KV (5% over V nom)	V nom=735 KV rms, phase-to-phase 735=600*sqrt(3)/sqrt(2) Rule 230H V max=772 KV (5% over V nom)
Rule 234H, Alternate Clearances, DC Calculations: Clearance to ROW is like clearance to buildings; V pole-to-ground, max=632 kV Table 234-5: H ref=3' (horizontal): Rule 234H3, horizontal electrical clearance: c=1.0: D=3.28*(632*1.8*1.15/(500*1.15))^1.667*1.03*1.0=13.3' With Altitude Adder, assumed Altitude=3000' (worst case): (3000'-1500')/1000'*3%=4.5% D alt =D*1.045=13.3*1.045=13.9' C total=H ref+D alt=3'+13.9'=16.9**' (bare)** **C total=17' (rounded)** **C total=20' (w/3' buffer)**	Equivalent max ac system voltage=735*1.05=772 KV Equivalent max ac system voltage, phase-to-ground=772/sqrt(3)=446 kV NESC Rule 234B, clearance to buildings, open supply conductor up to 22 kv: H basic=4.5' (**with 6 psf wind)** H basic=7.5' (**with no wind**) Voltage Adder: C adder=(446-22)*0.4"/12=14.133' Altitude adder : zero **Medium Wind (6 psf):** C total=H basic + C adder= 4.5' + 14.133'=**18.633' (bare)** **19' (rounded)** **22' (w/3' buffer)** **CHOSEN** **No Wind (0 psf):** C total=H basic + C adder= 7.5' + 14.133'=**21.633' (bare)** **22' (rounded)** **25' (w/3' buffer)** **CHOSEN**

NESC- Clearance Conductor-to-Water calculation

NESC- DC: V nom=600 KV peak, pole-ground V max=632 KV (5% over V nom)	**NESC- AC Equiv** V nom=735 KV rms, phase-to-phase 735=600*sqrt(3)/sqrt(2) Rule 230H V max=772 KV (5% over V nom)
Rule 232D, Table 232-3 item: e. Water areas not suitable for sail boating or where sail boating is prohibited: H ref=12.5’ f. Water areas suitable for sail boating, including rivers, lakes, ponds, canals with unobstructed surface area: (1) less than 0.08 km^2 (20 acres): H ref=16’ (2) over 0.08 to 0.8 km^2 (20 to 200 acres): H ref=24’ (3) over 0.8 to 8 km^2 (200 to 2000 acres): H ref=30’ (4) over 8 km^2 (2000 acres): Mississippi River Crossing: H ref=36’ For Ref Altitude < 1500 ft: V max=1.05*V nom=632 kV C ref=3.28*(632*1.8*1.15/(500*1.15)^1.667*1.03*1.2=15.96’ PU=1.8-maximum switching surge factor for +/- 600 kV DC Altitude at Mississippi River Crossing location: Alt=300’ from PLS-CADD Model 300’ < 1500’ results: Altitude Adder=0, results: C alt=C ref=15.96’ e. Water areas not suitable for sail boating or where sail boating is prohibited: C total=H ref+C alt=12.5’+15.96’=**28.46’ (bare)** **C total=29’ (rounded)** **C total=32’ (w/3’ buffer)** **CHOSEN** Water areas suitable for sail boating, including rivers, lakes, ponds, canals with unobstructed surface area: (1) less than 0.08 km^2 (20 acres): C total=H ref+C alt=16’+15.96’=**31.96’ (bare)** **C total=32’ (rounded)** **C total=35’ (w/3’ buffer)** **CHOSEN** (2) over 0.08 to 0.8 km^2 (20 to 200 acres): C total=H ref+C alt=24’+15.96’=**39.96’ (bare)** **C total=40’ (rounded)** **43’ (w/3’ buffer)** **CHOSEN** (3) over 0.8 to 8 km^2 (200 to 2000 acres): C total=H ref+C alt=30’+15.96’=**45.96’ (bare)** **C total=46’ (rounded)** **49’ (w/3’ buffer)** **CHOSEN** (4) over 8 km^2 (2000 acres): Mississippi River Crossing: C total=H ref+C alt=36’+15.96’=**51.96’ (bare)** **C total=52’ (rounded)** **55’ (w/3’ buffer)** **CHOSEN**	Equivalent max ac system voltage=735*1.05=772 KV Equivalent max ac system voltage, phase-to-ground=772/sqrt(3)=446 kV NESC Rule 232, Table 232-1, open supply conductor up to 22 kV: 6. Water areas not suitable for sail boating or where sail boating is prohibited: H basic=17’ 7. Water areas suitable for sail boating, including rivers, lakes, ponds, canals with unobstructed surface area: (1) less than 0.08 km^2 (20 acres): H basic=20.5’ (2) over 0.08 to 0.8 km^2 (20 to 200 acres): H basic=28.5’ (3) over 0.8 to 8 km^2 (200 to 2000 acres): H ref=34.5’ (4) over 8 km^2 (2000 acres): Mississippi River Crossing: H ref=40.5’ Voltage Adder: C adder=(446-22)*0.4”/12=14.1’ Altitude at Mississippi River Crossing location: Alt=300’ from PLS-CADD Model 300’ < 1500’ results: Altitude Adder=0, results: C alt=0 e. Water areas not suitable for sail boating or where sail boating is prohibited: C total=H basic + C adder= 17’ + 14.1’=**31.1’ (bare)** **C total=32’ (rounded)** **C total=35’ (w/3’ buffer)** f. Water areas suitable for sail boating, including rivers, lakes, ponds, canals with unobstructed surface area: (1) less than 0.08 km^2 (20 acres): C total=H basic + C adder= 20.5’ + 14.1’=**34.6’ (bare)** **C total=35’ (rounded)** **C total=38’ (w/3’ buffer)** (2) over 0.08 to 0.8 km^2 (20 to 200 acres): C total=H basic + C adder= 28.5’ + 14.1’=**42.6’ (bare)** **C total=43’ (rounded)** **C total=46’ (w/3’ buffer)** (3) over 0.8 to 8 km^2 (200 to 2000 acres): C total=H basic + C adder= 34.5’ + 14.1’=**48.6’ (bare)** **C total=49’ (rounded)** **C total=52’ (w/3’ buffer)** 4) over 8 km^2 (2000 acres): Mississippi River Crossing: C total=H basic + C adder= 40.5’ + 14.1’=**54.6’ (bare)** **C total=55’ (rounded)** **C total=58’ (w/3’ buffer)**

NESC-Clearance Conductor to Grain Bins calculation:

NESC- DC: V nom=600 KV peak, pole-ground V max=632 KV (5% over V nom)	**NESC- AC Equiv** V nom=735 KV rms, phase-to-phase 735=600*sqrt(3)/sqrt(2) Rule 230 H V max=772 KV (5% over V nom)
Rule 234H2, Table 234-5, item b: “other installation”” grain bins: V ref=9’; H ref=3’ Rule 234H3a : Electric Clearances: For Ref Altitude < 1500 ft: V=V max=1.05*V nom=1.05*600=632 kV: C ref=3.28*(V*PU*a/(500*k)^1.667*b*c C ref V =3.28*(632*1.8*1.15/(500*1.15)^1.667*1.03*1.2=15.96’ C ref H=3.28*(632*1.8*1.15/(500*1.15)^1.667*1.03*1.0=13.30’ Rule 234H3, b: For assumed maximum altitude for this line (worst case scenario): 3000 ft: Altitude Adder: (3000’-1500’)/1000’*3%=4.5% C alt V =C ref V *1.045=15.96’*1.045=16.68’ C alt H =C ref H *1.045=13.30’*1.045=13.89’ Grain Bins: **Vertical:** V total=V ref + C alt V = 9’ + 16.68’=**25.68’ (bare)** **26’ (rounded)** **29’ (w/3’ buffer)** **Horizontal:** H total=H ref + C alt H = 3’ + 13.89**’ =16.89’ (bare)** **17’ (rounded)** **20’ (w/3’ buffer)**	Equivalent max ac system voltage=735*1.05=772 KV Equivalent max ac system voltage, phase-to-ground=772/sqrt(3)=446 kV **CASE 1: Rule 234 F1: PERMANENT ELEVATOR** **NESC Figure 234-4 (a):** **Vertical:** NESC Rule 234F1.a, open supply conductor up to 22 kV: Grain Bins: V basic=18’ Rule 234G1: Voltage Adder: C adder=(446-22)*0.4”/12=14.1’ Altitude adder : zero (Altitude, worst case assumed: 3000 ft , which is less than 3300 ft) V total=V basic+ C adder=18’+14.1’=**32.1’ (bare)** **32.1’ (rounded)** **35.1’ (w/3’ buffer)** **CHOSEN** **Horizontal (At Rest, No Wind):** NESC Rule 234F1.b, open supply conductor up to 22 kV: Grain Bins: H basic=15’ Rule 234G1: Voltage Adder: C adder=(446-22)*0.4”/12=14.1’ Altitude adder : zero (Altitude, worst case assumed: 3000 ft , which is less than 3300 ft) H total=H basic+ C adder=15’+14.1’=**29.1’ (bare)** **29.1’ (rounded)** **32.1’ (w/3’ buffer)** **CHOSEN** **Horizontal (Displaced, 6 psf Wind):** NESC Rule 234D1b, open supply conductor up to 22 kV: Grain Bins with permanent elevator under wind are considered as “Building” under wind: H basic=4.5’ Rule 234G1: Voltage Adder: C adder=(446-22)*0.4”/12=14.1’ Altitude adder : zero (Altitude, worst case assumed: 3000 ft , which is less than 3300 ft) H total=H basic+ C adder=4.5’+14.1’=**18.6’ (bare)** **18.6’ (rounded)** **21.6’ (w/3’ buffer)** **CHOSEN**

CASE 2: RULE 234 F 2: PORTABLE ELEVATOR
ARE CONSIDERED BY NESC ONLY AT REST, NO WIND DISPLACEMENT:

CASE 2.1: LOADED SIDE
NESC Figure 234-4 (b):

Vertical:

32.1' (rounded)
35.1' (w/3' buffer)
CHOSEN

Horizontal (At Rest, No Wind):

32.1' (rounded)
35.1' (w/3' buffer)
CHOSEN

CASE 2.2: UN-LOADED SIDE
NESC Figure 234-4 (b):

UNLOADED SIDE is considered by NESC as "Buildings" Rule 234C

Vertical:

Rule 234 C, Table 234-1, 1.Building, b.Vertical,(1)
"building not accessible to pedestrians" (the elevator):

V basic=12.5' (No Wind)

Rule 234G1:
Voltage Adder: C adder=(446-22)*0.4"/12=14.1'

Altitude adder : zero
(Altitude, worst case assumed: 3000 ft , which is less than 3300 ft)

V total=V basic+ C adder=12.5'+14.1'=**26.6' (bare)**
26.6' (rounded)
29.6' (w/3' buffer)
CHOSEN

Horizontal (At Rest, No Wind):
Rule 234 C, Table 234-1, 1Building, a. Horizontal :

H basic=7.5' (No wind)

Rule 234G1:
Voltage Adder: C adder=(446-22)*0.4"/12=14.1'

Altitude adder : zero
(Altitude, worst case assumed: 3000 ft , which is less than 3300 ft)

H total=H basic+ C adder=7.5'+14.1'=**21.6' (bare)**
21..6' (rounded)
24.6' (w/3' buffer)
CHOSEN

Calculations of Required Vertical and Horizontal Clearances +/- 600 kV DC Pole Conductor to

Under-Crossing Lines or Parallel/Adjacent Lines

500 kV, 345 kV, 230 kV, 161 kV, 138 kV,115 kV, 69 kV, 35 kV, 25, 12.5 KV AC Conductors and 0 KV Groundwire

Different Structures, Different Utilities, Different Circuits

Upper Circuit:

$V_{\text{dc, crest (peak), pole-to-ground}}$=600 kV dc   Equivalent to: $V_{\text{ac, rms, phase-to-phase}} = 600\ kV * \frac{\sqrt{3}}{\sqrt{2}} = 735\ kV\ ac$

Lower Circuit (Crossing or Parallel):

Vertical Clearance: NESC Rule 233 C.2.a, Table 233-1:

$$V = \frac{\left[24 + \left(735 * \frac{1.05}{\sqrt{3}} + V_{lower} * \frac{1.05}{\sqrt{3}} - 22\right) * 0.4\right]}{12}$$

Horizontal Clearance: NESC Rule 233 B.1.a:

$$H = \frac{\left(735 * \frac{1.05}{\sqrt{3}} + V_{lower} * \frac{1.05}{\sqrt{3}} - 22\right) * 0.4}{12}$$

Altitude: Maximum 3000' in the entire P&E line, less than 3300', results: Altitude adder=0 (Rule 233C2.b for Vertical and Rule 233B.2 for Horizontal).

Circuit Type	Upper Circuit: 600 kV dc (equivalent 735 kV ac)				
	Crossing or Parallel: Lower Circuit: V lower [kV]	V [ft] (Bare)	**V [ft] (with 3'buffer)**	H [ft] (Bare)	**H [ft] (with 3'buffer)**
Transmission	500	26.2	**29.2**	24.2	**27.2**
	345	23.1	**26.1**	21.1	**24.1**
	230	20.8	**23.8**	18.8	**21.8**
	161	19.4	**22.4**	17.4	**20.4**
	138	18.9	**21.9**	16.9	**19.9**
	115	18.5	**21.5**	16.5	**19.5**
	69	17.5	**20.5**	15.5	**18.5**
Distribution	35	16.8	**19.8**	14.8	**17.8**
	25	16.6	**19.6**	14.6	**17.6**
	12.5	16.4	**19.4**	14.4	**17.4**
Groundwire	0	16.1	**19.1**	14.1	**17.1**

Required Vertical Clearances are used for Under-Crossing Lines, for following loading cases:

1. Upper 600 KV dc conductor at MOT or at 32 F, with Ice (0.5" for Heavy NESC locations; or 0.25" for Medium NESC locations), which ever results in greater sag, and Under-Crossed Line conductor at 60 F Bare.

2. Upper 600 KV dc conductor at 60 F, and Under-Crossed Line conductor at 60 F, 6 psf transverse wind (the transverse wind, from both directions, on the Under-Crossing Line is parallel to the 600 kV dc line, thus having no effect on the 600 kV dc line, but having an effect on the Under-Crossing Line, raising its conductor and getting it closer to the 600 kV dc conductor).

Required Vertical and Horizontal Clearances are used for Parallel or Adjacent Lines, for following cases:

1. Upper 600 kV dc conductor and Parallel Line conductor, both under 6 psf transverse wind, from both directions.

2. Upper 600 KV dc conductor at MOT or at 32 F, with Ice (0.5" for Heavy NESC locations; or 0.25" for Medium NESC locations), which ever results in greater sag, and Parallel or Adjacent Line conductor at 60 F Bare.

Vertical Clearances +/- 600 kV DC Pole Conductor (PC) to +/- 53 KV DC Metal Return Conductor (MRC):

Different Circuits, Same Supports, Same Utility

NESC- DC:	NESC- AC Equiv
Pole Conductor (PC): V nom=600 KV peak, pole-ground V max=632 KV (5% over V nom) Metal Return Conductor (MRC): V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	Pole Conductor (PC): V nom=735 KV rms, phase-to-phase 735=600*sqrt(3)/sqrt(2) Rule 230 H V max=772 KV (5% over V nom) Metal Return Conductor (MRC): V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230 H V max=68 KV (5% over V nom)
V max= V H = 632 KV dc pole to ground > 138 kV dc pole to ground **Therefore Alternative DC Calculations are applicable.** **NESC Rule 235C3: "Alternate Clearances":** can be used, if switching surge factor is known, but it cannot be less than the values from Rule 233C3 (crossing): **Vertical: Rule 233 C3.b (1): Electrical Component:** D=3.28*[((V H*PU+V L)*a)/(500*k)]^1.667*b*c Where: V H = 600*1.05=632 KV, dc, max, pole-to-ground V L = 53*1.05=56 KV, dc, max, pole-to-ground a =1.15 b = 1.03 c = 1.2 k=1.4 PU = 1.8 (switching surge factor) Results: D=12.46' DC Line Altitude Adder ("threshold" value:1500'): Assumed Altitude=3000' (worst case)> 1500', results: (3000'-1500')/1000'*3%=4.5% D alt =D*1.045=12.46*1.045=13.02' LIMITS: Rule 233 C3c:, Table 233-1. Vertical: the "Alternate Clearance" shall not be less than the clearances required by Rule 233C1 & 233C2, with the lower voltage circuit at ground potential: D=2+0.4/12*[600*1.05/sqrt(2)+0KV-22]=16.12', **rounded up: 17' (bare)** **D=17'+3' buffer=20' (with 3' buffer)**	**NESC Rule 235 C :** **Vertical Clearance of Different Circuits, Same Supports, Same Utility:** **Rule 235.C.2a, Table 235-5, 2d: SAME UTILITY, AT SUPPORTS:** V=[16/12+(50-8.7)*0.4/12]+[(735*1.05/sqrt(3)+65*1.05/sqrt(3)-50)*0.4/12]= =2.71' + 14.50'=17.2', **rounded up: 17.5' (bare)** **V=17.5'+3' buffer=20.5' (with 3' buffer) CHOSEN** **Rule 235.C.2.b(1),(b): SAME UTILITY, IN SPAN:** V=[16/12+(50-8.7)*0.4/12]*0.75 +[(735*1.05/sqrt(3)+65*1.05/sqrt(3)-50)*0.4/12]= =2.03' + 14.50'=16.53', **rounded up: 17' (bare)** **V=17'+3' buffer=20' (with 3' buffer) CHOSEN** AC Line Altitude Adder ("threshold" value 3300'): Assumed 3000' (worst case) < 3300', results: Altitude Adder=0.

Horizontal Clearances +/- 600 kV DC Pole Conductor (PC) to +/- 53 KV DC Metal Return Conductor (MRC):

Different Circuits, Same Supports, Same Utility

NESC- DC:	NESC- AC Equiv
Pole Conductor (PC): V nom=600 KV peak, pole-ground V max=632 KV (5% over V nom) Metal Return Conductor (MRC): V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	Pole Conductor (PC): V nom=735 KV rms, phase-to-phase 735=600*sqrt(3)/sqrt(2) Rule 230 H V max=772 KV (5% over V nom) Metal Return Conductor (MRC): V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230 H V max=68 KV (5% over V nom)
V max= V H = 632 KV dc pole to ground > 138 kV dc pole to ground **Therefore Alternative DC Calculations are applicable.** **NESC Rule 235B3: "Alternate Clearances":** can be used, if switching surge factor is known, but it cannot be less than the values from Rule 235B3.b: **Vertical: Rule 235 B3: Electrical Component:** D=3.28*[(V L-L*PU*a)/(500*k)]^1.667*b Where: V L-L = maximum dc operating voltage between poles of different Cricuits, same support structure: V L-L = V H+ V L = 632 + 56 =688 KV, dc, max, pole-to-pole V H = 600*1.05=632 KV, dc, max, pole-to-ground V L = 53*1.05=56 KV, dc, max, pole-to-ground PU = 1.8 (switching surge factor) a=1.15 b=1.03 k=1.4 **Results:** D=11' DC Line Altitude Adder ("threshold" value:1500'): Assumed Altitude=3000' (worst case)> 1500', results: (3000'-1500')/1000'*3%=4.5% **D alt**=D*1.045=11*1.045=**11.50' (bare)** **D alt=11.50't+3' buffer=14.50' (with 3' buffer)** **Limit: Rule 235B.3.b: the clearance derived from Rule 235B3a Should not be less than the basic clearance given in Table 235-1 computed for 169 kV ac:** **C limit=28.5/12+0.4/12*(169*1.05-50)=6.62' (bare)** **D =11.50' (bare)> C limit=6.62' (bare), OK** **Results:** **H=14.5' (with 3' buffer)**	**NESC Rule 235 B :** **Horizontal Clearance of Different Circuits, Same Supports, Same Utility:** **Rule 235B.1.a, Table 235-1: Supply Conductors of different circuits:** H=28.5/12+0.4/12*(735*1.05/sqrt(3)+65*1.05/sqrt(3)-50)= =2.375'+14.50'=16.875', **rounded up: 17' (bare)** **H=17'+3' buffer=20' (with 3' buffer) CHOSEN** **Rule 235B.1b, Clearance according to Sags:** C=0.3/12*(735*1.05/sqrt(3)+65*1.05/sqrt(3))+8/12*sqrt(56.195*12/12)= =12.125'+5'=**17.125', rounded: 17' (bare)** results**: C=17'+3' buffer=20' (with 3' buffer) CHOSEN** S=sag in ft, at 60 F, final, unloaded sag, no wind, no ice: 600 KV dc : ACSR Bluebird: S 60 F, final=56.81' in RS=1500' 53 kV dc: ACSR Chukar: S 60 F, final=55.58' in RS=1500' S avg = (56.81'+55.58')/2=56.195' AC Line Altitude Adder ("threshold" value 3300'): Assumed 3000' (worst case) < 3300', results: Altitude Adder=0.

Vertical Clearances +/- 600 kV DC Pole Conductor (PC) to 0 KV Shieldwire (OPGW):

Different Circuits, Same Supports, Same Utility

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NESC- DC:

Pole Conductor (PC):

V nom=600 KV
peak, pole-ground

V max=632 KV
(5% over V nom)

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NESC- AC Equiv

Pole Conductor (PC):

V nom=735 KV
rms, phase-to-phase
735=600*sqrt(3)/sqrt(2)
Rule 230 H

V max=772 KV
(5% over V nom)

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NESC Rule 235C3: "Alternate Clearances": can be used, if switching surge factor is known, but it cannot be less than the values from Rule 233C3 (crossing):

Vertical: Rule 233 C3.b (1): Electrical Component:

D=3.28*[((V H*PU+V L)*a)/(500*k)]^1.667*b*c

Where:
V H = 600*1.05=632 KV, dc, max, pole-to-ground
V L = 0 kV (shieldwire)
a =1.15
b = 1.03
c = 1.2
k=1.4
PU = 1.8 (switching surge factor)

Results:

D=11.50'

DC Line Altitude Adder ("threshold" value:1500'):

Assumed Altitude=3000' (worst case)> 1500', results:

(3000'-1500')/1000'*3%=4.5%

D alt =D*1.045=11.50*1.045=12'

LIMITS: Rule 233 C3c:, Table 233-1. Vertical: the "Alternate Clearance" shall not be less than the clearances required by Rule 233C1 & 233C2, with the lower voltage circuit at ground potential:

D=2+0.4/12*[600*1.05/sqrt(2)+0KV-22]=16.12',
rounded : 16' (bare)

D=16'+3' buffer=19' (with 3' buffer)

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NESC Rule 235 C :
Vertical Clearance of Different Circuits, Same Supports, Same Utility:

Rule 235.C.2a, Table 235-5, 2d: SAME UTILITY, AT SUPPORTS:

V=[16/12+(50-8.7)*0.4/12]+[(735*1.05/sqrt(3)+0*1.05/sqrt(3)-50)*0.4/12]=

=2.71' + 13.19'=15.9'**, rounded up: 16' (bare)**

V=16'+3' buffer=19' (with 3' buffer) CHOSEN

Rule 235.C.2.b(1),(b): SAME UTILITY, IN SPAN:

V=[16/12+(50-8.7)*0.4/12]*0.75 +[(735*1.05/sqrt(3)+0*1.05/sqrt(3)-50)*0.4/12]=

=2.03' + 13.19'=15.22'**, rounded up: 15.5' (bare)**

V=15.5'+3' buffer=18.5' (with 3' buffer) CHOSEN

AC Line Altitude Adder ("threshold" value 3300'):

Assumed 3000' (worst case) < 3300', results: Altitude Adder=0.

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Horizontal Clearances +/- 600 kV DC Pole Conductor (PC) to 0 KV Shieldwire (OPGW):

Different Circuits, Same Supports, Same Utility

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NESC- DC:

Pole Conductor (PC):

V nom=600 KV
peak, pole-ground

V max=632 KV
(5% over V nom)

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NESC- AC Equiv

Pole Conductor (PC):

V nom=735 KV
rms, phase-to-phase
735=600*sqrt(3)/sqrt(2)
Rule 230 H

V max=772 KV
(5% over V nom)

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NESC Rule 235B3: "Alternate Clearances": can be used, if switching surge factor is known, but it cannot be less than the values from Rule 235B3.b:

Vertical: Rule 235 B3: Electrical Component:

D=3.28*[(V L-L*PU*a)/(500*k)]^1.667*b

Where:
V L-L = maximum dc operating voltage between poles of different Cricuits, same support structure:
V L-L = V H+ V L = 632 + 0 =632 KV, dc, max, pole-to-pole

V H = 600*1.05=632 KV, dc, max, pole-to-ground
V L = 0*1.05= 0KV, dc, max, pole-to-ground (shieldwire)
PU = 1.8 (switching surge factor)
a=1.15
b=1.03
k=1.4

Results:
D=9.58'
DC Line Altitude Adder ("threshold" value:1500'):
Assumed Altitude=3000' (worst case)> 1500', results:
(3000'-1500')/1000'*3%=4.5%
D alt=D*1.045=9.58*1.045=**10' (bare)**

Dalt=10't+3' buffer=13' (with 3' buffer)

i **Limit: Rule 235B.3.b: the clearance derived from Rule 235B3a Should not be less than the basic clearance given in Table 235-1 computed for 169 kV ac:**
C limit=28.5/12+0.4/12*(169*1.05-500=6.62' (bare)
D =10' (bare)> C limit=6.62' (bare), OK

Results:
H=13' (with 3' buffer)

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NESC Rule 235 B :
Horizontal Clearance of Different Circuits, Same Supports, Same Utility:

Rule 235B.1.a, Table 235-1: Supply Conductors of different circuits:

H=28.5/12+0.4/12*(735*1.05/sqrt(3)+0*1.05/sqrt(3)-50)=
=2.375'+13.19'=15.565'**, rounded up: 16' (bare)**

H=16'+3' buffer=19' (with 3' buffer) CHOSEN

Rule 235B.1b, Clearance according to Sags:

C=0.3/12*(735*1.05/sqrt(3)+0*1.05/sqrt(3))+8/12*sqrt(48.345*12/12)=
=11.139'+4.635'=**15.774', rounded: 16' (bare)**

results**: C=16'+3' buffer=19' (with 3' buffer) CHOSEN**

S=sag in ft, at 60 F, final, unloaded sag, no wind, no ice:

600 KV dc : ACSR Bluebird: S 60 F, final=56.81' in RS=1500'

0 kV dc: Shieldwire (OPGW): S 60 F, final=39.88' in RS=1500'

S avg =(56.81'+39.88')/2=48.345'

AC Line Altitude Adder ("threshold" value 3300'):

Assumed 3000' (worst case) < 3300', results: Altitude Adder=0.

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Vertical Clearances +/- 53 kV DC Metal Return Conductor (MRC) to 0 KV Shieldwire (OPGW):

Different Circuits, Same Supports, Same Utility

NESC- DC:	NESC- AC Equiv:
Metal Return Conductor (MRC): V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	Metal Return Conductor (MRC): V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230 H V max=68 KV (5% over V nom)
V max= 56 KV dc pole to ground < 138 kV dc pole to ground **Therefore Alternative DC Calculations are N/A.** But, if is necessary to know what would be the values, here are the calculations: **NESC Rule 235C3: "Alternate Clearances":** can be used, if switching surge factor is known, but it cannot be less than the values from Rule 233C3 (crossing): **Vertical: Rule 233 C3.b (1): Electrical Component:** D=3.28*[((V H*PU+V L)*a)/(500*k)]^1.667*b*c Where: V H = 53*1.05=56 KV, dc, max, pole-to-ground V L = 0 KV (shieldwire) a =1.15 b = 1.03 c = 1.2 k=1.4 PU = 1.8 (switching surge factor) Results: D=0.2' DC Line Altitude Adder ("threshold" value:1500'): Assumed Altitude=3000' (worst case)> 1500', results: (3000'-1500')/1000'*3%=4.5% D alt =D*1.045=0.2*1.045=0.21' LIMITS: Rule 233 C3c:, Table 233-1. Vertical: the "Alternate Clearance" shall not be less than the clearances required by Rule 233C1 & 233C2, with the lower voltage circuit at ground potential: D=2+0.4/12*[53*1.05/sqrt(2)+0KV-22]=2.58', **rounded up: 3' (bare)** **D=3'+1' buffer=4' (with 1' buffer)**	**NESC Rule 235 C :** **Vertical Clearance of Different Circuits, Same Supports, Same Utility:** **Rule 235.C.2a, Table 235-5, 2d: SAME UTILITY, AT SUPPORTS:** **Because : 68/sqrt(3)=39.4 KV, ac, max, phase-to-ground, which is less than 50 KV, there is no additional adder of 0.4 "/ per each KV over 50 KV:** V=[16/12+(50-8.7)*0.4/12]=2.71', **rounded up: 3' (bare)** **V=3'+1' buffer=4' (with 1' buffer) CHOSEN** **Rule 235.C.2.b(1),(b): SAME UTILITY, IN SPAN:** V=[16/12+(50-8.7)*0.4/12]*0.75=2.03', **rounded : 2' (bare)** **V=2'+1' buffer=3' (with 1' buffer) CHOSEN** AC Line Altitude Adder ("threshold" value 3300'): Assumed 3000' (worst case) < 3300', results: Altitude Adder=0.

Horizontal Clearances +/- 53 kV DC Metal Return Conductor (MRC) to 0 KV Shieldwire (OPGW):

Different Circuits, Same Supports, Same Utility

NESC- DC:	NESC- AC Equiv
Metal Return Conductor (MRC): V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	Metal Return Conductor (MRC): V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230 H V max=68 KV (5% over V nom)
V max= 56 KV dc pole to ground < 138 kV dc pole to ground **Therefore Alternative DC Calculations are N/A.** But, if is necessary to know what would be the values, here are the calculations: **NESC Rule 235B3: "Alternate Clearances":** can be used, if switching surge factor is known, but it cannot be less than the values from Rule 235B3.b: **Vertical: Rule 235 B3: Electrical Component:** D=3.28*[(V L-L*PU*a)/(500*k)]^1.667*b Where: V L-L = maximum dc operating voltage between poles of different circuits, same support structure: V L-L = V H+ V L = 56 + 0 =56 KV, dc, max, pole-to-pole V H = 53*1.05=56 KV, dc, max, pole-to-ground V L = 0*1.05=0 KV (shieldwire) PU = 1.8 (switching surge factor) a=1.15 b=1.03 k=1.4 **Results:** D=0.17' DC Line Altitude Adder ("threshold" value:1500'): Assumed Altitude=3000' (worst case)> 1500', results: (3000'-1500')/1000'*3%=4.5% **D alt**=D*1.045=0.17*1.045=**0.18' , rounded up: 1'(bare)** **D alt=1 ' +1' buffer=2' (with 1' buffer)**	**NESC Rule 235 B :** **Horizontal Clearance of Different Circuits, Same Supports, Same Utility:** **Rule 235B.1.a, Table 235-1: Supply Conductors of different circuits:** **Because : 68/sqrt(3)=39.4 KV, ac, max, phase-to-ground, which is less than 50 KV, there is no additional adder of 0.4 "/ per each KV over 50 KV:** H=28.5/12=2.375'**, rounded up: 2.5' (bare)** **H=2.5'+1' buffer=3.5' (with 1' buffer)** **Rule 235B.1b, Clearance according to Sags:** C=0.3/12*(65*1.05/sqrt(3)+0 kV) + 8/12*sqrt(47.73*12/12)= =0.985'+4.6'=**5.5' (bare);** results**: C=5.5' +1' buffer=6.5' (with 1' buffer) CHOSEN** S=sag in ft, at 60 F, final, unloaded sag, no wind, no ice: 53 kV dc: ACSR Chukar: S 60 F, final=55.58' in RS=1500' 0 KV dc: Shieldwire (OPGW): S 60 F, final=39.88' in RS=1500' S avg =(55.58'+39.88')/2=47.73' AC Line Altitude Adder ("threshold" value 3300'): Assumed 3000' (worst case) < 3300', results: Altitude Adder=0.

Calculations of Required Vertical and Horizontal Clearances +/- 600 kV DC Pole Conductor to

Other Utility Structure, Signs, Billboards, Fences, Buildings (Roof Accessible and Not Accessible to Pedestrians),

Bridges Super Structure (No Personnel Access), Bridge Deck, Swimming Pools

Summary Table: "AC EQUIVALENT CALCULATIONS"

(CHOSEN, because result in the highest values for all cases, except "other utility structure"):

Case	Reference Clearance 234B, 234C, 234D, 234E		Voltage Adder: Rule 234G1		Total Clearance Without Buffer		**Total Clearance With 3' Buffer**	
	Vertical [ft]	Horizontal [ft]	D Vertical [ft]	D Horizontal [ft]	Vertical [ft]	Horizontal [ft]	**Vertical [ft]**	**Horizontal [ft]**
From Other Supporting Structures (Other Utility Structure)	5.5	5.0 (at rest) 4.5 (displaced)	13.2	13.2 (at rest) 14.2 (displaced)	18.7	18.2 (at rest) 18.7 (displaced)	**21.7**	**21.2 (at rest) 21.7 (displaced)**
From Signs, Billboards, Fences, except Bridges and Buildings, above or under catwalks (Accessible to Pedestrians)	13.5	7.5 (at rest) 4.5 (displaced)	14.1	14.1 (at rest) 14.1 (displaced)	27.6	21.6 (at rest) 18.6 (displaced)	**30.6**	**24.6 (at rest) 21.6 (displaced)**
From Signs, Billboards, Fences, except Bridges and Buildings, no catwalks (Not-Accessible to Pedestrians)	8.0	7.5 (at rest) 4.5 (displaced)	14.1	14.1 (at rest) 14.1 (displaced)	22.1	21.6 (at rest) 18.6 (displaced)	**25.1**	**24.6 (at rest) 21.6 (displaced)**
From Buildings (Roof Accessible to Pedestrians)	13.5	7.5 (at rest) 4.5 (displaced)	14.1	14.1 (at rest) 14.1 (displaced)	27.6	21.6 (at rest) 18.6 (displaced)	**30.6**	**24.6 (at rest) 21.6 (displaced)**
Buildings (Roof Not-Accessible to Pedestrians)	12.5	7.5 (at rest) 4.5 (displaced)	14.1	14.1 (at rest) 14.1 (displaced)	26.6	21.6 (at rest) 18.6 (displaced)	**29.6**	**24.6 (at rest) 21.6 (displaced)**
From Bridges Super Structure (No Personnel Access)	12.5	7.5 (at rest) 4.5 (displaced)	14.1	14.1 (at rest) 14.1 (displaced)	26.6	21.6 (at rest) 18.6 (displaced)	**29.6**	**24.6 (at rest) 21.6 (displaced)**
From Bridge Deck	18.5	7.5 (at rest) 4.5 (displaced)	14.1	14.1 (at rest) 14.1 (displaced)	32.6	21.6 (at rest) 18.6 (displaced)	**35.6**	**24.6 (at rest) 21.6 (displaced)**
From Swimming Pools (V=Dim. "A") (H=Dim. "B")	25	17 (at rest) (not defined displaced)	14.1	14.1 (at rest) (not defined displaced)	39.1	31.1 (at rest) (not defined displaced)	**42.1**	**34.1 (at rest) (not defined displaced)**

Summary Table: ALTERNATE CALCULATIONS (Known Switching Surge Factor): Rule 234H2+Rule 234H3: H ref+D

(NOT CHOSEN, because it does not result in the highest value for any case, except for "other utility structure"):

Case	Reference Height Rule 234H2		Electrical Component Rule 234H3a		Alternate Clearance Total Without Buffer		**Alternate Clearance Total With 3' Buffer**	
	Vertical [ft]	Horizontal [ft]	D Vertical [ft]	D Horizontal [ft]	Vertical [ft]	Horizontal [ft]	**Vertical [ft]**	**Horizontal [ft]**
From Other Supporting Structures (Other Utility Structure)	6	5	16.7	13.9	22.7	18.9 (rest & displaced)	**25.7**	**21.9** (rest & displaced)
From Signs, Billboards, Fences, except Bridges and Buildings, above or under catwalks (Accessible to Pedestrians)	9	3	16.7	13.9	25.7	16.9 (rest & displaced)	**28.7**	**19.9** (rest & displaced)
From Signs, Billboards, Fences, except Bridges and Buildings, no catwalks (Not-Accessible to Pedestrians)	9	3	16.7	13.9	25.7	16.9 (rest & displaced)	**28.7**	**19.9** (rest & displaced)
From Buildings (Roof Accessible to Pedestrians)	9	3	16.7	13.9	25.7	16.9 (rest & displaced)	**28.7**	**19.9** (rest & displaced)
Buildings (Roof Not-Accessible to Pedestrians)	9	3	16.7	13.9	25.7	16.9 (rest & displaced)	**28.7**	**19.9** (rest & displaced)
From Bridges Super Structure (No Personnel Access)	9	3	16.7	13.9	25.7	16.9 (rest & displaced)	**28.7**	**19.9** (rest & displaced)
From Bridge Deck	15	3	16.7	13.9	31.7	16.9 (rest & displaced)	**34.7**	**19.9** (rest & displaced)
From Swimming Pools (V=Dim. "A") (H=Dim. "B")	18	14	16.7	13.9	34.7	27.9 (at rest) (not defined displaced)	**37.7**	**30.9** (at rest) (not defined displaced)

Note 1: Limits: Rule 234H4 The Alternate Clearance shall not be less than the clearance required by Rule 234B, Table 234-2, 234-3, as applicable, computed for 98 kV ac rms to ground or 139 kV dc peak to ground by Rule 234G.

Rule 234H3, b: DC Line Altitude Adder ("threshold" value: 1500'): Assumed Altitude=3000' (worst case)> 1500', results: (3000'-1500')/1000'*3%=4.5%, **apply K alt=1.045 to Electrical Components Rule 234H3a: D Vertical and D Horizontal.**

The Clearances specified in Rule 234B, 234C, 234D, 234E (Equivalent AC) are compared to Clearances using Alternate Clearances per Rule 234H2 & 234H3, because: **V max= 632 KV dc pole to ground > 139 kV dc pole to ground, therefore Alternative DC Calculations can be applied for Pole Conductor (with known switching surge factor: PU=1.8), but they do not control.**

To be safe, and covered for majority of cases, are used "AC Equivalent" Calcs: Rule 234 B ,C , D, & E, which result in the highest required clearances for all cases (except for "other utility structure").

$V_{\text{dc, crest (peak), pole-to-ground}}$=600 kV dc   Equivalent to: $V_{\text{ac, rms, phase-to-phase}} = 600\ kV * \frac{\sqrt{3}}{\sqrt{2}} = 735\ kV\ ac$

Clearances of Wires from Other Supporting Structures (Other Utility Structure, Light or Traffic Light Stand):

Standard Clearances Calculations per **Rule 234B:**

Bare values:

234B1a: H=5.0'+0.4/12*[735*1.05/sqrt(3)-50]= 18.2' (at rest)

234B1b: H=4.5'+0.4/12*[735*1.05/sqrt(3)-22]=18.7' (displaced, 6 psf wind)

234B2: V=5.5'+0.4/12*[735*1.05/sqrt(3)-50]=18.7'

These values obtained per **Rule 234B (AC Equivalent)** **are not replaced** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, Table 234-5, d+ 234H3a:**

Bare values:

H=18.9' (at rest and displaced 6 psf)

V=22.7'

Clearances of Wires from Signs, Billboards, Chimneys, Antennas, Tanks, Other Installations, except Bridges and Buildings, above or under catwalks and other surfaces upon which personnel walk (Accessible to Pedestrians):

Standard Clearances Calculations per **Rule 234C:**

Bare values:

Rule 234C1a, Table 234-1, item 2.a(1): H=7.5'+0.4/12*[735*1.05/sqrt(3)-22]=21.6' (at rest)

Rule 234C1b: H=4.5'+0.4/12*[735*1.05/sqrt(3)-22]=18.6' (displaced)

Rule 234C1a, Table 234-1, item 2.b (1): V=13.5'+0.4/12*[735*1.05/sqrt(3)-22]=27.6'

These values obtained per **Rule 234C (AC Equivalent)** **are not replaced** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, Table 234-5, b+ 234H3a:**

Bare values:

H=16.9' (at rest and displaced 6 psf)

V=25.7'

Clearances of Wires from Signs, Billboards, Chimneys, Antennas, Tanks, Other Installations, except Bridges and Buildings, no catwalks (or other portions that are Non-Accessible to Pedestrians):

Standard Clearances Calculations per **Rule 234C:**

Bare values:

Rule 234C1a, Table 234-1, item 2.a(2): H=7.5'+0.4/12*[735*1.05/sqrt(3)-22]=21.6' (at rest)

Rule 234C1b: H=4.5'+0.4/12*[735*1.05/sqrt(3)-22]=18.6' (displaced)

Rule 234C1a, Table 234-1, item 2.b (2): V=8.0'+0.4/12*[735*1.05/sqrt(3)-22]=22.1'

These values obtained per **Rule 234C (AC Equivalent)** **<u>are not replaced</u>** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, <u>Table 234-5, b</u>+ 234H3a:**

Bare values: H=16.9' (at rest and displaced 6 psf)

V=25.7'

<u>Clearances of Wires from Buildings (Roof Accessible to Pedestrians):</u>

Standard Clearances Calculations per **Rule 234C:**

Bare values:

Rule 234C1a, Table 234-1, item 1.a: H=7.5'+0.4/12*[735*1.05/sqrt(3)-22]=21.6' (at rest)

Rule 234C1b: H=4.5'+0.4/12*[735*1.05/sqrt(3)-22]=18.6' (displaced)

Rule 234C1a, Table 234-1, item 1.b(2): V=13.5'+0.4/12*[735*1.05/sqrt(3)-22]=27.6'

These values obtained per **Rule 234C (AC Equivalent**) **<u>are not replaced</u>** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2<u>, Table 234-5, a</u> + 234H3a:**

Bare values:

H=16.9' (at rest and displaced 6 psf)

V=25.7'

<u>Clearances of Wires from Buildings (Roof Not Accessible to Pedestrians):</u>

Standard Clearances Calculations per **Rule 234C:**

Bare values:

Rule 234C1a, Table 234-1, item 1.a: H=7.5'+0.4/12*[735*1.05/sqrt(3)-22]=21.6' (at rest)

Rule 234C1b: H=4.5'+0.4/12*[735*1.05/sqrt(3)-22]=18.6' (displaced)

Rule 234C1a, Table 234-1, item 1.b(1): V=12.5'+0.4/12*[735*1.05/sqrt(3)-22]=26.6'

These values obtained per **Rule 234C (AC Equivalent**) **<u>are not replaced</u>** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2<u>, Table 234-5, a</u>+ 234H3a:**

Bare values:

H=16.9' (at rest and displaced 6 psf)

V=25.7'

<u>Clearances of Wires from Bridges Super Structure (No Personnel Access):</u>

Standard Clearances Calculations per **Rule 234D:**

Standard Clearances Calculations per **Rule 234D:**

Bare values:

Rule 234D1a, Table 234-2, item 2.a(2): H=7.5'+0.4/12*[735*1.05/sqrt(3)-22]=21.6' (at rest)

Rule 234D1b: H=4.5'+0.4/12*[735*1.05/sqrt(3)-22]=18.6' (displaced)

Rule 234D1a, Table 234-2, item 1.b: V=12.5'+0.4/12*[735*1.05/sqrt(3)-22]=26.6'

These values obtained per **Rule 234D (AC Equivalent**) **are not replaced** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, Table 234-5, c+ 234H3a:**

Bare values:

H=16.9’ (at rest and displaced 6 psf)

V=25.7’

Clearances of Wires from Bridge Deck:

Standard Clearances Calculations per **Rule 234D:**

Standard Clearances Calculations per **Rule 234D:**

Bare values:

Rule 234D1a, Table 234-2, item 2.a(2): H=7.5’+0.4/12*[735*1.05/sqrt(3)-22]=21.6’ (at rest)

Rule 234D1b: H=4.5’+0.4/12*[735*1.05/sqrt(3)-22]=18.6’ (displaced)

Rule 234D1a, Table 234-2, item 1.b+Commentary: V=12.5’+6’+0.4/12*[735*1.05/sqrt(3)-22]=32.6’

These values obtained per **Rule 234D (AC Equivalent**) **are not replaced** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, Table 234-5, c+ 234H3a:**

Bare values:

H=16.9’ (at rest and displaced 6 psf)

V=31.7’

Clearances of Wires from Swimming Pools (Vertical=Dimension “A”; Horizontal=Dimension “B”):

Standard Clearances Calculations per **Rule 234E:**

Bare values:

Rule 234E1, Table 234-3, item B (Figure 234-3, Dim.”B”): H=17’+0.4/12*[735*1.05/sqrt(3)-22]=31.1’ (at rest) (not defined displaced, under wind)

Rule 234E1, Table 234-3, item A (Figure 234-3, Dim.”A”): V=25’+0.4/12*[735*1.05/sqrt(3)-22]=39.1’ (at rest)

These values obtained per **Rule 234E (AC Equivalent**) **are not replaced** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, Table 234-5, e,f+ 234H3a:**

Bare values:

H=27.9’ (at rest) (not defined displaced, under wind)

V=34.7’

Rule 234H2, Table 234-5: Reference Heights (used in Alternate Calculations only):

Case	Reference Height Rule 234H2	
	Vertical [ft]	Horizontal [ft]
a) Buildings	9	3
b) Signs, Billboards	9	3
c) Bridge Super Structure	9	3
d) Supporting Structure of Another Line	6	5
e) Swimming Pools (Dim." A") - used for Vert.	18	N/A
f) Swimming Pools (Dim." B") - used for Hor.	14	14

Rule 234 H3, a: Electrical Component:

D=3.28* [(V*(PU)*a)/(500*k)]^1.667*b*c [ft]

Where:

V, nom, dc, pole-to-ground [kV]	600
V = V max, dc, pole-to-ground [kV]	632

a	1.15
b	1.03
(Vertical) c	1.2
(Horizontal) c	1.0
k	1.15
PU	1.8

Results:

Electrical Component Rule 234H3a		Electrical Component Rule 234H3a With Altitude Adder: k alt=1.045 (see Rule 234H3b calculation)	
D Vertical [ft]	D Horizontal [ft]	D Vertical [ft]	D Horizontal [ft]
15.96	13.30	15.96 * 1.045 = 16.7	13.30 * 1.045 = 13.9

Appendix B-OPGW Detailed Specification:

This +/-600 kV dc line line will go through Oklahoma, Arkansas, and Tennessee, and according to Global Atmospherics Ground Flash Density (GFD) Map, the GFD could be in these regions maximum:
GFD max= 6 [strokes/sqkm/year], which is a significant value, enough to require a lower maximum allowable shielding angle, probably 15 degrees.

For an GFD=6 [strokes/sqkm/year], and considering, at this preliminary design criteria stage, an average tower height of 40 m=131 ft (the dc lines are more compact than ac lines, at same extra high voltage) , and a distance between the 2 OPGWs of about 14 m=45 ft, and assuming the average ruling span at 400 m=1312 ft, for an exposure interval of 30 years, and assuming 95% of the lightning strikes are negative and 5% are positive (which is a typical case) results the worst lighting charge to be Q=168 Coulombs (negative polarity), using IEEE 1243 method.

That will require the OPGW to have in the outer layer a wire diameter of minimum 3.00 mm (ACS 20.3%IACS).

Power Engineers is recommending to be used only AW20.3%IACS wires in the outer layer, no AL6201 wires to be used in the outer layer of the OPGW.
This minimum size of wire in the outer layer: 3.00 mm is necessary, to be sure that after lightning strike, the remnant strength in the OPGW will still be over 75% of the original OPGW RBS, per IEEE 1138 OPGW lightning test method.

See attached calculations prepared by Power Engineers in “Lightning Algorithm-Expected Charge .xlsx” Spreadsheet, that is attached as Appendix C to this Preliminary Design Criteria.

Also, because this dc line will be in a region with 1.00" ice with concurrent wind of 4.1 psf (NESC), a good assumption is that the OPGW maximum working tension will be at about 85%RBS under 1.00" ice+4.1 psf wind, in order for the OPGW sag to be at 85% of the conductor sag at 60 F, Final, bare cable.

Therefore, the OPGW must have Cable Tension for Zero Fiber Strain (CTZFS) of at least 85%RBS.
Due to this requirement any OPGW with central tube design: fibers in central stainless steel tube, or fibers in central stainless steel tube inside an aluminum pipe, are not recommended by Power Engineers.

These types of designs do not meet CTZFS=85%RBS.
At this level of high tension, in these type of designs, there will be some allowable fiber strain, about 0.20%-0.33%, which can result in fiber attenuation [dB/km].

The only design that will meet Cable Tension for Zero Fiber Strain (CTZFS)=85%RBS it will be the stranded stainless steel tube design, where the fibers are located inside these stranded stainless steel tubes.
The fibers need to be in an element that has a lay length (pitch), because the EFL (Excess Fiber Length) itself inside the tube is not sufficient to provide CTZFS=85%RBS.

Minimum EFL (Excess Fiber Length) in the stainless steel tube must be 0.5%, and the lay length (pitch) of the inner layer, containing the stainless steel tubes, must be tight enough to obtain an enough fiber free elongation in tension to obtain CTZFS=85%RBS.

Therefore, Power Engineers recommends the inner layer lay ratio to be in the range: 10-13.
That means the inner layer lay length (pitch) must be 10 to 13 times the diameter over that inner layer.

The preferred design, for maximum 48 fibers, will be a design with 2 stainless steel tubes in the inner layer, having each maximum 24 fibers.

If more than 12 F per tube will be used, the fibers will be grouped in 12 fibers, each group of 12 fibers should be differentiated using stripes, not string binders.

The string binders take out some of the fiber EFL, so stripes is a better solution.

The OPGW design with fibers inside stranded plastic buffer tubes located inside an AL Pipe will also meet CTZFS=85%RBS, but they are much bigger designs that the stranded stainless steel tube designs, for same required RBS and fault current rating, thus resulting in bigger loading tree force (L,T,V) on the structure.

Plus, these types of designs are suitable to be used for sectionalized OPGW, but for this dc line the OPGW will not be sectionalized, it will be grounded every structure, so no need to use these types of OPGW designs, the stranded stainless steel OPGW will be a better solution.

The OPGW Rated breaking Strength (RBS) will be calculated as 90% of the OPGW UTS (Ultimate Tensile Strength), as defined in IEEE 1138 standard for OPGW.

The hollow stainless steel tubes will not be considered in the calculation of the OPGW RBS, only the wires.

The type of fiber to be used, due to the line length: 800 miles, must be G.655C (NZDSF=Non-Zero Dispersion Shifted Fiber, large Core Area), and not SMF G.652D (Low Water Peak).

G.655C type of fiber allows reaching longer lengths without using repeaters (amplifiers) to reduce the non-linear effects, which determines fiber losses (fiber attenuation, in dB/km).

The G.655C fibers attenuation limits should be:

- 0.22 db/km @ 1550 nm
- 0.25 dB/km @ 1625 nm

Important Note: these will be the “cabled” fiber maximum allowed attenuation values, not the “uncabled” fibers value (incoming fiber from fiber’s manufacturer).

At this Preliminary Design Criteria phase, Power Engineers recommends the OPGW with the following mechanical, electrical, and optical characteristics:

- Maximum Cable Diameter: D c=0.591 inches
- Minimum Wire Diameter in the Outer Layer: D wire=3.00 mm
- Maximum Weight: W=0.475 lbs/ft
- Minimum Rated Breaking Strength: RBS=25369 lbs
- Minimum Cable Tension for Zero Fiber Strain=85%RBS
- Minimum Total Cross-Sectional Area: A=0.19 sq in
- Minimum Fault Current Rating: I^2*t=98 kA^2*sec; which corresponds to:
    - I=14.0 kA; t=0.50 sec (worst case scenario: longest fault current duration: 30 cycles)
    - I=31.3 kA; t=0.10 sec (best case scenario: shortest fault current duration: 10 cycles)

      (fault current: initial temperature=40 C; final temperature=210 C)

- Maximum DC Resistance at 20 deg C: R dc=0.7945 Ohm/mile
- Outer Layer of Wire Lay Direction: Left
- Fiber Type: G.655C: fiber attenuation limits: 0.22 dB/km @ 1550 nm; 0.25 dB/km @ 1625 nm.
- Fiber Count: Minimum: 12; Maximum 48
- PLS-CADD .wir file: polynomial coefficients from SAG10 chart 1-1427

Algorithm To Establish Calculated Lightning Charge Levels at Customer Location:

This spreadsheet to be used ONLY when customer DID NOT provide lightning charge level in his technical specifications, and that lightning charge level must be established at customer location.

Line Geometry Input:

1. Tower Height: h_t **42** [m] **Note**: **"h_t" should be provided by customer.**

ONLY if the customer does not know the tower height: h t , it can be assumed:

for Distribution Lines, 0 kV < V <= 69 kV:	h_t =	25	[m]
for Transmission Lines, 69 kV < V <= 115 kV:	h_t =	30	[m]
for Transmission Lines, 115 kV < V <= 230 kV:	h_t =	35	[m]
for Transmission Lines, 230 kV < V <= 345 kV:	h_t =	40	[m]
for Transmission Lines, 345 kV < V <= 1000 kV:	h_t =	45	[m]

2. Number of Groundwires: N_{GW} **2** [-] **Note**: **"N_{GW}" should be provided by customer.**

3. Groundwires Spacing: b **8.8** [m] **Note**: **"b" should be provided by customer.**
if 2 groundwires: N_{GW} = 2, then "b" has a value
if 1 groundwire: N_{GW} = 1, then "b" = 0

ONLY if the customer does not know the spacing between the 2 groundwires: b, it can be assumed:

for Distribution Lines, 0 kV < V <= 69 kV:	b =	2	[m]
for Transmission Lines, 69 kV < V <= 115 kV:	b =	3	[m]
for Transmission Lines, 115 kV < V <= 230 kV:	b =	4	[m]
for Transmission Lines, 230 kV < V <= 345 kV:	b =	5	[m]
for Transmission Lines, 345 kV < V <= 1000 kV:	b =	6	[m]

4. Average Span: S **457** [m] **Note**: **"S" should be provided by customer.**

ONLY if the customer does not know the average span: S, of that line, it can be assumed:

for Distribution Lines, 0 kV < V <= 69 kV:	S =	100	[m]
for Transmission Lines, 69 kV < V <= 115 kV:	S =	225	[m]
for Transmission Lines, 115 kV < V <= 230 kV:	S =	275	[m]
for Transmission Lines, 230 kV < V <= 345 kV:	S =	300	[m]
for Transmission Lines, 345 kV < V <= 1000 kV:	S =	325	[m]

5. Line Length: L **30** [km] **Note**: **"L" should be provided by customer.**

Meteorological Input:

1. Ground Flash Density: N_g **1.15** [strokes/km^2/year] (also called : GFD) ; GFDline=GFD^0.078=6^0.078=1.15

Notes:

1. For USA: use the GFD map from spreadsheets: "Vidalia" **OR** **"USA GFD Map- Global Atmospherics"** **(this one is more detailed)**
2. For Canada: use the GFD map from spreadsheet "**Canada GFD Map-CEA**".
3. For South Africa: use the GFD map from spreadsheet "**South Africa GFD Map-CSIR**".
4. For the rest of the world: use 10% of the total OTD data from the the web site provided in the spreadsheet **"Rest of the World".**

Reason:

OTD data: only 10% are flashes cloud -to- ground (the one you are interested in: GFD)

the rest 90% are flashes cloud-to-cloud or intracloud (you are not interested in these data)

2. Precent Negative Flashes (PNF) in the total number of flashes:

PNF= 0.95 [probability, absolute value]

Note: if not known from OTD data, it can be used as default: PNF= 0.95 (95%).

3. Precent Positive Flashes (PPF) in the total number of flashes:

PPF= 0.05 [probability, absolute value]

Note: if not known from OTD data, it can be used as default: PNF= 0.05 (5%).

Probability Input:

Exposure Interval: **Y** **30** **[years]**

Important Check: $Y \cdot L \cdot N_g$ **1035** **[strokes/km]** **O.K.**

Note: The product: "Y*L*Ng" MUST be MAXIMUM 4000 [strokes/km]

Reason for the product "Y*L*Ng" limitation: for long lines cases, to avoid level of charges too high, resulting in OPGW design cost prohibitive.

Calculations (Output Data):

1. **Total Number of Flashes to the Line**: N_{Line} :

Ericsson's formula: $N_{Line} = 0.10 \cdot N_g \cdot \left(28 \cdot h_t^{0.6} + b\right)$ **[strikes/100 km/year]**

where: $R_a = 14 \cdot h_t^{0.6}$ **R_a = attractive radius [m]**

$N_{Line} =$ **31** **[strikes/100 km/year]**

2. **Total Number of Flashes to the Tower**: N_{tower} :

IEEE proposed formula: $N_{tower} = \frac{b}{S} \cdot N_{Line}$ **[strikes/100 km/year]**

$N_{tower} =$ **0** **[strikes/100 km/year]**

3. **Total Number of Flashes to the OPGW**: N_{OPGW} :

IEEE proposed formula: $N_{OPGW} = \frac{N_{Line} - N_{tower}}{N_{GW}}$ **[strikes/100 km/year]**

$N_{OPGW} =$ **15** **[strikes/100 km/year]**

4. **Basic Probability Level for stroke current, rate of rise and total flash charge:** **P:**

IEEE proposed formula: $P = \frac{100}{Y \cdot L \cdot N_{OPGW}}$ **[probability, absolute value]**

$P =$ **0.0074** **[probability, absolute value]**

0.74 **[probability,precent]**

5. Probability Design Level for Negative First Stroke Flashes: P_{first}^{neg}

IEEE proposed formula: $P_{first}^{neg} = \frac{P}{PNF}$ **[probability, absolute value]**

$P_{first}^{neg} =$ **0.0078** **[probability, absolute value]**

0.78 **[probability, precent]**

6. Corresponding Number of Negative Flashes to this Probability Design Level: **NNF:**

IEEE proposed formula: $NNF = \frac{1}{P_{first}^{neg}}$ **128** **[negative flashes]**

5. Probability Design Level for Positive First Stroke Flashes: P_{first}^{pos}

IEEE proposed formula: $P_{first}^{pos} = \frac{P}{PPF}$ **[probability, absolute value]**

$P_{first}^{pos} =$ **0.1481** **[probability, absolute value]**

14.81 **[probability, precent]**

6. Corresponding Number of Positive Flashes to this Probability Design Level: **NPF:**

IEEE proposed formula: $NPF = \frac{1}{P_{first}^{pos}}$ **7** **[positive flashes]**

7. Negative First Stroke Peak Amplitude: $I_{first}^{neg\,*}$

probabilistic function: **log normal:**

IEEE formula: $P_{(I>I^*)} = \frac{1}{1+\left(\frac{I^*}{31}\right)^{2.6}}$ **where:** $I_m = 31 \quad [kA]$ **median current for negative first stroke**

$$I_{first}^{neg*} = 31 \cdot \left(\left(P_{first}^{neg}\right)^{-1} - 1\right)^{\frac{1}{2.6}}$$ [kA]

$I_{first}^{neg\,*} =$ **200** [kA]

8. Positive First Stroke Peak Amplitude: $I_{first}^{pos\,*}$

probabilistic function: **log normal:**

IEEE formula: $P_{(I>I^*)} = \dfrac{1}{1+\left(\dfrac{I^*}{31}\right)^{2.6}}$ **where:** $I_m = 31 \quad [kA]$ **median current for positive first stroke**

$$I_{first}^{pos*} = 31\cdot\left(\left(P_{first}^{pos}\right)^{-1} - 1\right)^{\frac{1}{2.6}}$$ [kA]

$I_{first}^{pos\,*} =$ **61** [kA]

9. Negative Subsequent Strokes Probability: P_{subs}^{neg}

Typically: 2 subsequent strokes for every first stroke:

IEEE formula: $P_{subs}^{neg} = \dfrac{P_{first}^{neg}}{2}$ **[probability, absolute value]**

$P_{subs}^{neg} =$ **0.0039** **[probability, absolute value]**

0.39 **[probability, precent]**

10. Negative Subsequent Strokes Peak Amplitude: $I_{subs}^{neg\,*}$

IEEE formula:

$P_{(I>I^*)} = \dfrac{1}{1+\left(\dfrac{I^*}{12}\right)^{2.7}}$ **where:** $I_m = 12 \quad [kA]$ **median current for negative subsequent strokes**

$$I_{subs}^{neg*} = 12\cdot\left(\left(P_{subs}^{neg}\right)^{-1} - 1\right)^{\frac{1}{2.7}}$$ [kA]

$I_{subs}^{neg\,*} =$ **93** [kA]

11. Positive Subsequent Strokes Probability: P_{subs}^{pos}

Typically: 2 subsequent strokes for every first stroke:

IEEE formula: $$P_{subs}^{pos} = \frac{P_{first}^{pos}}{2}$$ **[probability, absolute value]**

$P_{subs}^{pos} =$ **0.0741** **[probability, absolute value]**

7.41 **[probability, precent]**

12. Positive Subsequent Strokes Peak Amplitude: $I_{subs}^{pos\,*}$

IEEE formula:

$$P_{(I>I^*)} = \frac{1}{1+\left(\frac{I^*}{12}\right)^{2.7}}$$

where: $I_m = 12 \quad [kA]$ **median current for for positive subsequent strokes**

$$I_{subs}^{pos*} = 12 \cdot \left(\left(P_{subs}^{pos}\right)^{-1} - 1\right)^{\frac{1}{2.7}}$$ [kA]

$I_{subs}^{pos\,*} =$ **31** [kA]

13. Negative Flash Total Charge: $Q_{negative}$

probabilistic function: log-normal:

Berger's curve for negative flashes:

$$P_{(Qnegative)} = \frac{1}{1+\left(\frac{Q_{negative}}{7}\right)^{1.7}}$$

where: $Q_{negative\ \ med} = 7 \quad [C]$ **median charge value for negative flashes in Berger's curve**

$$Q_{negative} = 7 \cdot \left(\left(P_{first}^{neg}\right)^{-1} - 1\right)^{\frac{1}{1.7}}$$

$Q_{negative} =$ **121** [C]

14. Positive Flash Total Charge: $Q_{positive}$

probabilistic function: log-normal:

Berger's curve for positive flashes:

$$P_{(Q_{positive})} = \frac{1}{1 + \left(\frac{Q_{positive}}{85}\right)^{2.0}}$$

where: $Q_{positive\ \ med} = 85\ [C]$ **median charge value for positive flashes in Berger's curve**

$$Q_{positive} = 85 \cdot \left(\left(P_{first}^{pos}\right)^{-1} - 1\right)^{\frac{1}{2.0}}$$

$Q_{positive} =$ **204** [C]

Note: **Qpositive<2*Qnegative, TEST WILL BE DONE ONLY FOR Qnegative**

Theoretical Requirements:

Total Negative Charge:

$Q_{negative}$ **121** [C]

First Stroke:

Peak Amplitude: $I_{first}^{neg\,*} =$ **200** [kA]

Rise Time: $t_r =$ **1.2** [μsec]

Pulse Duration: **(Time to a half of the Amplitude)** $t_d =$ **50** [μsec]

2 Subsequent Strokes:

Peak Amplitude: $I_{subs}^{neg\,*} =$ **93** [kA]

Rise Time: $t_r =$ **0.1** [μsec]

Pulse Duration: **(Time to a half of the Amplitude)** $t_d =$ **10** [μsec]

Note:
Between first stroke and the 2 subsequent strokes, there could be any combination of intermediate current component "B" and continuing current component "C", as long as the total charge remains:

$Q_{negative} =$ **121** [C]

Test Variables:

Total Negative Charge: $Q_{negative} =$ **121** [C]

If Test done ONLY with the intermediate component "B" and the continuing component "C":

intermediate component "B":			continuous component "C":		
charge:	$Q_B =$	**10** [C]	charge:	$Q_C =$	**111** [C]
mean current:	$I_{B\ mean} =$	**2000** [A]	current:	$I_C =$	**250** [A]
time:	$t_B =$	**0.005** [sec]	time:	$t =$	**0.444** [sec]

Theoretical Requirements:

Total Positive Charge:

$Q_{positive}$ = **204** [C]

First Stroke:

Peak Amplitude: I^{pos*}_{first} = **61** [kA]

Rise Time: t_r = **1.2** [µsec]

Pulse Duration: **(Time to a half of the Amplitude)** t_d = **50** [µsec]

2 Subsequent Strokes:

Peak Amplitude: I^{pos*}_{subs} = **31** [kA]

Rise Time: t_r = **0.1** [µsec]

Pulse Duration: **(Time to a half of the Amplitude)** t_d = **10** [µsec]

Note:
Between first stroke and the 2 subsequent strokes, there could be any combination of intermediate current component "B" and continuing current component "C", as long as the total charge remains:

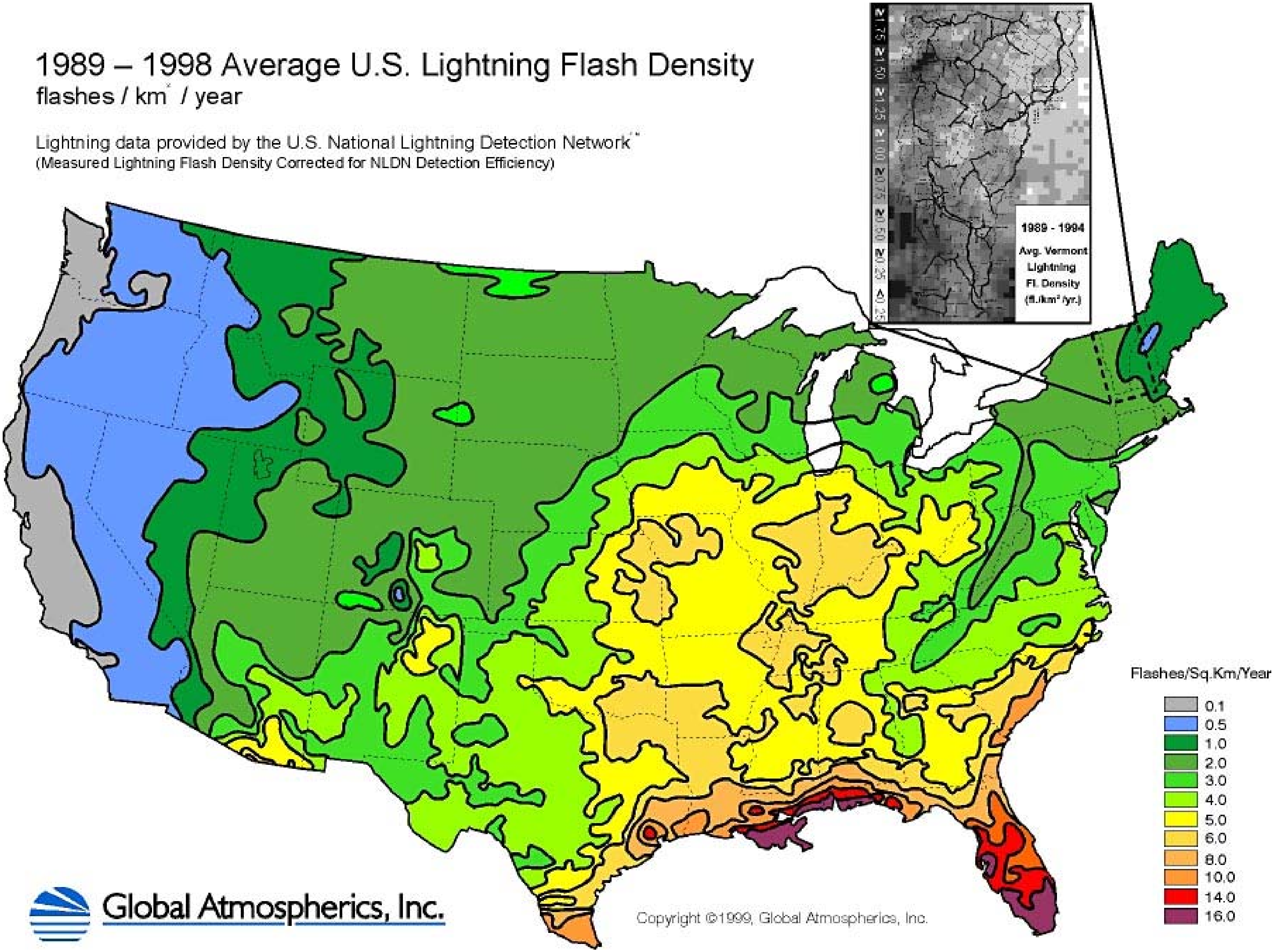
$Q_{positive}$ = **204** [C]

Test Variables:

Total Positive Charge: $Q_{positive}$ = **204** [C]

If Test done ONLY with the intermediate component "B" and the continuing component "C":

intermediate component "B":			**continuous component "C":**		
charge:	Q_B =	**10** [C]	**charge:**	Q_C =	**194** [C]
mean current:	$I_{B\ mean}$ =	**2000** [A]	**current:**	I_C =	**250** [A]
time:	t_B =	**0.005** [sec]	**time:**	t =	**0.775** [sec]


1989 – 1998 Average U.S. Lightning Flash Density
flashes / km² / year
Lightning data provided by the U.S. National Lightning Detection Network
(Measured Lightning Flash Density Corrected for NLDN Detection Efficiency)
1989 - 1994
Avg. Vermont Lightning Fl. Density (fl./km²/yr.)
Flashes/Sq.Km/Year
0.1
0.5
1.0
2.0
3.0
4.0
5.0
6.0
8.0
10.0
14.0
16.0
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Wire Type: AW20.3% (all wires) **Tensile Strength: TS:** 195 [kpsi] **Conductivity: λ:** 20.3 [%]

Gap: 5 [cm] **Tolerance:** + / - 1 cm

Input below Total Charge from Customer Technical Specifications.

If is not provided, please follow the algorithm from spreadsheet "Calculated Charge" to determine the total charge at customer location, and then input below.

Note: only if positive charge is twice as large as the negative charge, there will be a test also for the positive charge, and you input the positive charge below.

Otherwise, positive charge does not matter.

Remnant Strength: 75 [%] RBS

Negative polarity: Q 121 [C] **Positive polarity: Q** 242 [C]

Wire Diameter: D 3.12 [mm] **Wire Diameter: D** 3.12 [mm]

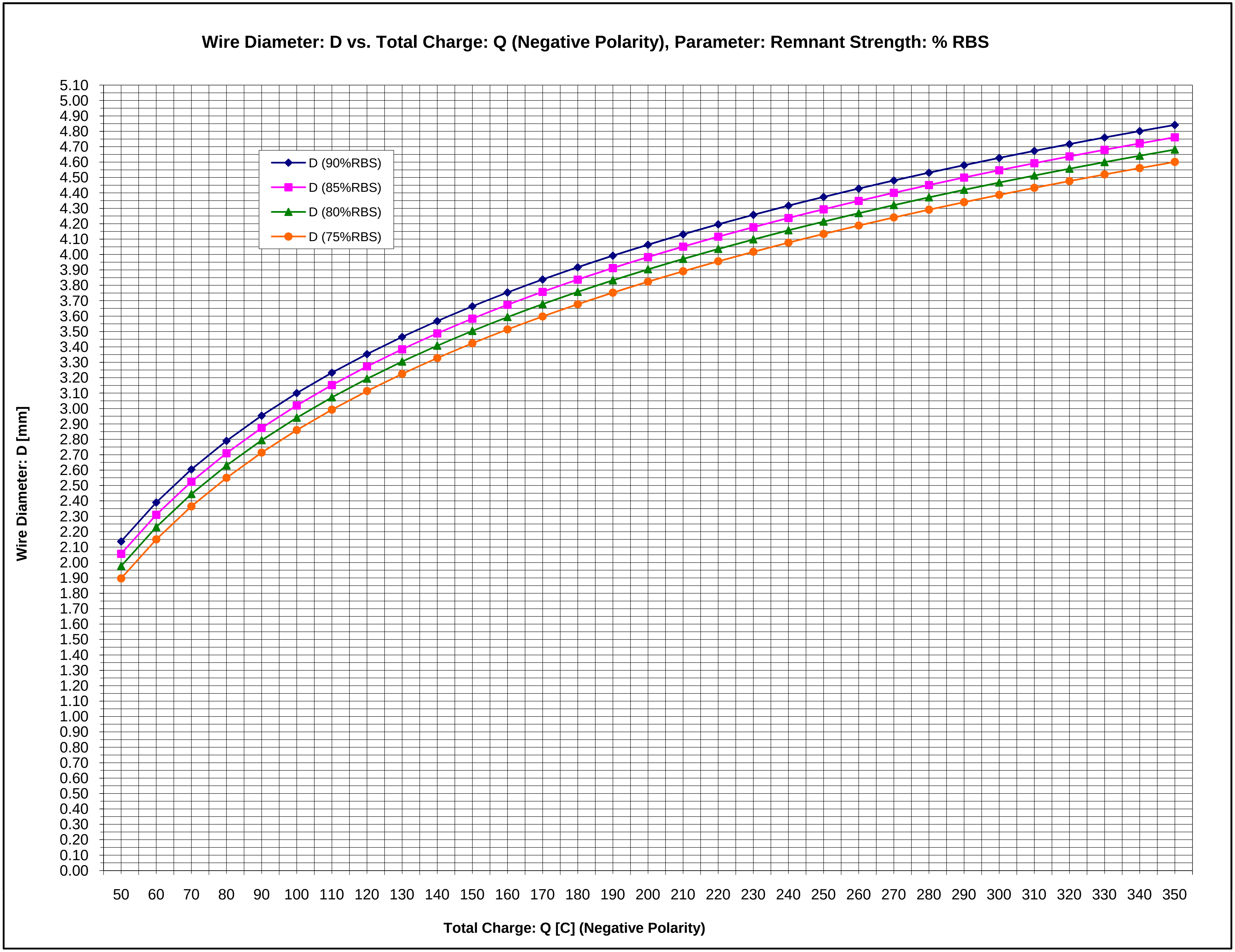
RBS= Rated Breaking Strength of the cable, NOT of the individual wire

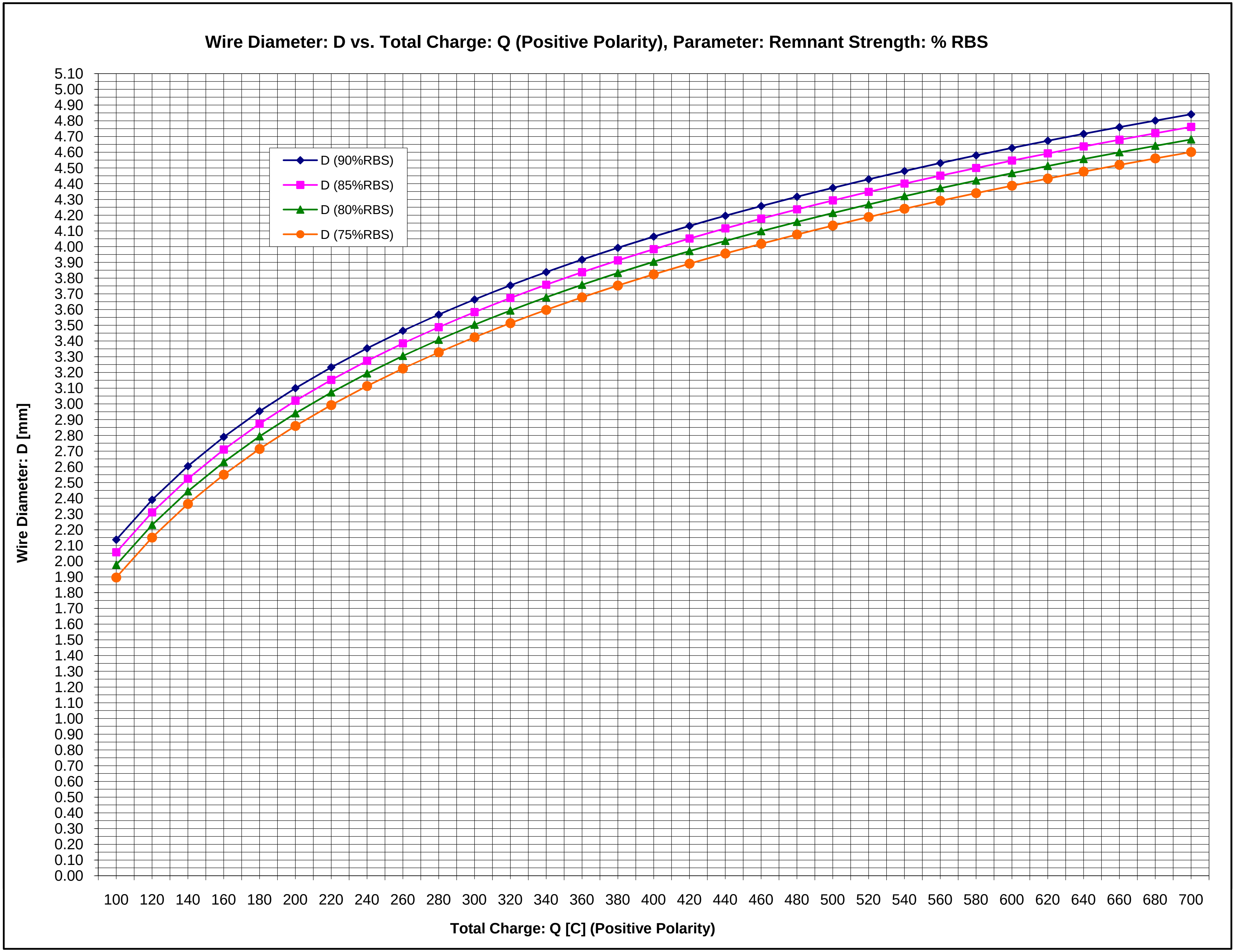
Negative Polarity:

Q [C]	D (90%RBS) [mm]	D (85%RBS) [mm]	D (80%RBS) [mm]	D (75%RBS) [mm]
50	2.14	2.06	1.98	1.90
60	2.39	2.31	2.23	2.15
70	2.60	2.52	2.44	2.36
80	2.79	2.71	2.63	2.55
90	2.95	2.87	2.79	2.71
100	3.10	3.02	2.94	2.86
110	3.23	3.15	3.07	2.99
120	3.35	3.27	3.19	3.11
130	3.46	3.38	3.30	3.22
140	3.57	3.49	3.41	3.33
150	3.66	3.58	3.50	3.42
160	3.75	3.67	3.59	3.51
170	3.84	3.76	3.68	3.60
180	3.92	3.84	3.76	3.68
190	3.99	3.91	3.83	3.75
200	4.06	3.98	3.90	3.82
210	4.13	4.05	3.97	3.89
220	4.20	4.12	4.04	3.96
230	4.26	4.18	4.10	4.02
240	4.32	4.24	4.16	4.08
250	4.37	4.29	4.21	4.13
260	4.43	4.35	4.27	4.19
270	4.48	4.40	4.32	4.24
280	4.53	4.45	4.37	4.29
290	4.58	4.50	4.42	4.34
300	4.63	4.55	4.47	4.39
310	4.67	4.59	4.51	4.43
320	4.72	4.64	4.56	4.48
330	4.76	4.68	4.60	4.52
340	4.80	4.72	4.64	4.56
350	4.84	4.76	4.68	4.60

Positive Polarity:

Q [C]	D (90%RBS) [mm]	D (85%RBS) [mm]	D (80%RBS) [mm]	D (75%RBS) [mm]
100	2.14	2.06	1.98	1.90
120	2.39	2.31	2.23	2.15
140	2.60	2.52	2.44	2.36
160	2.79	2.71	2.63	2.55
180	2.95	2.87	2.79	2.71
200	3.10	3.02	2.94	2.86
220	3.23	3.15	3.07	2.99
240	3.35	3.27	3.19	3.11
260	3.46	3.38	3.30	3.22
280	3.57	3.49	3.41	3.33
300	3.66	3.58	3.50	3.42
320	3.75	3.67	3.59	3.51
340	3.84	3.76	3.68	3.60
360	3.92	3.84	3.76	3.68
380	3.99	3.91	3.83	3.75
400	4.06	3.98	3.90	3.82
420	4.13	4.05	3.97	3.89
440	4.20	4.12	4.04	3.96
460	4.26	4.18	4.10	4.02
480	4.32	4.24	4.16	4.08
500	4.37	4.29	4.21	4.13
520	4.43	4.35	4.27	4.19
540	4.48	4.40	4.32	4.24
560	4.53	4.45	4.37	4.29
580	4.58	4.50	4.42	4.34
600	4.63	4.55	4.47	4.39
620	4.67	4.59	4.51	4.43
640	4.72	4.64	4.56	4.48
660	4.76	4.68	4.60	4.52
680	4.80	4.72	4.64	4.56
700	4.84	4.76	4.68	4.60


Wire Diameter: D vs. Total Charge: Q (Negative Polarity), Parameter: Remnant Strength: % RBS
D (90%RBS)
D (85%RBS)
D (80%RBS)
D (75%RBS)
Wire Diameter: D [mm]
Total Charge: Q [C] (Negative Polarity)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.10
50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350


Wire Diameter: D vs. Total Charge: Q (Positive Polarity), Parameter: Remnant Strength: % RBS
D (90%RBS)
D (85%RBS)
D (80%RBS)
D (75%RBS)
Wire Diameter: D [mm]
5.10
5.00
4.90
4.80
4.70
4.60
4.50
4.40
4.30
4.20
4.10
4.00
3.90
3.80
3.70
3.60
3.50
3.40
3.30
3.20
3.10
3.00
2.90
2.80
2.70
2.60
2.50
2.40
2.30
2.20
2.10
2.00
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700
Total Charge: Q [C] (Positive Polarity)

Formulas:

RBS= Rated Breaking Strength of the cable, NOT of the individual wire

Negative Polarity:

For Remanent Strength=90% RBS:

$$D=0.144702564\frac{TS}{\lambda}\cdot\ln\left(0.001041026\frac{TS}{\lambda}\cdot Q\right)+3.10$$

$$D=1.39\ln(0.01\cdot Q)+3.10$$

For Remanent Strength=85% RBS:

$$D=0.144702564\frac{TS}{\lambda}\cdot\ln\left(0.001041026\frac{TS}{\lambda}\cdot Q\right)+3.02$$

$$D=1.39\ln(0.01\cdot Q)+3.02$$

For Remanent Strength=80% RBS:

$$D=0.144702564\frac{TS}{\lambda}\cdot\ln\left(0.001041026\frac{TS}{\lambda}\cdot Q\right)+2.94$$

$$D=1.39\ln(0.01\cdot Q)+2.94$$

For Remanent Strength=75% RBS:

$$D=0.144702564\frac{TS}{\lambda}\cdot\ln\left(0.001041026\frac{TS}{\lambda}\cdot Q\right)+2.86$$

$$D=1.39\ln(0.01\cdot Q)+2.86$$

Positive Polarity:

For Remanent Strength=90% RBS:

$$D=0.144702564\frac{TS}{\lambda}\cdot\ln\left(0.001041026\frac{TS}{\lambda}\cdot Q/2\right)+3.10$$

$$D=1.39\ln(0.01\cdot Q/2)+3.10$$

For Remanent Strength=85% RBS:

$$D=0.144702564\frac{TS}{\lambda}\cdot\ln\left(0.001041026\frac{TS}{\lambda}\cdot Q/2\right)+3.02$$

$$D=1.39\ln(0.01\cdot Q/2)+3.02$$

For Remanent Strength=80% RBS:

$$D=0.144702564\frac{TS}{\lambda}\cdot\ln\left(0.001041026\frac{TS}{\lambda}\cdot Q/2\right)+2.94$$

$$D=1.39\ln(0.01\cdot Q/2)+2.94$$

For Remanent Strength=75% RBS:

$$D=0.144702564\frac{TS}{\lambda}\cdot\ln\left(0.001041026\frac{TS}{\lambda}\cdot Q/2\right)+2.86$$

$$D=1.39\ln(0.01\cdot Q/2)+2.86$$

		4
1	90	
2	85	
3	80	
4	75	

Appendix E-Sag and Tension Calculations

By: CIM 05/29/2014
Checked: ANR 05/29/2014

PLS-CADD Version 13.00x64   3:22:27 PM Thursday, May 29, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Lattice Tower (Design Span 1500 ft)   '

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

HEAVY NESC

Sag and Tension- 3 Bundle- ACSR BLUEBIRD
MOT-Emergency and Normal
Ruling Span=1500 ft (Towers)

Section #3 from structure #1 to structure #20, start set #11 'COND-L,Ahead', end set #11 'COND-L,Ahead'
Cable 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\cables\bluebird_acsr_dc.wir', Ruling span (ft) 1500
Sagging data: Catenary (ft) 5586.74, Horiz. Tension (lbs) 14028.3 Condition I Temperature (deg F) 60
Weather case for final after creep Everyday 60F, Equivalent to 79.3 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B: 0F, 0.5", 4 psf, Equivalent to 24.1 (deg F) temperature increase

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 Heavy-Rule 250B: 0F, 0.5", 4 psf	0.92	3.92	4.32	23761	23498	39	5434	51.84	22033	21752	37	5030	56.01	23761	23498	39	5434	51.84
2	NESC Extreme Wind-Rule 250C: 60 F, 20.74 psf	3.04	2.51	3.95	20564	20328	34	5151	54.70	18900	18645	31	4724	59.66	20247	20008	34	5070	55.58
3	NESC Extreme Ice w/Conc.Wind-Rule 250D: 15F, 1", 4.1 psf	1.29	5.95	6.08	29993	29587	50	4864	57.94	28824	28403	48	4669	60.36	29993	29587	50	4864	57.94
4	Everyday 60F	0.00	2.51	2.51	14176	14026	24	5586	50.43	12620	12455	21	4960	56.81	13649	13494	23	5374	52.42
5	Galloping Sag: 32deg, .5", 0psf	0.00	3.92	3.92	21176	20933	35	5343	52.72	19441	19180	32	4896	57.56	20915	20670	35	5276	53.39
6	Galloping Swing: 32deg, .5", 2 psf	0.46	3.92	3.94	21290	21046	35	5336	52.80	19558	19295	32	4892	57.61	21039	20792	35	5271	53.45
7	COnstruction Snub-Off: 0F	0.00	2.51	2.51	15627	15488	26	6168	45.65	13750	13595	23	5414	52.03	15073	14930	25	5946	47.37
8	Stringing/Broken: 0F, 4 psf	0.59	2.51	2.58	15963	15820	26	6135	45.90	14078	13920	23	5398	52.19	15421	15274	26	5923	47.55
9	Medium Wind: 60F, 6 psf	0.88	2.51	2.66	14888	14730	25	5535	50.89	13302	13127	22	4933	57.12	14369	14205	24	5338	52.77
10	High Wind: 60F, 85 mph	2.72	2.51	3.70	19520	19300	32	5218	53.99	17850	17611	30	4761	59.19	19152	18928	32	5117	55.06
11	NESC Extreme Wind at 45deg Angle: 60F, 10.37 psf	1.52	2.51	2.94	16161	15987	27	5444	51.74	14537	14346	24	4885	57.69	15671	15492	26	5275	53.40
12	Uplift: -20 F	0.00	2.51	2.51	16194	16058	27	6395	44.03	14195	14045	24	5593	50.36	15641	15502	26	6174	45.61
13	0F	0.00	2.51	2.51	15627	15488	26	6168	45.65	13750	13595	23	5414	52.03	15073	14930	25	5946	47.37
14	32F	0.00	2.51	2.51	14811	14666	25	5841	48.22	13115	12955	22	5159	54.61	14267	14117	24	5622	50.10
15	60F	0.00	2.51	2.51	14176	14026	24	5586	50.43	12620	12455	21	4960	56.81	13649	13494	23	5374	52.42
16	90F	0.00	2.51	2.51	13566	13410	22	5341	52.75	12142	11971	20	4767	59.12	13062	12901	22	5138	54.84
17	120F	0.00	2.51	2.51	13016	12854	22	5119	55.04	11710	11534	19	4593	61.37	12539	12373	21	4927	57.19
18	MOT-normal:160F (71C)	0.00	2.51	2.51	12368	12199	21	4858	58.01	11197	11013	19	4386	64.28	11926	11752	20	4680	60.22
19	MOT-emergency: 177F (81C)	0.00	2.51	2.51	12115	11944	20	4757	59.25	10998	10812	18	4306	65.49	11690	11513	19	4585	61.48

By: CIM 05/29/2014
Checked: ANR 05/29/2014

PLS-CADD Version 13.00x64 3:31:22 PM Thursday, May 29, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Lattice Tower (Design Span 1500 ft) '

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

HEAVY NESC

Sag and Tension- MRC ACSR CHUKAR
MOT-Emergency and Normal
Ruling Span=1500 ft (Towers)

Section #3 from structure #1 to structure #20, start set #11 'COND-L,Ahead', end set #11 'COND-L,Ahead'
Cable 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\cables\chukar_acsr_dc.wir', Ruling span (ft) 1500
Sagging data: Catenary (ft) 5752.05, Horiz. Tension (lbs) 11935.5 Condition I Temperature (deg F) 60
Weather case for final after creep Everyday 60F, Equivalent to 80.7 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B: 0F, 0.5", 4 psf, Equivalent to 28.7 (deg F) temperature increase

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 Heavy-Rule 250B: 0F, 0.5", 4 psf	0.87	3.38	3.79	20982	20753	41	5474	51.46	19527	19283	38	5086	55.40	20982	20753	41	5474	51.46
2	NESC Extreme Wind-Rule 250C: 60 F, 20.74 psf	2.77	2.08	3.46	18208	18004	36	5204	54.14	16749	16529	33	4778	58.99	17896	17689	35	5113	55.10
3	NESC Extreme Ice w/Conc.Wind-Rule 250D: 15F, 1", 4.1 psf	1.23	5.31	5.45	26697	26331	52	4830	58.35	25892	25517	51	4681	60.22	26697	26331	52	4830	58.35
4	Everyday 60F	0.00	2.08	2.08	12057	11935	24	5752	48.97	10654	10520	21	5070	55.58	11505	11379	23	5484	51.37
5	Galloping Sag: 32deg, .5", 0psf	0.00	3.38	3.38	18536	18329	36	5420	51.98	17016	16793	33	4965	56.75	18256	18046	36	5336	52.79
6	Galloping Swing: 32deg, .5", 2 psf	0.43	3.38	3.41	18650	18441	37	5408	52.09	17133	16908	34	4959	56.82	18383	18171	36	5329	52.86
7	COnstruction Snub-Off: 0F	0.00	2.08	2.08	13349	13237	26	6379	44.14	11649	11524	23	5554	50.72	12749	12633	25	6088	46.26
8	Stringing/Broken: 0F, 4 psf	0.53	2.08	2.14	13686	13571	27	6334	44.46	11980	11851	23	5531	50.93	13101	12981	26	6059	46.48
9	Medium Wind: 60F, 6 psf	0.80	2.08	2.22	12771	12641	25	5683	49.56	11340	11197	22	5034	55.97	12229	12095	24	5438	51.81
10	High Wind: 60F, 85 mph	2.47	2.08	3.23	17236	17048	34	5286	53.30	15755	15551	31	4821	58.45	16861	16668	33	5168	54.52
11	NESC Extreme Wind at 45deg Angle: 60F, 10.37 psf	1.38	2.08	2.49	14029	13884	28	5566	50.61	12563	12404	25	4973	56.67	13518	13368	27	5359	52.57
12	Uplift: -20 F	0.00	2.08	2.08	13853	13745	27	6624	42.50	12041	11919	24	5744	49.03	13250	13138	26	6332	44.47
13	0F	0.00	2.08	2.08	13349	13237	26	6379	44.14	11649	11524	23	5554	50.72	12749	12633	25	6088	46.26
14	32F	0.00	2.08	2.08	12624	12507	25	6027	46.72	11087	10957	22	5281	53.35	12045	11924	24	5746	49.01
15	60F	0.00	2.08	2.08	12057	11935	24	5752	48.97	10654	10520	21	5070	55.58	11505	11379	23	5484	51.37
16	90F	0.00	2.08	2.08	11515	11389	23	5488	51.32	10235	10096	20	4865	57.92	10993	10862	22	5235	53.82
17	120F	0.00	2.08	2.08	11028	10898	22	5252	53.64	9857	9713	19	4681	60.21	10540	10404	21	5014	56.20
18	MOT-normal:160F (71C)	0.00	2.08	2.08	10455	10318	20	4973	56.67	9410	9261	18	4463	63.16	10010	9868	20	4756	59.26
19	MOT-emergency: 177F (81C)	0.00	2.08	2.08	10235	10096	20	4865	57.92	9238	9086	18	4379	64.39	9806	9662	19	4656	60.53
20	MOT-normal:235F (113C)-MRC	0.00	2.08	2.08	9567	9420	19	4540	62.10	8711	8551	17	4121	68.44	9186	9033	18	4353	64.76
21	MOT-emergency: 289F (143C)-MRC	0.00	2.08	2.08	9041	8886	18	4283	65.84	8291	8124	16	3915	72.06	8702	8541	17	4116	68.51

Emergency MOT=289 F > 212 F and Normal regime MOT=235 F > 212 F:
Conductor Model: "Aluminum can go into compression" (does not bird-cage):
Virtual Compressive Stress=Actual Compressive Stress*(A o/A t)=1.5*1.3986/1.5126=1.387 kpsi
Plus, being an ACSR conductor with **%steel area**: (1.5126-1.3986)/1.5126*100=**7.5%** , and **MOT over 212 F**, it will have also "**High Temperature Creep**", which will increase the final sag after creep (probably maximum another 1 ft in RS=1500 ft).

By: CIM 05/29/2014
Checked: ANR 05/29/2014

Sag and Tension OPGW
Sag OPGW/Conductor Ratio
Ruling Span=1500 ft (Towers)

PLS-CADD Version 13.00x64   3:43:00 PM Thursday, May 29, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Lattice Tower (Design Span 1500 ft)   '

HEAVY NESC

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

OPGW Sag at 32 F, 0.5" Ice, No Wind, Final After Load / Cond Sag at 32 F, No Ice, No Wind, Final After Load=47.60' / 50.10' * 100=95%, OK

Section #1 from structure #1 to structure #20, start set #1 'OPGW-L, Ahead', end set #1 'OPGW-L, Ahead'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\49ay85acs-2c 1-1427.wir', Ruling span (ft) 1500
Sagging data: Catenary (ft) 7662.79, Horiz. Tension (lbs) 3624.5 Condition I Temperature (deg F) 60
Weather case for final after creep Everyday 60F, Equivalent to 37.8 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B: 0F, 0.5", 4 psf, Equivalent to 46.6 (deg F) temperature increase

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.	Vert	Res.	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-Rule 250B: 0F, 0.5", 4 psf	0.53	1.15	1.57	8860	8768	35	5593	50.36	8860	8768	35	5593	50.36	8860	8768	35	5593	50.36
2	NESC Extreme Wind-Rule 250C: 60 F, 20.74 psf	1.02	0.47	1.13	6716	6659	26	5917	47.60	6616	6558	26	5827	48.33	6558	6499	26	5775	48.77
3	NESC Extreme Ice w/Conc.Wind-Rule 250D: 15F, 1", 4.1 psf	0.89	2.45	2.61	12166	11984	48	4598	61.30	12166	11984	48	4598	61.30	12166	11984	48	4598	61.30
4	Everyday 60F	0.00	0.47	0.47	3647	3625	14	7663	36.73	3409	3385	13	7157	39.33	3359	3336	13	7052	39.92
5	Galloping Sag: 32deg, .5", 0psf	0.00	1.15	1.15	7025	6960	28	6045	46.58	6942	6876	27	5972	47.15	6878	6812	27	5917	47.60
6	Galloping Swing: 32deg, .5", 2 psf	0.27	1.15	1.18	7148	7081	28	5994	46.99	7072	7005	28	5929	47.50	7008	6941	28	5874	47.94
7	COnstruction Snub-Off: 0F	0.00	0.47	0.47	4088	4067	16	8599	32.73	3805	3784	15	7999	35.18	3743	3721	15	7867	35.78
8	Stringing/Broken: 0F, 4 psf	0.20	0.47	0.51	4304	4282	17	8357	33.68	4033	4010	16	7826	35.97	3969	3946	16	7701	36.55
9	Medium Wind: 60F, 6 psf	0.30	0.47	0.56	4105	4079	16	7314	38.49	3879	3852	15	6906	40.77	3827	3799	15	6813	41.33
10	High Wind: 60F, 85 mph	0.91	0.47	1.03	6302	6251	25	6090	46.24	6177	6125	24	5967	47.19	6117	6065	24	5909	47.66
11	NESC Extreme Wind at 45deg Angle: 60F, 10.37 psf	0.51	0.47	0.70	4803	4770	19	6853	41.08	4603	4569	18	6563	42.90	4548	4514	18	6484	43.42
12	Uplift: -20 F	0.00	0.47	0.47	4259	4239	17	8962	31.40	3961	3941	16	8331	33.78	3894	3873	15	8187	34.38
13	0F	0.00	0.47	0.47	4088	4067	16	8599	32.73	3805	3784	15	7999	35.18	3743	3721	15	7867	35.78
14	32F	0.00	0.47	0.47	3840	3818	15	8073	34.86	3582	3559	14	7525	37.41	3526	3503	14	7407	38.00
15	60F	0.00	0.47	0.47	3647	3625	14	7663	36.73	3409	3385	13	7157	39.33	3359	3336	13	7052	39.92
16	90F	0.00	0.47	0.47	3462	3439	14	7270	38.72	3244	3220	13	6807	41.36	3201	3177	13	6716	41.92
17	120F	0.00	0.47	0.47	3297	3273	13	6919	40.69	3099	3073	12	6498	43.33	3060	3035	12	6416	43.89
18	MOT-normal:160F (71C)	0.00	0.47	0.47	3103	3078	12	6507	43.27	2927	2901	12	6134	45.91	2894	2868	11	6063	46.45
19	MOT-emergency: 177F (81C)	0.00	0.47	0.47	3029	3003	12	6349	44.35	2862	2836	11	5995	46.98	2831	2804	11	5927	47.51
20	MOT-normal:235F (113C)-MRC	0.00	0.47	0.47	2806	2779	11	5876	47.93	2665	2637	11	5575	50.52	2639	2610	10	5519	51.04
21	MOT-emergency: 289F (143C)-MRC	0.00	0.47	0.47	2633	2605	10	5507	51.15	2512	2482	10	5247	53.69	2489	2459	10	5199	54.19

OPGW Sag at 32 F, 0.5" Ice, No Wind, Final After Creep / Cond Sag at 32 F, No Ice, No Wind, Final After Creep=47.15' / 54.61' * 100= 86.33% < 95%, OK

OPGW Sag at 60 F, No Ice, No Wind, Final After Creep / Cond Sag at 60 F, No Ice, No Wind, Final After Creep=39.33' / 56.81' * 100=69.2% < 85%, OK

OPGW Sag at 60 F, No Ice, No Wind, Final After Load / Cond Sag at 60 F, No Ice, No Wind, Final After Load=39.91' / 52.42' * 100=76.1% < 85%, OK

PLS-CADD Version 13.00x64   3:54:54 PM Thursday, May 29, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 05/29/2014
Checked: ANR 05/29/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

HEAVY NESC

Sag and Tension- 3 Bundle-ACSR BLUEBIRD
MOT- Emergency and Normal
Ruling Span=1200 ft (Poles)

Section #3 from structure #1 to structure #25, start set #13 'COND-L, Back', end set #11 'COND-L, Ahead'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\bluebird_acsr_dc.wir', Ruling span (ft) 1200
Sagging data: Catenary (ft) 5416.97, Horiz. Tension (lbs) 13602 Condition I Temperature (deg F) 60
Weather case for final after creep Everyday 60F, Equivalent to 73.7 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B: 0F, 0.5", 4 psf, Equivalent to 22.7 (deg F) temperature increase

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.	Vert	Res.	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-Rule 250B: 0F, 0.5", 4 psf	0.92	3.92	4.32	22985	22716	38	5253	34.30	20908	20626	35	4770	37.79	22985	22716	38	5253	34.30
2	NESC Extreme Wind-Rule 250C: 60 F, 20.74 psf	3.04	2.51	3.95	19491	19277	32	4884	36.90	17538	17307	29	4385	41.11	19089	18871	32	4782	37.69
3	NESC Extreme Ice w/Conc.Wind-Rule 250D: 15F, 1", 4.1 psf	1.29	5.95	6.08	28306	27899	47	4586	39.30	26856	26437	45	4346	41.48	28306	27899	47	4586	39.30
4	Everyday 60F	0.00	2.51	2.51	13758	13602	23	5417	33.26	11860	11692	20	4656	38.71	13096	12936	22	5152	34.98
5	Galloping Sag: 32deg, .5", 0psf	0.00	3.92	3.92	20342	20093	34	5129	35.13	18268	18003	30	4596	39.22	20013	19762	33	5045	35.72
6	Galloping Swing: 32deg, .5", 2 psf	0.46	3.92	3.94	20441	20190	34	5119	35.21	18375	18109	30	4591	39.26	20124	19871	33	5038	35.77
7	COnstruction Snub-Off: 0F	0.00	2.51	2.51	15770	15624	26	6222	28.95	13347	13188	22	5252	34.31	15074	14925	25	5944	30.31
8	Stringing/Broken: 0F, 4 psf	0.59	2.51	2.58	16071	15922	27	6174	29.18	13646	13485	23	5229	34.46	15392	15241	26	5910	30.48
9	Medium Wind: 60F, 6 psf	0.88	2.51	2.66	14396	14235	24	5349	33.68	12482	12307	21	4625	38.97	13758	13593	23	5108	35.28
10	High Wind: 60F, 85 mph	2.72	2.51	3.70	18560	18356	31	4963	36.31	16597	16377	28	4428	40.71	18102	17895	30	4838	37.25
11	NESC Extreme Wind at 45deg Angle: 60F, 10.37 psf	1.52	2.51	2.94	15548	15376	26	5236	34.41	13601	13415	23	4568	39.46	14948	14772	25	5030	35.82
12	Uplift: -20 F	0.00	2.51	2.51	16589	16446	28	6549	27.50	13954	13800	23	5496	32.79	15908	15762	26	6277	28.70
13	0F	0.00	2.51	2.51	15770	15624	26	6222	28.95	13347	13188	22	5252	34.31	15074	14925	25	5944	30.31
14	32F	0.00	2.51	2.51	14624	14472	24	5764	31.26	12495	12331	21	4911	36.70	13931	13776	23	5486	32.84
15	60F	0.00	2.51	2.51	13758	13602	23	5417	33.26	11860	11692	20	4656	38.71	13096	12936	22	5152	34.98
16	90F	0.00	2.51	2.51	12949	12789	21	5093	35.38	11266	11093	19	4418	40.81	12333	12168	20	4846	37.19
17	120F	0.00	2.51	2.51	12244	12079	20	4810	37.47	10747	10569	18	4209	42.84	11680	11511	19	4584	39.32
18	MOT-normal:160F (71C)	0.00	2.51	2.51	11443	11271	19	4489	40.16	10149	9965	17	3968	45.44	10937	10761	18	4285	42.07
19	MOT-emergency: 177F (81C)	0.00	2.51	2.51	11141	10967	18	4368	41.28	9922	9735	16	3877	46.52	10659	10480	18	4174	43.20

PLS-CADD Version 13.00x64   4:20:09 PM Thursday, May 29, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/11/2014
Checked: ANR 04/11/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

HEAVY NESC

Sag and Tension- MRC ACSR Chukar:
MOT-Emergency and Normal
Ruling Span=1200 ft (Poles)

Section #3 from structure #1 to structure #25, start set #13 'COND-L, Back', end set #11 'COND-L, Ahead'
Cable 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\cables\chukar_acsr_dc.wir', Ruling span (ft) 1200
Sagging data: Catenary (ft) 5581.93, Horiz. Tension (lbs) 11582.5 Condition I Temperature (deg F) 60
Weather case for final after creep Everyday 60F, Equivalent to 75.1 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B: 0F, 0.5", 4 psf, Equivalent to 26.2 (deg F) temperature increase

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 Heavy-Rule 250B: 0F, 0.5", 4 psf	0.87	3.38	3.79	20211	19977	40	5269	34.20	18471	18225	36	4807	37.49	20211	19977	40	5269	34.20
2	NESC Extreme Wind-Rule 250C: 60 F, 20.74 psf	2.77	2.08	3.46	17202	17019	34	4919	36.64	15502	15304	30	4424	40.75	16812	16625	33	4806	37.51
3	NESC Extreme Ice w/Conc.Wind-Rule 250D: 15F, 1", 4.1 psf	1.23	5.31	5.45	25086	24720	49	4535	39.75	24033	23658	47	4340	41.54	25086	24720	49	4535	39.75
4	Everyday 60F	0.00	2.08	2.08	11710	11583	23	5582	32.28	10006	9869	20	4756	37.90	11032	10901	22	5254	34.30
5	Galloping Sag: 32deg, .5", 0psf	0.00	3.38	3.38	17755	17541	35	5187	34.74	15952	15725	31	4650	38.77	17416	17200	34	5086	35.43
6	Galloping Swing: 32deg, .5", 2 psf	0.43	3.38	3.41	17857	17641	35	5174	34.83	16059	15831	31	4643	38.82	17524	17306	34	5076	35.50
7	COnstruction Snub-Off: 0F	0.00	2.08	2.08	13494	13375	26	6446	27.95	11309	11180	22	5388	33.44	12750	12628	25	6086	29.60
8	Stringing/Broken: 0F, 4 psf	0.53	2.08	2.14	13791	13670	27	6380	28.23	11613	11481	23	5358	33.63	13072	12948	26	6043	29.81
9	Medium Wind: 60F, 6 psf	0.80	2.08	2.22	12352	12220	24	5494	32.80	10629	10486	21	4714	38.23	11695	11559	23	5197	34.67
10	High Wind: 60F, 85 mph	2.47	2.08	3.23	16337	16164	32	5012	35.96	14611	14424	29	4472	40.31	15887	15711	31	4871	37.00
11	NESC Extreme Wind at 45deg Angle: 60F, 10.37 psf	1.38	2.08	2.49	13479	13337	26	5347	33.70	11738	11584	23	4644	38.81	12866	12720	25	5099	35.34
12	Uplift: -20 F	0.00	2.08	2.08	14216	14099	28	6795	26.51	11849	11723	23	5649	31.89	13482	13363	26	6440	27.97
13	0F	0.00	2.08	2.08	13494	13375	26	6446	27.95	11309	11180	22	5388	33.44	12750	12628	25	6086	29.60
14	32F	0.00	2.08	2.08	12475	12352	24	5953	30.26	10563	10429	21	5026	35.86	11757	11630	23	5605	32.15
15	60F	0.00	2.08	2.08	11710	11583	23	5582	32.28	10006	9869	20	4756	37.90	11032	10901	22	5254	34.30
16	90F	0.00	2.08	2.08	10994	10863	22	5235	34.42	9486	9344	19	4503	40.03	10370	10235	20	4932	36.54
17	120F	0.00	2.08	2.08	10373	10239	20	4934	36.52	9035	8889	18	4284	42.09	9804	9665	19	4658	38.70
18	MOT-normal:160F (71C)	0.00	2.08	2.08	9670	9530	19	4593	39.25	8516	8365	17	4031	44.73	9169	9024	18	4349	41.45
19	MOT-emergency: 177F (81C)	0.00	2.08	2.08	9405	9263	18	4464	40.38	8320	8167	16	3936	45.82	8929	8782	18	4232	42.60
20	MOT-normal:235F (113C)-MRC	0.00	2.08	2.08	8629	8479	17	4086	44.13	7738	7578	15	3652	49.40	8227	8073	16	3890	46.36
21	MOT-emergency: 289F (143C)-MRC	0.00	2.08	2.08	8046	7890	16	3802	47.44	7289	7123	14	3433	52.57	7699	7538	15	3633	49.66

Emergency MOT=289 F > 212 F and Normal regime MOT=235 F > 212 F:
Conductor Model: "Aluminum can go into compression" (does not bird-cage):
Virtual Compressive Stress=Actual Compressive Stress*(A o/A t)=1.5*1.3986/1.5126=1.387 kpsi
Plus, being an ACSR conductor with **%steel area**: (1.5126-1.3986)/1.5126*100=**7.5%** , and **MOT over 212 F**, it will have also "**High Temperature Creep**", which will increase the final sag after creep (probably maximum another 0.75 ft in RS=1200 ft).

PLS-CADD Version 13.00x64   4:42:57 PM Thursday, May 29, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 05/29/2014
Checked: ANR 05/29/2104

Sag and Tension OPGW
Based on Conductor ACSR
Bluebird Sagging Condition
Ruling Span=1200 ft (Poles)

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

HEAVY NESC

OPGW Sag at 32 F, 0.5" Ice, No Wind, Final After Load / Cond Sag at 32 F, No Ice, No Wind, Final After Load=31.20' / 32.84' * 100=95%, OK

Section #1 from structure #1 to structure #25, start set #3 'OPGW-L, Back', end set #1 'OPGW-L, Ahead'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\49ay85acs-2c 1-1427.wir', Ruling span (ft) 1200
Sagging data: Catenary (ft) 8219.66, Horiz. Tension (lbs) 3887.9 Condition I Temperature (deg F) 60
Weather case for final after creep Everyday 60F, Equivalent to 38.1 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B: 0F, 0.5", 4 psf, Equivalent to 41.0 (deg F) temperature increase

Ruling Span Sag Tension Report

#	Description	--Cable Load-- Hor. (lbs/ft)	Vert (lbs/ft)	Res. (lbs/ft)	R.S. Initial Cond. Max. Tens. (lbs)	Hori. Tens. (lbs)	Max Ten %UL	C (ft)	R.S. Sag (ft)	R.S. Final Cond. After Creep Max. Tens. (lbs)	Hori. Tens. (lbs)	Max Ten %UL	C (ft)	R.S. Sag (ft)	R.S. Final Cond. After Load Max. Tens. (lbs)	Hori. Tens. (lbs)	Max Ten %UL	C (ft)	R.S. Sag (ft)
1	NESC Heavy-Rule 250B: 0F, 0.5", 4 psf	0.53	1.15	1.57	8536	8443	34	5386	33.45	8536	8443	34	5386	33.45	8536	8443	34	5386	33.45
2	NESC Extreme Wind-Rule 250C: 60 F, 20.74 psf	1.02	0.47	1.13	6525	6477	26	5755	31.31	6367	6318	25	5614	32.10	6340	6291	25	5590	32.23
3	NESC Extreme Ice w/Conc.Wind-Rule 250D: 15F, 1", 4.1 psf	0.89	2.45	2.61	11329	11151	45	4278	42.14	11329	11151	45	4278	42.14	11329	11151	45	4278	42.14
4	Everyday 60F	0.00	0.47	0.47	3913	3888	15	8220	21.91	3543	3517	14	7435	24.22	3519	3493	14	7384	24.39
5	Galloping Sag: 32deg, .5", 0psf	0.00	1.15	1.15	6886	6818	27	5921	30.42	6745	6676	27	5798	31.07	6717	6648	26	5774	31.20
6	Galloping Swing: 32deg, .5", 2 psf	0.27	1.15	1.18	6990	6920	28	5857	30.76	6859	6789	27	5746	31.36	6832	6762	27	5723	31.48
7	COnstruction Snub-Off: 0F	0.00	0.47	0.47	4592	4568	18	9657	18.64	4163	4138	16	8749	20.58	4128	4103	16	8675	20.76
8	Stringing/Broken: 0F, 4 psf	0.20	0.47	0.51	4761	4736	19	9244	19.48	4355	4330	17	8450	21.31	4320	4295	17	8382	21.48
9	Medium Wind: 60F, 6 psf	0.30	0.47	0.56	4299	4272	17	7660	23.51	3960	3932	16	7050	25.55	3936	3908	16	7007	25.71
10	High Wind: 60F, 85 mph	0.91	0.47	1.03	6172	6128	24	5971	30.17	5982	5937	24	5784	31.15	5956	5911	23	5759	31.28
11	NESC Extreme Wind at 45deg Angle: 60F, 10.37 psf	0.51	0.47	0.70	4896	4864	19	6988	25.77	4602	4570	18	6565	27.44	4576	4543	18	6527	27.60
12	Uplift: -20 F	0.00	0.47	0.47	4854	4831	19	10213	17.63	4411	4387	17	9275	19.41	4374	4350	17	9196	19.58
13	0F	0.00	0.47	0.47	4592	4568	18	9657	18.64	4163	4138	16	8749	20.58	4128	4103	16	8675	20.76
14	32F	0.00	0.47	0.47	4207	4183	17	8844	20.36	3808	3783	15	7998	22.52	3779	3754	15	7936	22.69
15	60F	0.00	0.47	0.47	3913	3888	15	8220	21.91	3543	3517	14	7435	24.22	3519	3493	14	7384	24.39
16	90F	0.00	0.47	0.47	3631	3605	14	7623	23.63	3298	3272	13	6917	26.04	3277	3250	13	6871	[illegible]
17	120F	0.00	0.47	0.47	3386	3360	13	7104	25.35	3088	3061	12	6472	27.83	3069	3042	12	6432	28.01
18	MOT-normal:160F (71C)	0.00	0.47	0.47	3106	3079	12	6510	27.67	2850	2822	11	5967	30.19	2835	2807	11	5935	30.35
19	MOT-emergency: 177F (81C)	0.00	0.47	0.47	3002	2975	12	6289	28.64	2763	2735	11	5781	31.16	2748	2720	11	5750	31.33
20	MOT-normal:235F (113C)-MRC	0.00	0.47	0.47	2700	2671	11	5647	31.90	2508	2478	10	5239	34.40	2497	2467	10	5216	34.55
21	MOT-emergency: 289F (143C)-MRC	0.00	0.47	0.47	2478	2448	10	5176	34.81	2319	2288	9	4836	37.27	2310	2279	9	4818	37.41

OPGW Sag at 32 F, 0.5" Ice, No Wind, Final After Creep / Cond Sag at 32 F, No Ice, No Wind, Final After Creep=31.07' / 36.70' * 100=84.66% < 95%, OK

OPGW Sag at 60 F, No Ice, No Wind, Final After Creep / Cond Sag at 60 F, No Ice, No Wind, Final After Creep=24.22' / 38.71' * 100=62.6% < 85%, OK

OPGW Sag at 60 F, No Ice, No Wind, Final After Load / Cond Sag at 60 F, No Ice, No Wind, Final After Load=24.39' / 34.98' * 100=69.7% < 85%, OK

By: CIM 05/29/2014
Checked: ANR 05/29/2014

PLS-CADD Version 13.00x64 2:28:56 PM Friday, May 30, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Lattice Tower (Design Span 1500 ft) '

MEDIUM NESC

Sag and Tension- 3 Bundle- ACSR BLUEBIRD
MOT-Emergency and Normal
Ruling Span=1500 ft (Towers)

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

Section #3 from structure #1 to structure #20, start set #11 'COND-L,Ahead', end set #11 'COND-L,Ahead'
Cable 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\cables\bluebird_acsr_dc.wir', Ruling span (ft) 1500
Sagging data: Catenary (ft) 5474.39, Horiz. Tension (lbs) 13746.2 Condition I Temperature (deg F) 60
Weather case for final after creep Everyday 60F, Equivalent to 78.2 (deg F) temperature increase
Weather case for final after load NESC Medium-Rule 250B: 15F, 0.25", 4 psf, Equivalent to 11.8 (deg F) temperature increase

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)	After Creep Hori. Tens. (lbs)	After Creep Max Ten %UL	After Creep C (ft)	After Creep R.S. Sag (ft)	R.S. Final Cond. After Load Max. Tens. (lbs)	After Load Hori. Tens. (lbs)	After Load Max Ten %UL	After Load C (ft)	After Load R.S. Sag (ft)
2	NESC Medium-Rule 250B: 15F, 0.25", 4 psf	0.75	3.14	3.43	19147	18941	32	5529	50.95	17421	17198	29	5020	56.13	19147	18941	32	5529	50.95
3	NESC Extreme Wind-Rule 250C: 60 F, 20.74 psf	3.04	2.51	3.95	20239	19999	34	5068	55.60	18656	18398	31	4662	60.46	20239	19999	34	5068	55.60
4	NESC Extreme Ice w/Conc.Wind-Rule 250D: 15F, 1", 4.1 psf	1.29	5.95	6.08	29616	29206	49	4801	58.70	28478	28053	47	4612	61.12	29616	29206	49	4801	58.70
5	Everyday 60F	0.00	2.51	2.51	13899	13746	23	5474	51.46	12435	12267	21	4885	57.68	13649	13494	23	5374	52.42
6	Galloping Sag: 32deg, .5", 0psf	0.00	3.92	3.92	20826	20580	35	5253	53.63	19174	18910	32	4827	58.38	20826	20580	35	5253	53.63
7	Galloping Swing: 32deg, .5", 2 psf	0.46	3.92	3.94	20937	20689	35	5245	53.71	19288	19022	32	4823	58.44	20937	20689	35	5245	53.71
8	COnstruction Snub-Off: 0F	0.00	2.51	2.51	15278	15137	25	6028	46.72	13516	13359	22	5320	52.95	15072	14929	25	5946	47.37
9	Stringing/Broken: 0F, 4 psf	0.59	2.51	2.58	15606	15461	26	5995	46.97	13838	13678	23	5304	53.11	15421	15274	26	5923	47.55
10	Medium Wind: 60F, 6 psf	0.88	2.51	2.66	14599	14438	24	5426	51.92	13108	12931	22	4859	57.99	14368	14205	24	5338	52.78
11	High Wind: 60F, 85 mph	2.72	2.51	3.70	19198	18975	32	5130	54.92	17614	17372	29	4697	60.01	19148	18924	32	5116	55.07
12	NESC Extreme Wind at 45deg Angle: 60F, 10.37 psf	1.52	2.51	2.94	15866	15689	26	5343	52.73	14331	14137	24	4814	58.54	15670	15491	26	5275	53.41
13	Uplift: -20 F	0.00	2.51	2.51	15812	15674	26	6242	45.11	13939	13786	23	5490	51.31	15644	15505	26	6175	45.60
14	0F	0.00	2.51	2.51	15278	15137	25	6028	46.72	13516	13359	22	5320	52.95	15072	14929	25	5946	47.37
15	32F	0.00	2.51	2.51	14504	14357	24	5718	49.26	12907	12745	21	5076	55.51	14267	14117	24	5622	50.10
16	60F	0.00	2.51	2.51	13899	13746	23	5474	51.46	12435	12267	21	4885	57.68	13649	13494	23	5374	52.42
17	90F	0.00	2.51	2.51	13315	13157	22	5240	53.77	11974	11801	20	4700	59.97	13064	12903	22	5139	54.83
18	120F	0.00	2.51	2.51	12791	12628	21	5029	56.03	11558	11380	19	4532	62.20	12539	12373	21	4927	57.19
19	MOT-normal:160F (71C)	0.00	2.51	2.51	12171	12000	20	4779	58.97	11065	10879	18	4333	65.08	11921	11747	20	4678	60.25
20	MOT-emergency: 177F (81C)	0.00	2.51	2.51	11930	11756	20	4682	60.20	10873	10685	18	4255	66.27	11684	11507	19	4583	61.51

By: CIM 05/29/2014
Checked: ANR 05/29/2014

PLS-CADD Version 13.00x64   3:14:08 PM Friday, May 30, 2014
Power Engineers
Project Name: 'r:\pls\pls cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Lattice Tower (Design Span 1500 ft)   '

MEDIUM NESC

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

Sag and Tension- MRC ACSR CHUKAR
MOT-Emergency and Normal
Ruling Span=1500 ft (Towers)

Section #3 from structure #1 to structure #20, start set #11 'COND-L,Ahead', end set #11 'COND-L,Ahead'
Cable 'r:\pls\pls cadd\projects\132836 - plains & eastern ph1\cables\chukar_acsr_dc.wir', Ruling span (ft) 1500
Sagging data: Catenary (ft) 5606.75, Horiz. Tension (lbs) 11634 Condition I Temperature (deg F) 60
Weather case for final after creep Everyday 60F, Equivalent to 79.6 (deg F) temperature increase
Weather case for final after load NESC Medium-Rule 250B: 15F, 0.25", 4 psf, Equivalent to 13.5 (deg F) temperature increase

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.	Vert	Res.	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)
2	NESC Medium-Rule 250B: 15F, 0.25", 4 psf	0.70	2.65	2.94	16662	16488	33	5605	50.26	15152	14963	30	5086	55.40	16662	16488	33	5605	50.26
3	NESC Extreme Wind-Rule 250C: 60 F, 20.74 psf	2.77	2.08	3.46	17860	17653	35	5103	55.22	16484	16261	32	4700	59.96	17860	17653	35	5103	55.22
4	NESC Extreme Ice w/Conc.Wind-Rule 250D: 15F, 1", 4.1 psf	1.23	5.31	5.45	26307	25936	52	4758	59.24	25525	25145	50	4613	61.11	26307	25936	52	4758	59.24
5	Everyday 60F	0.00	2.08	2.08	11758	11634	23	5607	50.24	10457	10320	21	4974	56.66	11503	11376	23	5483	51.38
6	Galloping Sag: 32deg, .5", 0psf	0.00	3.38	3.38	18159	17947	36	5307	53.09	16728	16502	33	4879	57.75	18159	17947	36	5307	53.09
7	Galloping Swing: 32deg, .5", 2 psf	0.43	3.38	3.41	18273	18060	36	5297	53.19	16846	16618	33	4874	57.82	18273	18060	36	5297	53.19
8	COnstruction Snub-Off: 0F	0.00	2.08	2.08	12969	12854	25	6195	45.46	11398	11271	22	5432	51.86	12748	12632	25	6088	46.26
9	Stringing/Broken: 0F, 4 psf	0.53	2.08	2.14	13301	13183	26	6153	45.77	11726	11595	23	5412	52.05	13098	12978	26	6057	46.49
10	Medium Wind: 60F, 6 psf	0.80	2.08	2.22	12462	12329	24	5543	50.81	11135	10990	22	4941	57.03	12229	12094	24	5438	51.81
11	High Wind: 60F, 85 mph	2.47	2.08	3.23	16892	16700	33	5178	54.41	15502	15294	30	4742	59.43	16853	16661	33	5166	54.54
12	NESC Extreme Wind at 45deg Angle: 60F, 10.37 psf	1.38	2.08	2.49	13708	13560	27	5436	51.82	12344	12182	24	4884	57.70	13515	13365	26	5358	52.58
13	Uplift: -20 F	0.00	2.08	2.08	13440	13329	26	6424	43.83	11769	11645	23	5612	50.19	13250	13138	26	6331	44.47
14	0F	0.00	2.08	2.08	12969	12854	25	6195	45.46	11398	11271	22	5432	51.86	12748	12632	25	6088	46.26
15	32F	0.00	2.08	2.08	12288	12168	24	5864	48.03	10868	10736	21	5174	54.45	12042	11921	24	5745	49.02
16	60F	0.00	2.08	2.08	11758	11634	23	5607	50.24	10457	10320	21	4974	56.66	11503	11376	23	5483	51.38
17	90F	0.00	2.08	2.08	11248	11120	22	5359	52.57	10059	9918	20	4780	58.96	10993	10862	22	5235	53.82
18	120F	0.00	2.08	2.08	10789	10656	21	5136	54.86	9699	9553	19	4604	61.22	10538	10402	21	5013	56.21
19	MOT-normal:160F (71C)	0.00	2.08	2.08	10248	10109	20	4872	57.84	9272	9121	18	4395	64.14	10005	9863	20	4753	59.29
20	MOT-emergency: 177F (81C)	0.00	2.08	2.08	10040	9898	20	4770	59.08	9106	8953	18	4314	65.35	9800	9656	19	4653	60.57
21	MOT-normal:235F (113C)-MRC	0.00	2.08	2.08	9404	9254	18	4460	63.21	8599	8437	17	4066	69.36	9184	9031	18	4352	64.78
22	MOT-emergency: 289F (143C)-MRC	0.00	2.08	2.08	8902	8745	17	4214	66.91	8196	8027	16	3868	72.93	8700	8540	17	4116	68.53

Emergency MOT=289 F > 212 F and Normal regime MOT=235 F > 212 F:
Conductor Model: "Aluminum can go into compression" (does not bird-cage):
Virtual Compressive Stress=Actual Compressive Stress*(A o/A t)=1.5*1.3986/1.5126=1.387 kpsi
Plus, being an ACSR conductor with **%steel area**: (1.5126-1.3986)/1.5126*100=**7.5%** , and **MOT over 212 F**, it will have also "**High Temperature Creep**", which will increase the final sag after creep (probably maximum another 1 ft in RS=1500 ft).

By: CIM 05/29/2014
Checked: ANR 05/29/2014

Sag and Tension OPGW
Sag OPGW/Conductor Ratio
Ruling Span=1500 ft (Towers)

PLS-CADD Version 13.00x64 3:25:32 PM Friday, May 30, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Lattice Tower (Design Span 1500 ft)'

MEDIUM NESC

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

OPGW Sag at 32 F, 0.5" Ice, No Wind, Final After Load / Cond Sag at 32 F, No Ice, No Wind, Final After Load=47.60' / 50.10' * 100=95%, OK

Section #1 from structure #1 to structure #20, start set #1 'OPGW-L, Ahead', end set #1 'OPGW-L, Ahead'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\49ay85acs-2c 1-1427.wir', Ruling span (ft) 1500
Sagging data: Catenary (ft) 7384.78, Horiz. Tension (lbs) 3493 Condition I Temperature (deg F) 60
Weather case for final after creep Everyday 60F, Equivalent to 37.4 (deg F) temperature increase
Weather case for final after load NESC Medium-Rule 250B: 15F, 0.25", 4 psf, Equivalent to 22.3 (deg F) temperature increase

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. (lbs/ft)	Vert (lbs/ft)	Res. (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)
2	NESC Medium-Rule 250B: 15F, 0.25", 4 psf	0.36	0.73	1.02	6446	6391	25	6269	44.92	6333	6278	25	6157	45.73	6446	6391	25	6269	44.92
3	NESC Extreme Wind-Rule 250C: 60 F, 20.74 psf	1.02	0.47	1.13	6576	6518	26	5792	48.63	6483	6425	26	5708	49.34	6576	6518	26	5792	48.63
4	NESC Extreme Ice w/Conc.Wind-Rule 250D: 15F, 1", 4.1 psf	0.89	2.45	2.61	12025	11842	47	4543	62.05	12025	11842	47	4543	62.05	12025	11842	47	4543	62.05
5	Everyday 60F	0.00	0.47	0.47	3516	3493	14	7385	38.12	3300	3276	13	6925	40.65	3383	3360	13	7103	39.63
6	Galloping Sag: 32deg, .5", 0psf	0.00	1.15	1.15	6878	6812	27	5917	47.60	6798	6732	27	5847	48.17	6878	6812	27	5917	47.60
7	Galloping Swing: 32deg, .5", 2 psf	0.27	1.15	1.18	7001	6934	28	5868	47.99	6929	6860	27	5807	48.50	7001	6934	28	5868	47.99
8	COnstruction Snub-Off: 0F	0.00	0.47	0.47	3922	3901	15	8247	34.13	3666	3644	14	7703	36.54	3772	3750	15	7929	35.50
9	Stringing/Broken: 0F, 4 psf	0.20	0.47	0.51	4138	4116	16	8032	35.04	3891	3867	15	7547	37.30	4000	3976	16	7761	36.27
10	Medium Wind: 60F, 6 psf	0.30	0.47	0.56	3970	3943	16	7070	39.82	3765	3737	15	6700	42.02	3851	3824	15	6856	41.06
11	High Wind: 60F, 85 mph	0.91	0.47	1.03	6163	6111	24	5954	47.30	6045	5993	24	5838	48.24	6145	6093	24	5936	47.44
12	NESC Extreme Wind at 45deg Angle: 60F, 10.37 psf	0.51	0.47	0.70	4668	4635	18	6658	42.29	4482	4447	18	6389	44.07	4574	4539	18	6521	43.18
13	Uplift: -20 F	0.00	0.47	0.47	4080	4060	16	8583	32.79	3810	3788	15	8009	35.14	3924	3903	15	8252	34.11
14	0F	0.00	0.47	0.47	3922	3901	15	8247	34.13	3666	3644	14	7703	36.54	3772	3750	15	7929	35.50
15	32F	0.00	0.47	0.47	3692	3670	15	7760	36.27	3460	3437	14	7266	38.74	3551	3529	14	7460	37.73
16	60F	0.00	0.47	0.47	3516	3493	14	7385	38.12	3300	3276	13	6925	40.65	3383	3360	13	7103	39.63
17	90F	0.00	0.47	0.47	3344	3320	13	7020	40.10	3148	3123	12	6603	42.64	3222	3197	13	6760	41.65
18	120F	0.00	0.47	0.47	3192	3168	13	6697	42.04	3012	2987	12	6314	44.59	3078	3053	12	6454	43.63
19	MOT-normal:160F (71C)	0.00	0.47	0.47	3012	2986	12	6314	44.60	2853	2826	11	5976	47.13	2910	2884	11	6097	46.19
20	MOT-emergency: 177F (81C)	0.00	0.47	0.47	2944	2917	12	6168	45.66	2792	2765	11	5845	48.18	2846	2819	11	5960	47.25
21	MOT-normal:235F (113C)-MRC	0.00	0.47	0.47	2736	2708	11	5725	49.20	2607	2578	10	5451	51.68	2652	2623	10	5546	50.79
22	MOT-emergency: 289F (143C)-MRC	0.00	0.47	0.47	2574	2545	10	5380	52.36	2462	2432	10	5141	54.80	2500	2470	10	5222	53.95

OPGW Sag at 32 F, 0.5" Ice, No Wind, Final After Creep / Cond Sag at 32 F, No Ice, No Wind, Final After Creep=48.17' / 55.51' * 100= 86.78% < 95%, OK

OPGW Sag at 60 F, No Ice, No Wind, Final After Creep / Cond Sag at 60 F, No Ice, No Wind, Final After Creep=40.65' / 57.68' * 100=70.48% < 85%, OK

OPGW Sag at 60 F, No Ice, No Wind, Final After Load / Cond Sag at 60 F, No Ice, No Wind, Final After Load=39.63' / 52.42' * 100=75.6% < 85%, OK

By: CIM 05/29/2014
Checked: ANR 05/29/2014

PLS-CADD Version 13.00x64 3:55:58 PM Friday, May 30, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

Sag and Tension- 3 Bundle-ACSR BLUEBIRD
MOT- Emergency and Normal
Ruling Span=1200 ft (Poles)

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

MEDIUM NESC

Section #3 from structure #1 to structure #25, start set #13 'COND-L, Back', end set #11 'COND-L, Ahead'
Cable 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\cables\bluebird_acsr_dc.wir', Ruling span (ft) 1200
Sagging data: Catenary (ft) 5280.92, Horiz. Tension (lbs) 13260.4 Condition I Temperature (deg F) 60
Weather case for final after creep Everyday 60F, Equivalent to 72.6 (deg F) temperature increase
Weather case for final after load NESC Medium-Rule 250B: 15F, 0.25", 4 psf, Equivalent to 11.1 (deg F) temperature increase

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. (lbs/ft)	Vert (lbs/ft)	Res. (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)
2	NESC Medium-Rule 250B: 15F, 0.25", 4 psf	0.75	3.14	3.43	18608	18398	31	5370	33.55	16520	16296	27	4757	37.89	18608	18398	31	5370	33.55
3	NESC Extreme Wind-Rule 250C: 60 F, 20.74 psf	3.04	2.51	3.95	19119	18901	32	4789	37.63	17278	17045	29	4319	41.74	19081	18864	32	4780	37.71
4	NESC Extreme Ice w/Conc.Wind-Rule 250D: 15F, 1", 4.1 psf	1.29	5.95	6.08	27885	27475	46	4517	39.91	26488	26065	44	4285	42.08	27885	27475	46	4517	39.91
5	Everyday 60F	0.00	2.51	2.51	13418	13260	22	5281	34.12	11653	11483	19	4573	39.42	13099	12939	22	5153	34.97
6	Galloping Sag: 32deg, .5", 0psf	0.00	3.92	3.92	19933	19680	33	5024	35.87	17975	17708	30	4520	39.88	19933	19680	33	5024	35.87
7	Galloping Swing: 32deg, .5", 2 psf	0.46	3.92	3.94	20032	19778	33	5014	35.94	18076	17808	30	4515	39.93	20032	19778	33	5014	35.94
8	COnstruction Snub-Off: 0F	0.00	2.51	2.51	15311	15163	25	6038	29.83	13062	12902	22	5138	35.07	15074	14925	25	5944	30.31
9	Stringing/Broken: 0F, 4 psf	0.59	2.51	2.58	15609	15459	26	5995	30.05	13361	13198	22	5118	35.21	15392	15241	26	5910	30.48
10	Medium Wind: 60F, 6 psf	0.88	2.51	2.66	14055	13892	23	5220	34.52	12266	12090	20	4543	39.68	13759	13593	23	5108	35.28
11	High Wind: 60F, 85 mph	2.72	2.51	3.70	18190	17984	30	4862	37.07	16342	16121	27	4358	41.36	18099	17892	30	4837	37.26
12	NESC Extreme Wind at 45deg Angle: 60F, 10.37 psf	1.52	2.51	2.94	15199	15025	25	5116	35.22	13376	13188	22	4491	40.14	14948	14772	25	5030	35.83
13	Uplift: -20 F	0.00	2.51	2.51	16082	15936	27	6347	28.38	13640	13484	23	5370	33.55	15909	15763	26	6277	28.70
14	0F	0.00	2.51	2.51	15311	15163	25	6038	29.83	13062	12902	22	5138	35.07	15074	14925	25	5944	30.31
15	32F	0.00	2.51	2.51	14236	14083	24	5609	32.12	12259	12093	20	4816	37.42	13934	13779	23	5488	32.83
16	60F	0.00	2.51	2.51	13418	13260	22	5281	34.12	11653	11483	19	4573	39.42	13099	12939	22	5153	34.97
17	90F	0.00	2.51	2.51	12655	12492	21	4975	36.23	11085	10911	18	4345	41.49	12336	12172	20	4847	37.18
18	120F	0.00	2.51	2.51	11991	11824	20	4709	38.28	10589	10410	18	4146	43.49	11678	11509	19	4583	39.33
19	MOT-normal:160F (71C)	0.00	2.51	2.51	11230	11056	19	4403	40.94	10014	9829	17	3914	46.08	10936	10760	18	4285	42.08
20	MOT-emergency: 177F (81C)	0.00	2.51	2.51	10943	10767	18	4288	42.05	9796	9607	16	3826	47.14	10656	10477	18	4172	43.21

By: CIM 04/11/2014
Checked: ANR 04/11/2014

PLS-CADD Version 13.00x64   4:10:34 PM Friday, May 30, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

MEDIUM NESC

Sag and Tension- MRC ACSR Chukar:
MOT-Emergency and Normal
Ruling Span=1200 ft (Poles)

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

Section #3 from structure #1 to structure #25, start set #13 'COND-L, Back', end set #11 'COND-L, Ahead'
Cable 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\cables\chukar_acsr_dc.wir', Ruling span (ft) 1200
Sagging data: Catenary (ft) 5406.89, Horiz. Tension (lbs) 11219.3 Condition I Temperature (deg F) 60
Weather case for final after creep Everyday 60F, Equivalent to 73.3 (deg F) temperature increase
Weather case for final after load NESC Medium-Rule 250B: 15F, 0.25", 4 psf, Equivalent to 12.8 (deg F) temperature increase

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)
2	NESC Medium-Rule 250B: 15F, 0.25", 4 psf	0.70	2.65	2.94	16142	15962	32	5426	33.21	14332	14142	28	4807	37.49	16142	15962	32	5426	33.21
3	NESC Extreme Wind-Rule 250C: 60 F, 20.74 psf	2.77	2.08	3.46	16809	16623	33	4805	37.51	15221	15021	30	4342	41.52	16800	16613	33	4802	37.53
4	NESC Extreme Ice w/Conc.Wind-Rule 250D: 15F, 1", 4.1 psf	1.23	5.31	5.45	24661	24291	48	4456	40.46	23644	23265	46	4268	42.25	24661	24291	48	4456	40.46
5	Everyday 60F	0.00	2.08	2.08	11344	11215	22	5405	33.34	9788	9649	19	4650	38.76	11031	10900	22	5253	34.30
6	Galloping Sag: 32deg, .5", 0psf	0.00	3.38	3.38	17322	17105	34	5058	35.63	15641	15412	31	4557	39.56	17322	17105	34	5058	35.63
7	Galloping Swing: 32deg, .5", 2 psf	0.43	3.38	3.41	17425	17206	34	5046	35.71	15745	15515	31	4550	39.62	17425	17206	34	5046	35.71
8	COnstruction Snub-Off: 0F	0.00	2.08	2.08	13004	12883	25	6209	29.01	11011	10880	22	5243	34.37	12746	12624	25	6084	29.61
9	Stringing/Broken: 0F, 4 psf	0.53	2.08	2.14	13300	13177	26	6150	29.29	11312	11178	22	5217	34.54	13068	12944	26	6041	29.82
10	Medium Wind: 60F, 6 psf	0.80	2.08	2.22	11983	11849	23	5327	33.83	10404	10259	20	4612	39.08	11691	11555	23	5195	34.69
11	High Wind: 60F, 85 mph	2.47	2.08	3.23	15948	15772	31	4890	36.85	14339	14150	28	4387	41.09	15873	15696	31	4867	37.03
12	NESC Extreme Wind at 45deg Angle: 60F, 10.37 psf	1.38	2.08	2.49	13106	12961	26	5196	34.68	11499	11342	23	4547	39.64	12862	12716	25	5098	35.35
13	Uplift: -20 F	0.00	2.08	2.08	13678	13559	27	6534	27.57	11513	11385	23	5487	32.84	13478	13359	26	6438	27.98
14	0F	0.00	2.08	2.08	13004	12883	25	6209	29.01	11011	10880	22	5243	34.37	12746	12624	25	6084	29.61
15	32F	0.00	2.08	2.08	12060	11935	24	5752	31.32	10312	10177	20	4905	36.75	11753	11626	23	5603	32.16
16	60F	0.00	2.08	2.08	11344	11215	22	5405	33.34	9788	9649	19	4650	38.76	11031	10900	22	5253	34.30
17	90F	0.00	2.08	2.08	10680	10547	21	5083	35.45	9300	9157	18	4413	40.85	10368	10233	20	4932	36.54
18	120F	0.00	2.08	2.08	10104	9967	20	4803	37.52	8871	8724	17	4204	42.89	9802	9663	19	4657	38.71
19	MOT-normal:160F (71C)	0.00	2.08	2.08	9443	9301	19	4482	40.22	8377	8224	16	3964	45.50	9161	9017	18	4345	41.49
20	MOT-emergency: 177F (81C)	0.00	2.08	2.08	9196	9052	18	4362	41.33	8190	8036	16	3873	46.57	8921	8775	17	4229	42.64
21	MOT-normal:235F (113C)-MRC	0.00	2.08	2.08	8464	8312	17	4006	45.02	7633	7471	15	3601	50.11	8222	8068	16	3888	46.39
22	MOT-emergency: 289F (143C)-MRC	0.00	2.08	2.08	7908	7750	16	3735	48.30	7201	7034	14	3390	53.24	7695	7534	15	3631	49.69

Emergency MOT=289 F > 212 F and Normal regime MOT=235 F > 212 F:
Conductor Model: "Aluminum can go into compression" (does not bird-cage):
Virtual Compressive Stress=Actual Compressive Stress*(A o/A t)=1.5*1.3986/1.5126=1.387 kpsi
Plus, being an ACSR conductor with **%steel area**: (1.5126-1.3986)/1.5126*100=**7.5%** , and **MOT over 212 F**, it will have also "**High Temperature Creep**", which will increase the final sag after creep (probably maximum another 0.75 ft in RS=1200 ft).

By: CIM 05/30/2014
Checked: ANR 05/30/2104

Sag and Tension OPGW
Based on Conductor ACSR
Bluebird Sagging Condition
Ruling Span=1200 ft (Poles)

PLS-CADD Version 13.00x64 4:18:34 PM Friday, May 30, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

MEDIUM NESC

OPGW Sag at 32 F, 0.5" Ice, No Wind, Final After Load / Cond Sag at 32 F, No Ice, No Wind, Final After Load=31.19' / 32.83' * 100=95%, OK

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

Section #1 from structure #1 to structure #25, start set #3 'OPGW-L, Back', end set #1 'OPGW-L, Ahead'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\49ay85acs-2c 1-1427.wir', Ruling span (ft) 1200
Sagging data: Catenary (ft) 7840.38, Horiz. Tension (lbs) 3708.5 Condition I Temperature (deg F) 60
Weather case for final after creep Everyday 60F, Equivalent to 37.1 (deg F) temperature increase
Weather case for final after load NESC Medium-Rule 250B: 15F, 0.25", 4 psf, Equivalent to 20.2 (deg F) temperature increase

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)
2	NESC Medium-Rule 250B: 15F, 0.25", 4 psf	0.36	0.73	1.02	6401	6345	25	6223	28.95	6232	6176	25	6057	29.74	6401	6345	25	6223	28.95
3	NESC Extreme Wind-Rule 250C: 60 F, 20.74 psf	1.02	0.47	1.13	6368	6319	25	5614	32.09	6221	6171	25	5483	32.86	6367	6318	25	5614	32.09
4	NESC Extreme Ice w/Conc.Wind-Rule 250D: 15F, 1", 4.1 psf	0.89	2.45	2.61	11185	11005	44	4222	42.70	11185	11005	44	4222	42.70	11185	11005	44	4222	42.70
5	Everyday 60F	0.00	0.47	0.47	3732	3706	15	7836	22.98	3402	3376	13	7137	25.23	3543	3517	14	7436	24.22
6	Galloping Sag: 32deg, .5", 0psf	0.00	1.15	1.15	6719	6650	26	5776	31.19	6587	6517	26	5661	31.83	6719	6650	26	5776	31.19
7	Galloping Swing: 32deg, .5", 2 psf	0.27	1.15	1.18	6824	6753	27	5716	31.52	6701	6630	26	5612	32.11	6824	6753	27	5716	31.52
8	COnstruction Snub-Off: 0F	0.00	0.47	0.47	4364	4340	17	9175	19.62	3971	3947	16	8344	21.58	4163	4139	16	8750	20.58
9	Stringing/Broken: 0F, 4 psf	0.20	0.47	0.51	4539	4514	18	8809	20.44	4167	4141	16	8081	22.28	4355	4330	17	8451	21.31
10	Medium Wind: 60F, 6 psf	0.30	0.47	0.56	4126	4099	16	7349	24.51	3819	3791	15	6797	26.50	3962	3934	16	7053	25.54
11	High Wind: 60F, 85 mph	0.91	0.47	1.03	6013	5969	24	5815	30.98	5837	5792	23	5643	31.93	5983	5939	24	5786	31.14
12	NESC Extreme Wind at 45deg Angle: 60F, 10.37 psf	0.51	0.47	0.70	4725	4693	19	6742	26.72	4459	4426	18	6359	28.33	4603	4570	18	6566	27.43
13	Uplift: -20 F	0.00	0.47	0.47	4610	4586	18	9696	18.57	4201	4177	17	8830	20.39	4412	4387	17	9276	19.41
14	0F	0.00	0.47	0.47	4364	4340	17	9175	19.62	3971	3947	16	8344	21.58	4163	4139	16	8750	20.58
15	32F	0.00	0.47	0.47	4007	3982	16	8419	21.39	3646	3621	14	7655	23.53	3809	3784	15	7999	22.51
16	60F	0.00	0.47	0.47	3732	3706	15	7836	22.98	3402	3376	13	7137	25.23	3543	3517	14	7436	24.22
17	90F	0.00	0.47	0.47	3474	3448	14	7289	24.71	3178	3151	13	6661	27.04	3300	3273	13	6920	26.03
18	120F	0.00	0.47	0.47	3249	3222	13	6812	26.44	2984	2956	12	6250	28.82	3089	3061	12	6472	27.83
19	MOT-normal:160F (71C)	0.00	0.47	0.47	2992	2965	12	6268	28.74	2764	2736	11	5784	31.15	2852	2824	11	5970	30.18
20	MOT-emergency: 177F (81C)	0.00	0.47	0.47	2897	2869	11	6065	29.70	2683	2654	11	5610	32.11	2763	2735	11	5782	31.16
21	MOT-normal:235F (113C)-MRC	0.00	0.47	0.47	2618	2589	10	5474	32.91	2445	2414	10	5105	35.30	2508	2478	10	5240	34.39
22	MOT-emergency: 289F (143C)-MRC	0.00	0.47	0.47	2412	2381	10	5034	35.80	2268	2237	9	4729	38.12	2319	2288	9	4837	37.26

OPGW Sag at 32 F, 0.5" Ice, No Wind, Final After Creep / Cond Sag at 32 F, No Ice, No Wind, Final After Creep=31.83' / 37.42' * 100=85.06% < 95%, OK

OPGW Sag at 60 F, No Ice, No Wind, Final After Creep / Cond Sag at 60 F, No Ice, No Wind, Final After Creep=25.23' / 39.42' * 100=64.0% < 85%, OK

OPGW Sag at 60 F, No Ice, No Wind, Final After Load / Cond Sag at 60 F, No Ice, No Wind, Final After Load=24.22' / 34.97' * 100=69.3% < 85%, OK

PLS-CADD Version 12.50x64   12:59:23 PM Thursday, April 10, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

Appendix F- Ampacity Calculations

By: CIM 04/10/2014
Checked: ANR 04/10/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

IEEE Std. 738-2006 method of calculation

EMERGENCY REGIME-SUMMER: 3 BUNDLE-ACSR BLUEBIRD:
P rectifier=5184 MW; P pole=2592 MW; V=600 KV; I pole=4320 A; I cond=1440 A (3 bundle)
Emergency Regime is 20% over Normal Regime

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 2156 kcmil 84/19 Strands BLUEBIRD ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.762 (in)
Conductor dc resistance is 0.0423 (Ohm/mile) at 68.0 (deg F)
and 0.0499 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 7.512 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 7.267 (Watt/ft)
Convective cooling is 20.126 (Watt/ft)

Given a constant dc current of 1440.0 amperes,
The conductor temperature is 176.5 (deg F)

PLS-CADD Version 12.50x64   3:06:19 PM Thursday, April 10, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/10/2014
Checked: ANR 04/10/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

EMERGENCY REGIME-SUMMER: 3 BUNDLE-ACSR BOBOLINK:
P rectifier=5184 MW; P pole=2592 MW; V=600 KV; I pole=4320 A; I cond=1440 A (3 bundle)
Emergency Regime is 20% over Normal Regime

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 1431 kcmil 45/7 Strands BOBOLINK ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.427 (in)
Conductor dc resistance is 0.0635 (Ohm/mile) at 68.0 (deg F)
and 0.0765 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 6.083 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 10.322 (Watt/ft)
Convective cooling is 28.443 (Watt/ft)

Given a constant dc current of 1440.0 amperes,
The conductor temperature is 218.2 (deg F)

Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/10/2014
Checked: ANR 04/10/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

EMERGENCY REGIME-SUMMER: 3 BUNDLE-ACSR CHUKAR:
P rectifier=5184 MW; P pole=2592 MW; V=600 KV; I pole=4320 A; I cond=1440 A (3 bundle)
Emergency Regime is 20% over Normal Regime

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 1780 kcmil 84/19 Strands CHUKAR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.602 (in)
Conductor dc resistance is 0.0512 (Ohm/mile) at 68.0 (deg F)
and 0.0609 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 6.830 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 8.383 (Watt/ft)
Convective cooling is 23.340 (Watt/ft)

Given a constant dc current of 1440.0 amperes,
The conductor temperature is 192.3 (deg F)

PLS-CADD Version 12.50x64   2:01:28 PM Thursday, April 10, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/10/2014
Checked: ANR 04/10/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

EMERGENCY REGIME-SUMMER: 3 BUNDLE-ACSR/TW FALCON:
P rectifier=5184 MW; P pole=2592 MW; V=600 KV; I pole=4320 A; I cond=1440 A (3 bundle)
Emergency Regime is 20% over Normal Regime

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 1590 kcmil Type 13 FALCON-TW ACSR TW - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.402 (in)
Conductor dc resistance is 0.0569 (Ohm/mile) at 68.0 (deg F)
and 0.0682 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 5.977 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 8.971 (Watt/ft)
Convective cooling is 25.616 (Watt/ft)

Given a constant dc current of 1440.0 amperes,
The conductor temperature is 207.7 (deg F)

PLS-CADD Version 12.50x64   3:24:38 PM Thursday, April 10, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/10/2014
Checked: ANR 04/10/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

EMERGENCY REGIME-SUMMER: 4 BUNDLE-ACSR BLUEBIRD:
P rectifier=5184 MW; P pole=2592 MW; V=600 KV; I pole=4320 A; I cond=1080 A (4 bundle)
Emergency Regime is 20% over Normal Regime

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 1431 kcmil 45/7 Strands BOBOLINK ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.427 (in)
Conductor dc resistance is 0.0635 (Ohm/mile) at 68.0 (deg F)
and 0.0765 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 6.083 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 5.673 (Watt/ft)
Convective cooling is 17.521 (Watt/ft)

Given a constant dc current of 1080.0 amperes,
The conductor temperature is 174.3 (deg F)

PLS-CADD Version 12.50x64 3:47:37 PM Thursday, April 10, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/10/2014
Checked: ANR 04/10/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

EMERGENCY REGIME-SUMMER: 4 BUNDLE-ACSR CONDOR:
P rectifier=5184 MW; P pole=2592 MW; V=600 KV; I pole=4320 A; I cond=1080 A (4 bundle)
Emergency Regime is 20% over Normal Regime

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 795 kcmil 54/7 Strands CONDOR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.093 (in)
Conductor dc resistance is 0.1134 (Ohm/mile) at 68.0 (deg F)
and 0.1417 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 4.660 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 10.364 (Watt/ft)
Convective cooling is 30.470 (Watt/ft)

Given a constant dc current of 1080.0 amperes,
The conductor temperature is 244.2 (deg F)

PLS-CADD Version 12.50x64   8:26:01 AM Friday, April 11, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/11/2014
Checked: ANR 04/11/2014

Criteria Notes:

CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

EMERGENCY REGIME-SUMMER: 4 BUNDLE-ACSR/TW CARDINAL:
P rectifier=5184 MW; P pole=2592 MW; V=600 KV; I pole=4320 A; I cond=1080 A (4 bundle)
Emergency Regime is 20% over Normal Regime

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 954 kcmil Type 13 CARDINAL-TW ACSR TW - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.084 (in)
Conductor dc resistance is 0.0942 (Ohm/mile) at 68.0 (deg F)
and 0.1140 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 4.621 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 7.669 (Watt/ft)
Convective cooling is 24.311 (Watt/ft)

Given a constant dc current of 1080.0 amperes,
The conductor temperature is 216.3 (deg F)

Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/11/2014
Checked: ANR 04/11/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

EMERGENCY REGIME-SUMMER: 4 BUNDLE-ACSS DRAKE:
P rectifier=5184 MW; P pole=2592 MW; V=600 KV; I pole=4320 A; I cond=1080 A (4 bundle)
Emergency Regime is 20% over Normal Regime

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 795 kcmil 26/7 Strands DRAKE ACSS - Data Provided by Southwire
Conductor diameter is 1.108 (in)
Conductor dc resistance is 0.1097 (Ohm/mile) at 68.0 (deg F)
and 0.1335 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 4.724 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 9.430 (Watt/ft)
Convective cooling is 28.308 (Watt/ft)

Given a constant dc current of 1080.0 amperes,
The conductor temperature is 233.3 (deg F)

Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/10/2014
Checked: ANR 04/10/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

NORMAL REGIME-SUMMER: 3 BUNDLE-ACSR BLUEBIRD:
P rectifier=4320 MW; P pole=2160 MW; V=600 KV; I pole=3600 A; I cond=1200 A (3 bundle)

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 2156 kcmil 84/19 Strands BLUEBIRD ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.762 (in)
Conductor dc resistance is   0.0423 (Ohm/mile) at 68.0 (deg F)
and   0.0499 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   7.512 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is   5.391 (Watt/ft)
Convective cooling is   15.589 (Watt/ft)

Given a constant dc current of 1200.0 amperes,
The conductor temperature is 160.1 (deg F)

PLS-CADD Version 12.50x64   2:47:00 PM Thursday, April 10, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

By: CIM 04/10/2014
Checked: ANR 04/10/2014

NORMAL REGIME-SUMMER: 3 BUNDLE-ACSR BOBOLINK:
P rectifier=4320 MW; P pole=2160 MW; V=600 KV; I pole=3600 A; I cond=1200 A (3 bundle)

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 1431 kcmil 45/7 Strands BOBOLINK ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.427 (in)
Conductor dc resistance is 0.0635 (Ohm/mile) at 68.0 (deg F)
and 0.0765 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 6.083 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 6.941 (Watt/ft)
Convective cooling is 20.728 (Watt/ft)

Given a constant dc current of 1200.0 amperes,
The conductor temperature is 187.2 (deg F)

PLS-CADD Version 12.50x64   2:27:58 PM Thursday, April 10, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/10/2014
Checked: ANR 04/10/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

IEEE Std. 738-2006 method of calculation

NORMAL REGIME-SUMMER: 3 BUNDLE-ACSR CHUKAR:
P rectifier=4320 MW; P pole=2160 MW; V=600 KV; I pole=3600 A; I cond=1200 A (3 bundle)

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 1780 kcmil 84/19 Strands CHUKAR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.602 (in)
Conductor dc resistance is 0.0512 (Ohm/mile) at 68.0 (deg F)
and 0.0609 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 6.830 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 5.961 (Watt/ft)
Convective cooling is 17.573 (Watt/ft)

Given a constant dc current of 1200.0 amperes,
The conductor temperature is 170.4 (deg F)

Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/14/2014
Checked: ANR 04/14/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

NORMAL REGIME-SUMMER: 3 BUNDLE-ACSR/TW FALCON:
P rectifier=4320 MW; P pole=2160 MW; V=600 KV; I pole=3600 A; I cond=1200 A (3 bundle)

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 1590 kcmil Type 13 FALCON-TW ACSR TW - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.402 (in)
Conductor dc resistance is 0.0569 (Ohm/mile) at 68.0 (deg F)
and 0.0682 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 5.977 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 6.145 (Watt/ft)
Convective cooling is 18.847 (Watt/ft)

Given a constant dc current of 1200.0 amperes,
The conductor temperature is 180.3 (deg F)

Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/10/2014
Checked: ANR 04/10/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

NORMAL REGIME-SUMMER: 4 BUNDLE-ACSR BOBOLINK:
P rectifier=4320 MW; P pole=2160 MW; V=600 KV; I pole=3600 A; I cond=900 A (4 bundle)

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 1431 kcmil 45/7 Strands BOBOLINK ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.427 (in)
Conductor dc resistance is 0.0635 (Ohm/mile) at 68.0 (deg F)
and 0.0765 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 6.083 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 4.175 (Watt/ft)
Convective cooling is 13.462 (Watt/ft)

Given a constant dc current of 900.0 amperes,
The conductor temperature is 158.0 (deg F)

Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/10/2014
Checked: ANR 04/10/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

NORMAL REGIME-SUMMER: 4 BUNDLE-ACSR CONDOR:
P rectifier=4320 MW; P pole=2160 MW; V=600 KV; I pole=3600 A; I cond=900 A (4 bundle)

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 795 kcmil 54/7 Strands CONDOR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.093 (in)
Conductor dc resistance is   0.1134 (Ohm/mile) at 68.0 (deg F)
and   0.1417 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   4.660 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is   6.542 (Watt/ft)
Convective cooling is   21.405 (Watt/ft)

Given a constant dc current of 900.0 amperes,
The conductor temperature is 202.4 (deg F)

Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/11/2014
Checked: ANR 04/11/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

NORMAL REGIME-SUMMER: 4 BUNDLE-ACSR/TW CARDINAL:
P rectifier=4320 MW; P pole=2160 MW; V=600 KV; I pole=3600 A; I cond=900 A (4 bundle)

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 954 kcmil Type 13 CARDINAL-TW ACSR TW - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.084 (in)
Conductor dc resistance is   0.0942 (Ohm/mile) at 68.0 (deg F)
and   0.1140 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   4.621 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is   5.108 (Watt/ft)
Convective cooling is   17.556 (Watt/ft)

Given a constant dc current of 900.0 amperes,
The conductor temperature is 185.0 (deg F)

PLS-CADD Version 12.50x64   8:37:49 AM Friday, April 11, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/11/2014
Checked: ANR 04/11/2014

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

NORMAL REGIME-SUMMER: 4 BUNDLE-ACSS DRAKE:
P rectifier=4320 MW; P pole=2160 MW; V=600 KV; I pole=3600 A; I cond=900 A (4 bundle)

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 795 kcmil 26/7 Strands DRAKE ACSS - Data Provided by Southwire
Conductor diameter is 1.108 (in)
Conductor dc resistance is 0.1097 (Ohm/mile) at 68.0 (deg F)
and 0.1335 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 4.724 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 6.105 (Watt/ft)
Convective cooling is 20.170 (Watt/ft)

Given a constant dc current of 900.0 amperes,
The conductor temperature is 196.1 (deg F)

By: CIM 05/20/2014
Checked: ANR 05/201/2014

PLS-CADD Version 13.00x64 11:17:47 AM Tuesday, May 20, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

EMERGENCY REGIME-SUMMER: MRC ACSR BLUEBIRD:
P rectifier=5184 MW; P pole=2592 MW; V=600 KV; I pole=4320 A
Emergency regime is 20% over Normal Regime
If one pole is lost, its power will be taken (split) between the 2 MRC:
I mrc=I pole /2=4320/2=2160 A

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (user specified day, may not be day producing maximum solar heating)

Conductor description: 2156 kcmil 84/19 Strands BLUEBIRD ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.762 (in)
Conductor resistance is 0.0423 (Ohm/mile) at 68.0 (deg F)
and 0.0499 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 7.512 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 17.267 (Watt/ft)
Convective cooling is 39.805 (Watt/ft)

Given a constant ac current of 2160.0 amperes,
The conductor temperature is 247.6 (deg F)

By: CIM 04/11/2014
Checked: ANR 04/11/2014

Criteria Notes:

CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

EMERGENCY REGIME-SUMMER: MRC ACSR CHUKAR:
P rectifier=5184 MW; P pole=2592 MW; V=600 KV; I pole=4320 A
Emergency regime is 20% over Normal Regime
If one pole is lost, its power will be taken (split) between the 2 MRC:
I mrc=I pole /2=4320/2=2160 A

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 1780 kcmil 84/19 Strands CHUKAR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.602 (in)
Conductor dc resistance is 0.0512 (Ohm/mile) at 68.0 (deg F)
and 0.0609 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 6.830 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 22.402 (Watt/ft)
Convective cooling is 48.791 (Watt/ft)

Given a constant dc current of 2160.0 amperes,
The conductor temperature is 288.9 (deg F)

By: CIM 04/11/2014
Checked: ANR 04/11/2014

PLS-CADD Version 13.00x64 12:17:42 PM Tuesday, May 20, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

NORMAL REGIME-SUMMER: MRC ACSR BLUEBIRD:
P rectifier=4320 MW; P pole=2160 MW; V=600 KV; I pole=3600 A
If one pole is lost, its power will be taken (split) between the 2 MRC:
I mrc=I pole /2=3600/2=1800 A

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (user specified day, may not be day producing maximum solar heating)

Conductor description: 2156 kcmil 84/19 Strands BLUEBIRD ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.762 (in)
Conductor resistance is 0.0423 (Ohm/mile) at 68.0 (deg F)
and 0.0499 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 7.512 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 11.272 (Watt/ft)
Convective cooling is 28.777 (Watt/ft)

Given a constant ac current of 1800.0 amperes,
The conductor temperature is 207.7 (deg F)

Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

By: CIM 04/11/2014
Checked: ANR 04/11/2014

NORMAL REGIME-SUMMER: MRC ACSR CHUKAR:
P rectifier=4320 MW; P pole=2160 MW; V=600 KV; I pole=3600 A
If one pole is lost, its power will be taken (split) between the 2 MRC:
I mrc=I pole /2=3600/2=1800 A

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (day of the year with most solar heating)

Conductor description: 1780 kcmil 84/19 Strands CHUKAR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.602 (in)
Conductor dc resistance is 0.0512 (Ohm/mile) at 68.0 (deg F)
and 0.0609 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 6.830 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 13.797 (Watt/ft)
Convective cooling is 34.456 (Watt/ft)

Given a constant dc current of 1800.0 amperes,
The conductor temperature is 234.5 (deg F)

PLS-CADD Version 13.00x64   10:00:17 AM Tuesday, June 03, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

USED FOR MISSISSIPPI RIVER CROSSING SPAN=4000 FT

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

EMERGENCY REGIME-SUMMER: 3 BUNDLE-ACCR/TW PECOS:
P rectifier=5184 MW; P pole=2592 MW; V=600 KV; I pole=4320 A; I cond=1440 A (3 bundle)
Emergency Regime is 20% over Normal Regime

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (user specified day, may not be day producing maximum solar heating)

Conductor description: ACCR-TW_1622-T13 PECOS
Conductor diameter is 1.417 (in)
Conductor resistance is   0.0547 (Ohm/mile) at 68.0 (deg F)
                   and   0.0666 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

By: CIM 06/03/2014
Checked: ANR 06/03/2014

Solar heat input is   6.041 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is   8.818 (Watt/ft)
Convective cooling is   25.196 (Watt/ft)

Given a constant ac current of 1440.0 amperes,
The conductor temperature is 205.5 (deg F)

PLS-CADD Version 13.00x64   10:08:41 AM Tuesday, June 03, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

USED FOR MISSISSIPPI RIVER CROSSING SPAN=4000 FT

IEEE Std. 738-2006 method of calculation

NORMAL REGIME-SUMMER: 3 BUNDLE-ACCR/TW PECOS:
P rectifier=4320 MW; P pole=2160 MW; V=600 KV; I pole=3600 A; I cond=1200 A (3 bundle)

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (user specified day, may not be day producing maximum solar heating)

Conductor description: ACCR-TW_1622-T13 PECOS
Conductor diameter is 1.417 (in)
Conductor resistance is 0.0547 (Ohm/mile) at 68.0 (deg F)
and 0.0666 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

By: CIM 06/03/2014
Checked: ANR 06/03/2014

Solar heat input is 6.041 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is 6.049 (Watt/ft)
Convective cooling is 18.536 (Watt/ft)

Given a constant ac current of 1200.0 amperes,
The conductor temperature is 178.6 (deg F)

PLS-CADD Version 13.00x64   10:45:33 AM Tuesday, June 03, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

USED AS MRC FOR MISSISSIPPI RIVER CROSSING SPAN=4000 FT

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

EMERGENCY REGIME-SUMMER: MRC ACCR/TW PECOS:
P rectifier=5184 MW; P pole=2592 MW; V=600 KV; I pole=4320 A
Emergency regime is 20% over Normal Regime
If one pole is lost, its power will be taken (split) between the 2 MRC:
I mrc=I pole /2=4320/2=2160 A

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (user specified day, may not be day producing maximum solar heating)

Conductor description: ACCR-TW_1622-T13 PECOS
Conductor diameter is 1.417 (in)
Conductor resistance is   0.0547 (Ohm/mile) at 68.0 (deg F)
                    and   0.0666 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

By: CIM 06/3/2014
Checked: ANR 06/3/2014

Solar heat input is   6.041 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is   26.450 (Watt/ft)
Convective cooling is   55.560 (Watt/ft)

Given a constant ac current of 2160.0 amperes,
The conductor temperature is 328.2 (deg F)

PLS-CADD Version 13.00x64   10:37:07 AM Tuesday, June 03, 2014
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\132836 - plains & eastern ph1\132836\clean line_plains & eastern 600kv dc_segment 1.DON'
Line Title: 'Tubular Steel Poles (Design Span = 1200 ft)'

USED AS MRC FOR MISSISSIPPI RIVER CROSSING SPAN=4000 FT

Criteria Notes:
CLEAN LINE ENERGY:
PLAINS & EASTERN +/-600kV HVDC CONCEPTUAL ESTIMATE

NORMAL REGIME-SUMMER: MRC ACCR/TW PECOS:
P rectifier=4320 MW; P pole=2160 MW; V=600 KV; I pole=3600 A
If one pole is lost, its power will be taken (split) between the 2 MRC:
I mrc=I pole /2=3600/2=1800 A

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 3000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2014) (user specified day, may not be day producing maximum solar heating)

Conductor description: ACCR-TW_1622-T13 PECOS
Conductor diameter is 1.417 (in)
Conductor resistance is   0.0547 (Ohm/mile) at 68.0 (deg F)
                    and   0.0666 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

By: CIM 06/3/2014
Checked: ANR 06/3/2014

Solar heat input is   6.041 (Watt/ft) (corresponds to Global Solar Radiation of 102.315 (Watt/ft^2) - which was calculated)
Radiation cooling is   15.349 (Watt/ft)
Convective cooling is   38.309 (Watt/ft)

Given a constant ac current of 1800.0 amperes,
The conductor temperature is 258.5 (deg F)

Note: Appendix G is using Power & Ampacity from conceptual design Rev.D, however the conclusions are still valid for the updated performance requirements.

POWER ENGINEERS

Appendix G

Clean Line Energy-Plains & Eastern +/- 600 kV HVDC Line

Mississippi River Crossing Span=4000 Ft; Ruling Span=3254 ft

Conductors Comparison and Selection

Conductor Type	**Normal Regime** I pole=3100 A; I conductor=I pole/3=1033.3 A	**Emergency Regime (20% over Normal regime)** I pole=3720 A; I conductor=I pole/3=1240 A
ACSS/TW CUMBERLAND $4.06/ft	MOT=152 F (67 C): Final Sag @ MOT: 441.82' 0 F- Final Controls @ 25%RBS	MOT=166 (74 C): Final Sag @ MOT: 442.91' 0 F- Final Controls @ 25%RBS
ACCR FALCON $29.04/ft	MOT=159 F (71 C): Final Sag @ MOT: 320.33' NESC Rule 250D-Initial Controls @ 75%RBS	MOT=177 F (81 C): Final Sag @ MOT: 321.97' NESC Rule 250D-Initial Controls @ 75%RBS
ACCR/TW CUMBERLAND **$34.5/ft**	MOT=152 F (67 C): Final Sag @ MOT: 295.71' 0 F- Final Controls @ 25%RBS	MOT=166 F (74 C): **Final Sag @ MOT: 297.75'** **Lowest (Tightest) Sag** 0 F- Final Controls @ 25%RBS
ACCR/TW PECOS **$24.16/ft** **(selected)**	MOT=160 F (71 C): Final Sag @ MOT: 297.07' NESC Rule 250D- Initial Controls @ 75%RBS	MOT=178 F (81 C): **Final Sag @ MOT: 299.71'** **Sags only 2' more than Cumberland, but is $10/ft less expensive, result in $ 0.5 million savings.** NESC Rule 250D- initial Controls @ 75%RBS

River Crossing Tower Designation:

SST-2VRCHS= Self-Supporting Tower 0^0-2^0 V-String-River Crossing Heavy Suspension

River Crossing Tower Height (using ACCR/TW Cumberland):

H=Water Clearance+ Final Sag@ MOT+Vertical Clearance Conductor-OPGW-Foundation Height=55'+297.75'+38.53'-1 =390.28' (exact); H=390' (rounded)

PLS-CADD structure name: sst_2vrchs.315.60.15_390; Common Portion=315'; Body Extension=60'; Leg Extension=15'; Height=390'.

River Crossing Tower Height (using ACCR/TW Pecos):

H=Water Clearance+ Final Sag@ MOT+Vertical Clearance Conductor-OPGW-Foundation Height=55'+299.71'+38.53'-1 =392.24' (exact); H=392' (rounded)

PLS-CADD structure name: sst_2vrchs.317.60.15_392; Common Portion=317'; Body Extension=60'; Leg Extension=15'; Height=392'.

Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\clean line_plains & eastern 600kv dc_segment 7.DON'

Criteria notes:
Clean Line Preliminary Cost Comparison

Stringing Chart Report

Section #88 from structure #322 to structure #325, start set #12 'COND-R,Ahead', end set #11 'COND-L,Ahead'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\cumberland_accr_tw_dc.wir', Ruling span (ft) 3253.8
Sagging data: Catenary (ft) 7320.9, Horiz. Tension (lbs) 15410.5 Condition I Temperature (deg F) 60
Results below for condition 'Creep RS'
Calculations done using actual span lengths and vertical projections

Span Length (ft)	Mid Span Sag 152 F (ft)	Mid Span Sag 166 F (ft)	Left Struct Number	Span Vertical Projection (ft)
1230.4	28.16	28.35	322	202.80
3999.3	295.71	297.75	323	160.30
2604.4	125.52	126.38	324	-283.70

Span Length (ft)	3 Wave Time 152 F Sec.	3 Wave Time 166 F Sec.	Left Struct Number	Span Vertical Projection (ft)
1230.4	15.9	15.9	322	202.80
3999.3	51.4	51.6	323	160.30
2604.4	33.5	33.6	324	-283.70

Horiz Tension 152 F (lbs)	Horiz Tension 166 F (lbs)
14345	14248

Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\clean line_plains & eastern 600kv dc_segment 7.DON'

Criteria notes:
Clean Line Preliminary Cost Comparison

Stringing Chart Report

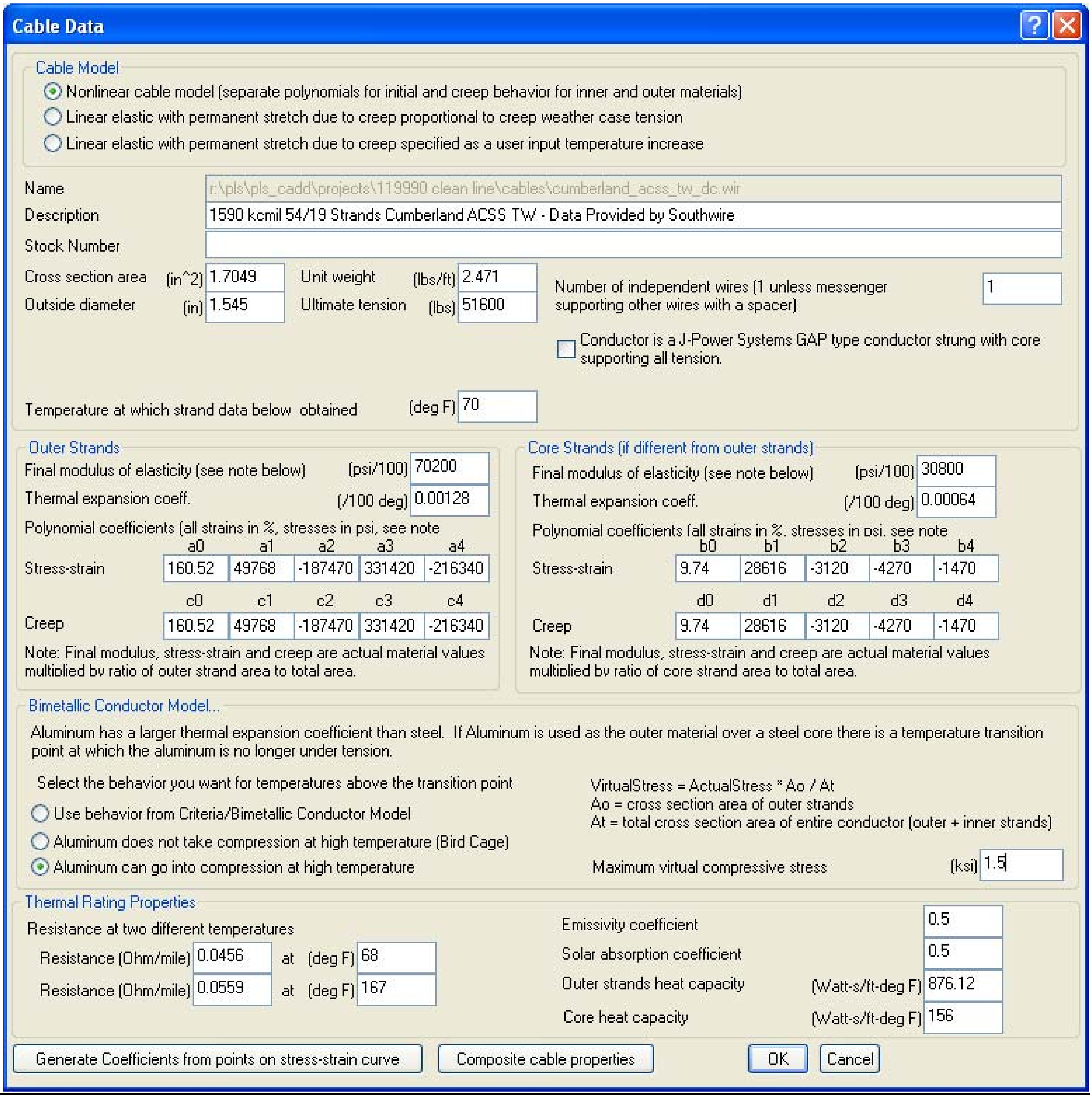
Section #88 from structure #322 to structure #325, start set #12 'COND-R,Ahead', end set #11 'COND-L,Ahead'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\mississippi river crossing-conductor selection\pecos_accr_tw_dc.wir',
Ruling span (ft) 3253.8
Sagging data: Catenary (ft) 7312.4, Horiz. Tension (lbs) 12972.2 Condition I Temperature (deg F) 60
Results below for condition 'Creep RS'
Calculations done using actual span lengths and vertical projections

Span Length (ft)	Mid Span Sag 160 F (ft)	Mid Span Sag 178 F (ft)	Left Struct Number	Span Vertical Projection (ft)
1230.4	28.29	28.54	322	202.80
3999.3	297.07	299.71	323	160.30
2604.4	126.10	127.21	324	-283.70

Span Length (ft)	3 Wave Time 160 F Sec.	3 Wave Time 178 F Sec.	Left Struct Number	Span Vertical Projection (ft)
1230.4	15.9	16.0	322	202.80
3999.3	51.5	51.8	323	160.30
2604.4	33.6	33.7	324	-283.70

Horiz Tension 160 F (lbs)	Horiz Tension 178 F (lbs)
12035	11930

ACSS/TW Cumberland-with DC Resistances:



Cable Data

Cable Model
- (●) Nonlinear cable model (separate polynomials for initial and creep behavior for inner and outer materials)
- ( ) Linear elastic with permanent stretch due to creep proportional to creep weather case tension
- ( ) Linear elastic with permanent stretch due to creep specified as a user input temperature increase

Name: r:\pls\pls_cadd\projects\119990 clean line\cables\cumberland_acss_tw_dc.wir
Description: 1590 kcmil 54/19 Strands Cumberland ACSS TW - Data Provided by Southwire
Stock Number:

Cross section area (in^2) 1.7049 | Unit weight (lbs/ft) 2.471
Outside diameter (in) 1.545 | Ultimate tension (lbs) 51600

Number of independent wires (1 unless messenger supporting other wires with a spacer) 1

[ ] Conductor is a J-Power Systems GAP type conductor strung with core supporting all tension.

Temperature at which strand data below obtained (deg F) 70

Outer Strands
Final modulus of elasticity (see note below) (psi/100) 70200
Thermal expansion coeff. (/100 deg) 0.00128
Polynomial coefficients (all strains in %, stresses in psi, see note

	a0	a1	a2	a3	a4
Stress-strain	160.52	49768	-187470	331420	-216340

	c0	c1	c2	c3	c4
Creep	160.52	49768	-187470	331420	-216340

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of outer strand area to total area.

Core Strands (if different from outer strands)
Final modulus of elasticity (see note below) (psi/100) 30800
Thermal expansion coeff. (/100 deg) 0.00064
Polynomial coefficients (all strains in %, stresses in psi, see note

	b0	b1	b2	b3	b4
Stress-strain	9.74	28616	-3120	-4270	-1470

	d0	d1	d2	d3	d4
Creep	9.74	28616	-3120	-4270	-1470

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of core strand area to total area.

Bimetallic Conductor Model...
Aluminum has a larger thermal expansion coefficient than steel. If Aluminum is used as the outer material over a steel core there is a temperature transition point at which the aluminum is no longer under tension.

Select the behavior you want for temperatures above the transition point
- ( ) Use behavior from Criteria/Bimetallic Conductor Model
- ( ) Aluminum does not take compression at high temperature (Bird Cage)
- (●) Aluminum can go into compression at high temperature

VirtualStress = ActualStress * Ao / At
Ao = cross section area of outer strands
At = total cross section area of entire conductor (outer + inner strands)

Maximum virtual compressive stress (ksi) 1.5

Thermal Rating Properties
Resistance at two different temperatures
Resistance (Ohm/mile) 0.0456 at (deg F) 68
Resistance (Ohm/mile) 0.0559 at (deg F) 167

Emissivity coefficient 0.5
Solar absorption coefficient 0.5
Outer strands heat capacity (Watt-s/ft-deg F) 876.12
Core heat capacity (Watt-s/ft-deg F) 156

[Generate Coefficients from points on stress-strain curve] [Composite cable properties] [OK] [Cancel]

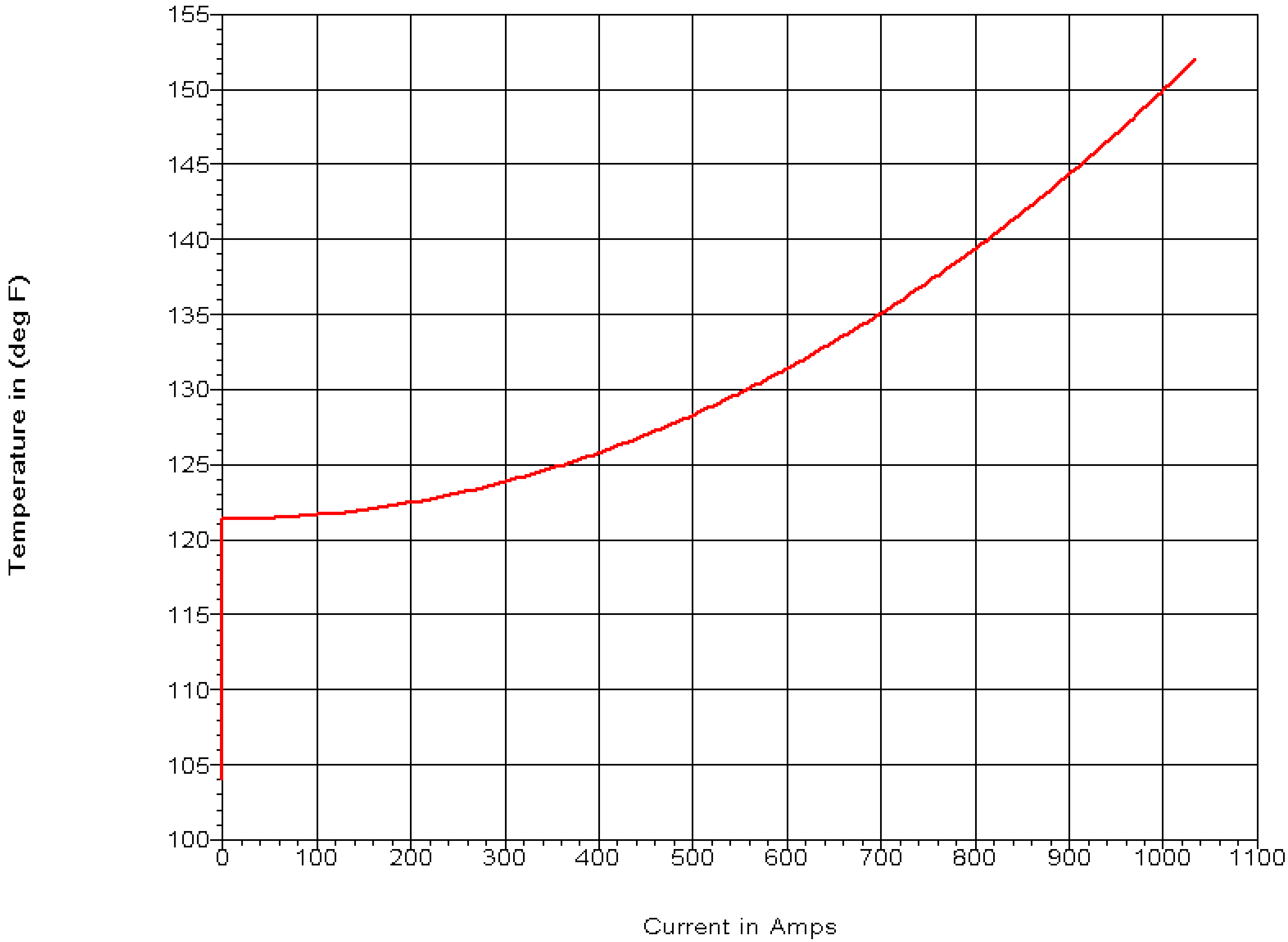
IEEE Std. 738-2006 method of calculation
Normal Regime: I pole=3100 A; I conductor=I pole/3=1033.3 A

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 300 (ft)-at Mississippi River Crossing Span=4000 ft.
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2010) (day of the year with most solar heating)

Conductor description: 1590 kcmil 54/19 Strands Cumberland ACSS TW - Data Provided by Southwire
Conductor diameter is 1.545 (in)
Conductor resistance is   0.0456 (Ohm/mile) at 68.0 (deg F)
                    and   0.0559 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   6.074 (Watt/ft) (corresponds to Global Solar Radiation of   94.350 (Watt/ft^2) - which was calculated)
Radiation cooling is   3.954 (Watt/ft)
Convective cooling is   13.103 (Watt/ft)

Given a constant dc current of 1033.3 amperes,
The conductor temperature is 152.0 (deg F)=67 (deg C)


Temperature in (deg F)
155
150
145
140
135
130
125
120
115
110
105
100
0
100
200
300
400
500
600
700
800
900
1000
1100
Current in Amps

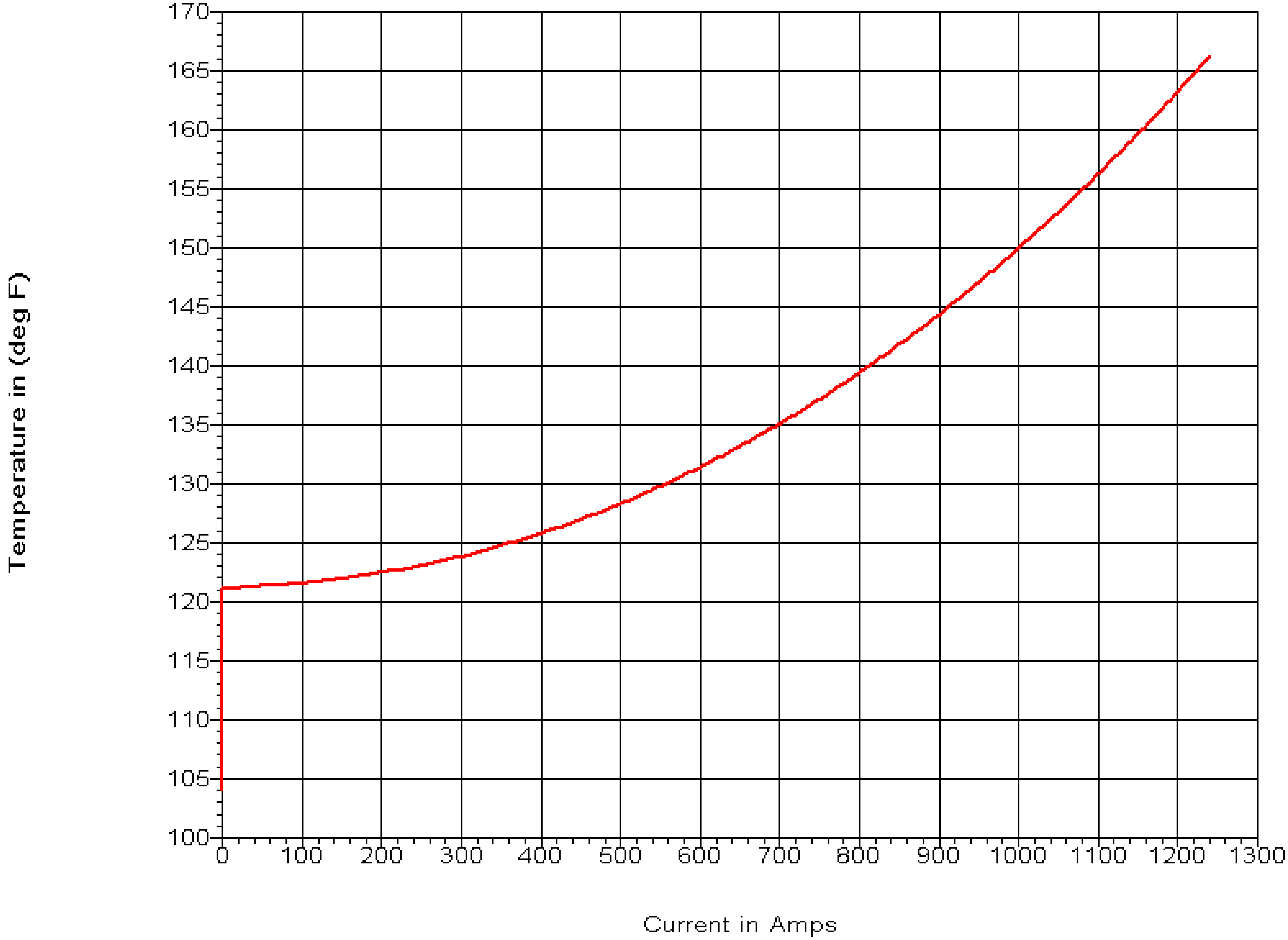
IEEE Std. 738-2006 method of calculation
EMERGENCY REGIME: I pole=3720 A; I conductor=I pole/3=1240 A
(20% over normal regime: I pole=3100 A; I conductor=I pole/3=1033.3 A)

Air temperature is 104.00 (deg F)=40 (deg C)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 300 (ft)-at Mississippi River Crossing Span=4000 ft.
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2010) (day of the year with most solar heating)

Conductor description: 1590 kcmil 54/19 Strands Cumberland ACSS TW - Data Provided by Southwire
Conductor diameter is 1.545 (in)
Conductor resistance is   0.0456 (Ohm/mile) at 68.0 (deg F)
                    and   0.0559 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   6.074 (Watt/ft) (corresponds to Global Solar Radiation of   94.350 (Watt/ft^2) - which was calculated)
Radiation cooling is   5.329 (Watt/ft)
Convective cooling is   17.004 (Watt/ft)

Given a constant dc current of 1240.0 amperes,
The conductor temperature is 166.3 (deg F)=74 (deg C)


Temperature in (deg F)
170
165
160
155
150
145
140
135
130
125
120
115
110
105
100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Current in Amps

ACCR/TW Pecos-with DC Resistances:

Cable Data

Cable Model

- (•) Nonlinear cable model (separate polynomials for initial and creep behavior for inner and outer materials)
- ( ) Linear elastic with permanent stretch due to creep proportional to creep weather case tension
- ( ) Linear elastic with permanent stretch due to creep specified as a user input temperature increase

Name: r:\pls\pls_cadd\projects\119990 clean line\cables\mississippi river crossing-conductor selection\pecos_acss_tw_dc.wir

Description: ACCR-TW_1622-T13 PECOS

Stock Number:

Cross section area (in^2) 1.437 | Unit weight (lbs/ft) 1.774

Outside diameter (in) 1.417 | Ultimate tension (lbs) 55500

Number of independent wires (1 unless messenger supporting other wires with a spacer) 1

[ ] Conductor is a J-Power Systems GAP type conductor strung with core supporting all tension.

Temperature at which strand data below obtained (deg F) 71

Outer Strands

Final modulus of elasticity (see note below) (psi/100) 73166

Thermal expansion coeff. (/100 deg) 0.00128

Polynomial coefficients (all strains in %, stresses in psi, see note

	a0	a1	a2	a3	a4
Stress-strain		47982	-26959	-10541	5466
	c0	c1	c2	c3	c4
Creep		22891	-16083	4103	-2138

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of outer strand area to total area.

Core Strands (if different from outer strands)

Final modulus of elasticity (see note below) (psi/100) 40134

Thermal expansion coeff. (/100 deg) 0.00035

Polynomial coefficients (all strains in %, stresses in psi, see note

	b0	b1	b2	b3	b4
Stress-strain		42224	-8710	-4138	2156
	d0	d1	d2	d3	d4
Creep		42224	-8710	-4138	2156

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of core strand area to total area.

Bimetallic Conductor Model...

Aluminum has a larger thermal expansion coefficient than steel. If Aluminum is used as the outer material over a steel core there is a temperature transition point at which the aluminum is no longer under tension.

Select the behavior you want for temperatures above the transition point

- ( ) Use behavior from Criteria/Bimetallic Conductor Model
- ( ) Aluminum does not take compression at high temperature (Bird Cage)
- (•) Aluminum can go into compression at high temperature

VirtualStress = ActualStress * Ao / At
Ao = cross section area of outer strands
At = total cross section area of entire conductor (outer + inner strands)

Maximum virtual compressive stress (ksi) 1.25

Thermal Rating Properties

Resistance at two different temperatures

Resistance (Ohm/mile) 0.0547 at (deg F) 68

Resistance (Ohm/mile) 0.0666 at (deg F) 167

Emissivity coefficient 0.5

Solar absorption coefficient 0.5

Outer strands heat capacity (Watt-s/ft-deg F) 367.7

Core heat capacity (Watt-s/ft-deg F) 20.1

[Generate Coefficients from points on stress-strain curve] [Composite cable properties] [OK] [Cancel]

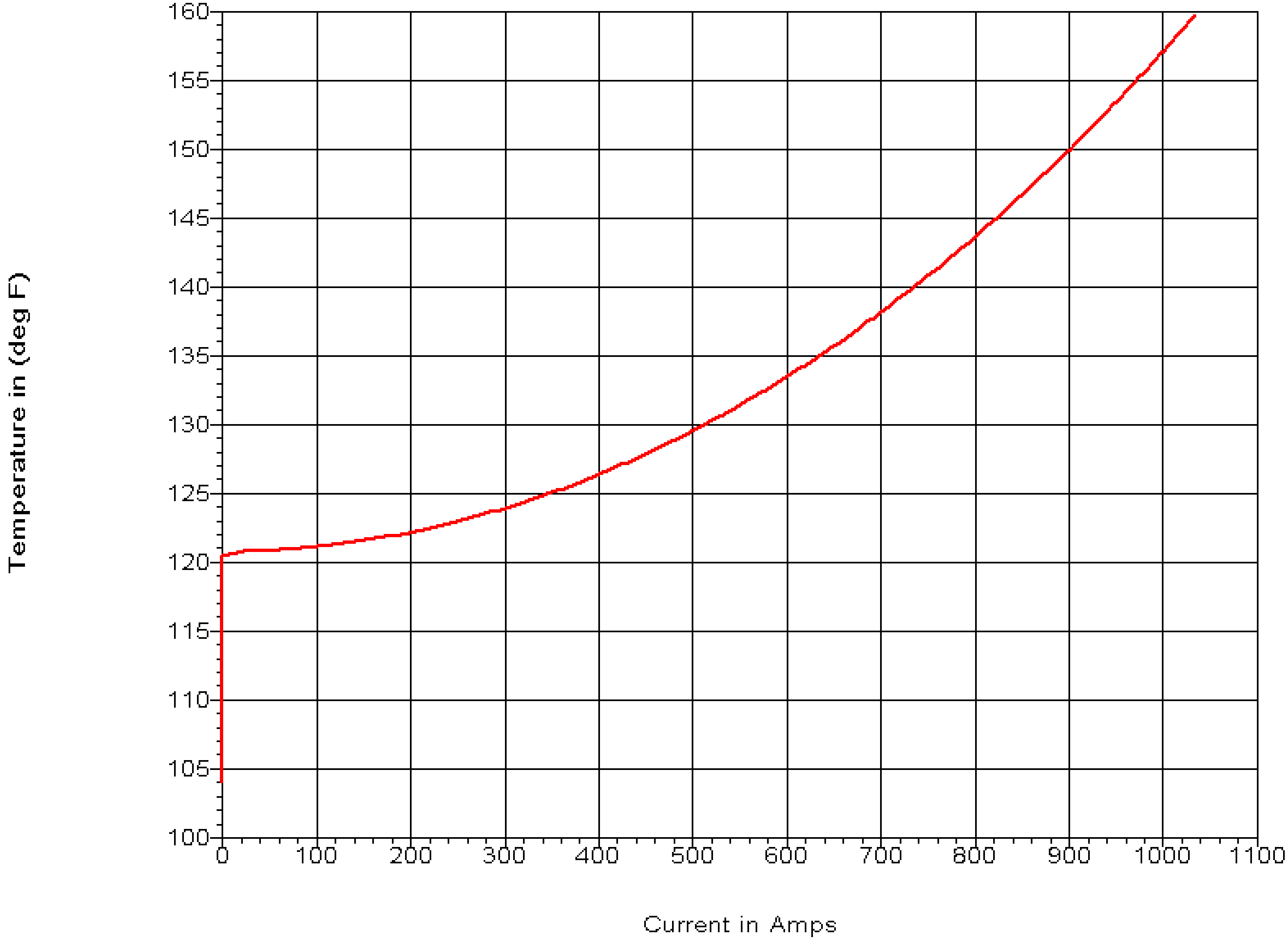
IEEE Std. 738-2006 method of calculation
NORMAL REGIME: I pole=3100 A; I conductor=I pole/3=1033.3 A

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 300 (ft)-at Mississippi River Crossing Span=4000 ft
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2010) (day of the year with most solar heating)

Conductor description: ACCR-TW_1622-T13 PECOS
Conductor diameter is 1.417 (in)
Conductor resistance is 0.0547 (Ohm/mile) at 68.0 (deg F)
and 0.0666 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 5.571 (Watt/ft) (corresponds to Global Solar Radiation of 94.350 (Watt/ft^2) - which was calculated)
Radiation cooling is 4.300 (Watt/ft)
Convective cooling is 14.563 (Watt/ft)

Given a constant dc current of 1033.3 amperes,
The conductor temperature is 159.7 (deg F)=71 (deg C)



160
155
150
145
140
135
130
125
120
115
110
105
100
Temperature in (deg F)
0
100
200
300
400
500
600
700
800
900
1000
1100
Current in Amps

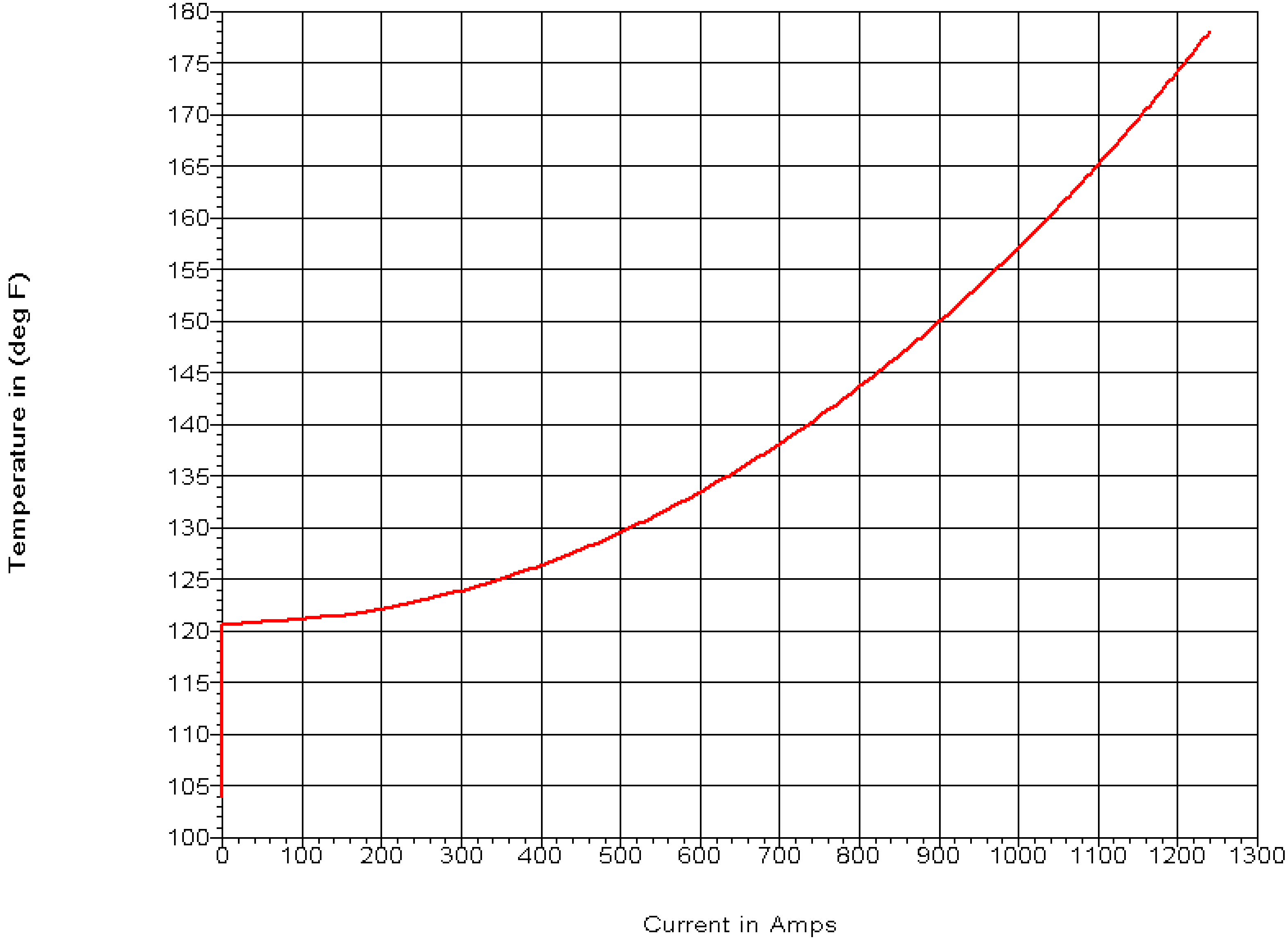
IEEE Std. 738-2006 method of calculation
EMERGENCY REGIME=: I pole=3720 A; I conductor=I pole/3=1240 A
(20% over Normal regime: I pole=3100 A; I conductor=I pole/3=1033.3 A)

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 300 (ft)-At Mississippi River Crossing Span=4000 ft.
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2010) (day of the year with most solar heating)

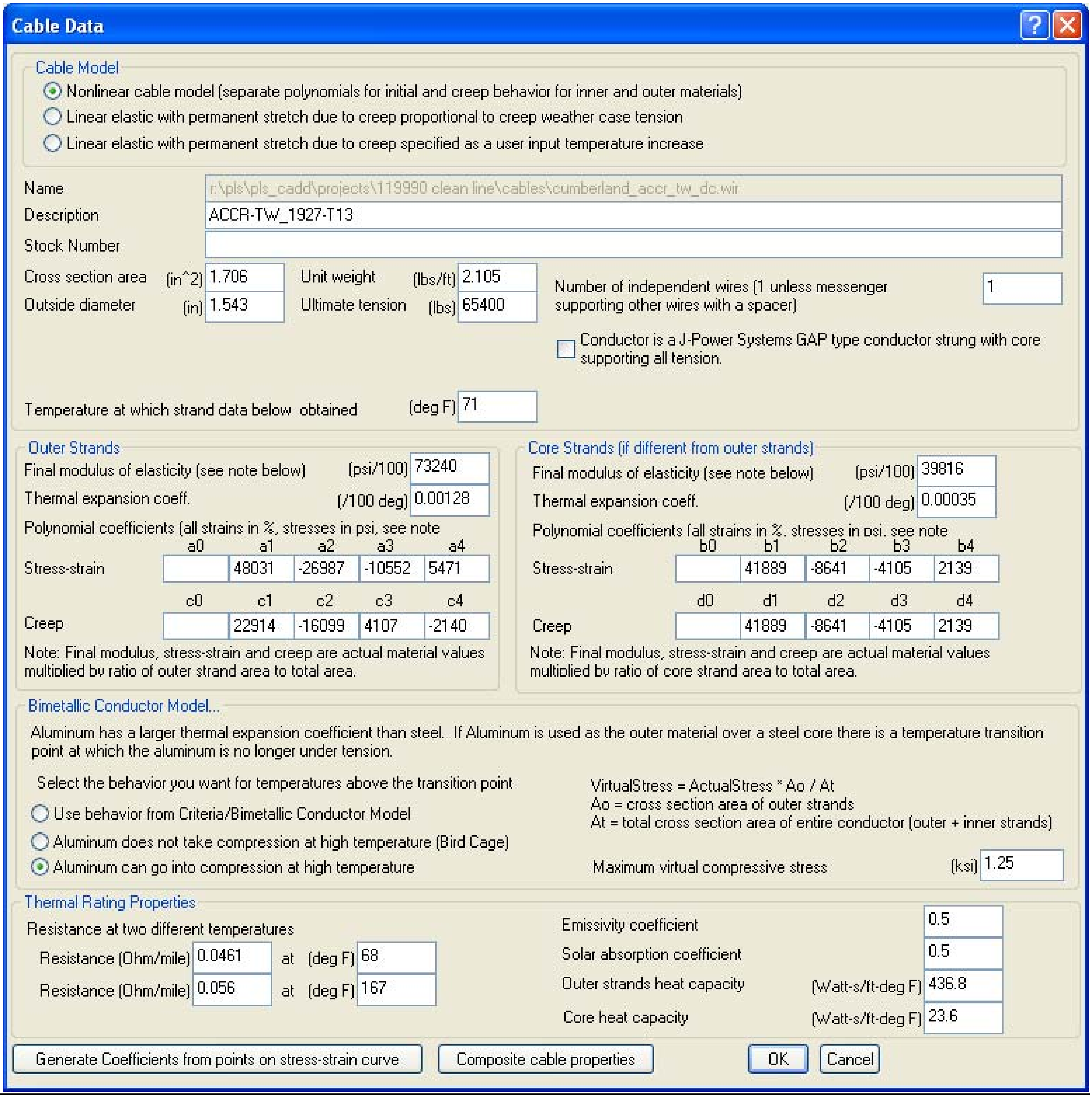
Conductor description: ACCR-TW_1622-T13 PECOS
Conductor diameter is 1.417 (in)
Conductor resistance is   0.0547 (Ohm/mile) at 68.0 (deg F)
                    and   0.0666 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   5.571 (Watt/ft) (corresponds to Global Solar Radiation of   94.350 (Watt/ft^2) - which was calculated)
Radiation cooling is   5.998 (Watt/ft)
Convective cooling is   19.356 (Watt/ft)

Given a constant dc current of 1240.0 amperes,
The conductor temperature is 178.1 (deg F)


Temperature in (deg F)
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
105
100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Current in Amps

ACCR/TW Cumberland- with DC Resistances:



Cable Data

Cable Model

- (•) Nonlinear cable model (separate polynomials for initial and creep behavior for inner and outer materials)
- ( ) Linear elastic with permanent stretch due to creep proportional to creep weather case tension
- ( ) Linear elastic with permanent stretch due to creep specified as a user input temperature increase

Name: r:\pls\pls_cadd\projects\119990 clean line\cables\cumberland_accr_tw_dc.wir

Description: ACCR-TW_1927-T13

Stock Number:

Cross section area (in^2) 1.706 | Unit weight (lbs/ft) 2.105

Outside diameter (in) 1.543 | Ultimate tension (lbs) 65400

Number of independent wires (1 unless messenger supporting other wires with a spacer): 1

[ ] Conductor is a J-Power Systems GAP type conductor strung with core supporting all tension.

Temperature at which strand data below obtained (deg F) 71

Outer Strands

Final modulus of elasticity (see note below) (psi/100) 73240

Thermal expansion coeff. (/100 deg) 0.00128

Polynomial coefficients (all strains in %, stresses in psi, see note

	a0	a1	a2	a3	a4
Stress-strain		48031	-26987	-10552	5471

	c0	c1	c2	c3	c4
Creep		22914	-16099	4107	-2140

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of outer strand area to total area.

Core Strands (if different from outer strands)

Final modulus of elasticity (see note below) (psi/100) 39816

Thermal expansion coeff. (/100 deg) 0.00035

Polynomial coefficients (all strains in %, stresses in psi, see note

	b0	b1	b2	b3	b4
Stress-strain		41889	-8641	-4105	2139

	d0	d1	d2	d3	d4
Creep		41889	-8641	-4105	2139

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of core strand area to total area.

Bimetallic Conductor Model...

Aluminum has a larger thermal expansion coefficient than steel. If Aluminum is used as the outer material over a steel core there is a temperature transition point at which the aluminum is no longer under tension.

Select the behavior you want for temperatures above the transition point

- ( ) Use behavior from Criteria/Bimetallic Conductor Model
- ( ) Aluminum does not take compression at high temperature (Bird Cage)
- (•) Aluminum can go into compression at high temperature

VirtualStress = ActualStress * Ao / At
Ao = cross section area of outer strands
At = total cross section area of entire conductor (outer + inner strands)

Maximum virtual compressive stress (ksi) 1.25

Thermal Rating Properties

Resistance at two different temperatures

Resistance (Ohm/mile) 0.0461 at (deg F) 68

Resistance (Ohm/mile) 0.056 at (deg F) 167

Emissivity coefficient 0.5

Solar absorption coefficient 0.5

Outer strands heat capacity (Watt-s/ft-deg F) 436.8

Core heat capacity (Watt-s/ft-deg F) 23.6

[Generate Coefficients from points on stress-strain curve] [Composite cable properties] [OK] [Cancel]

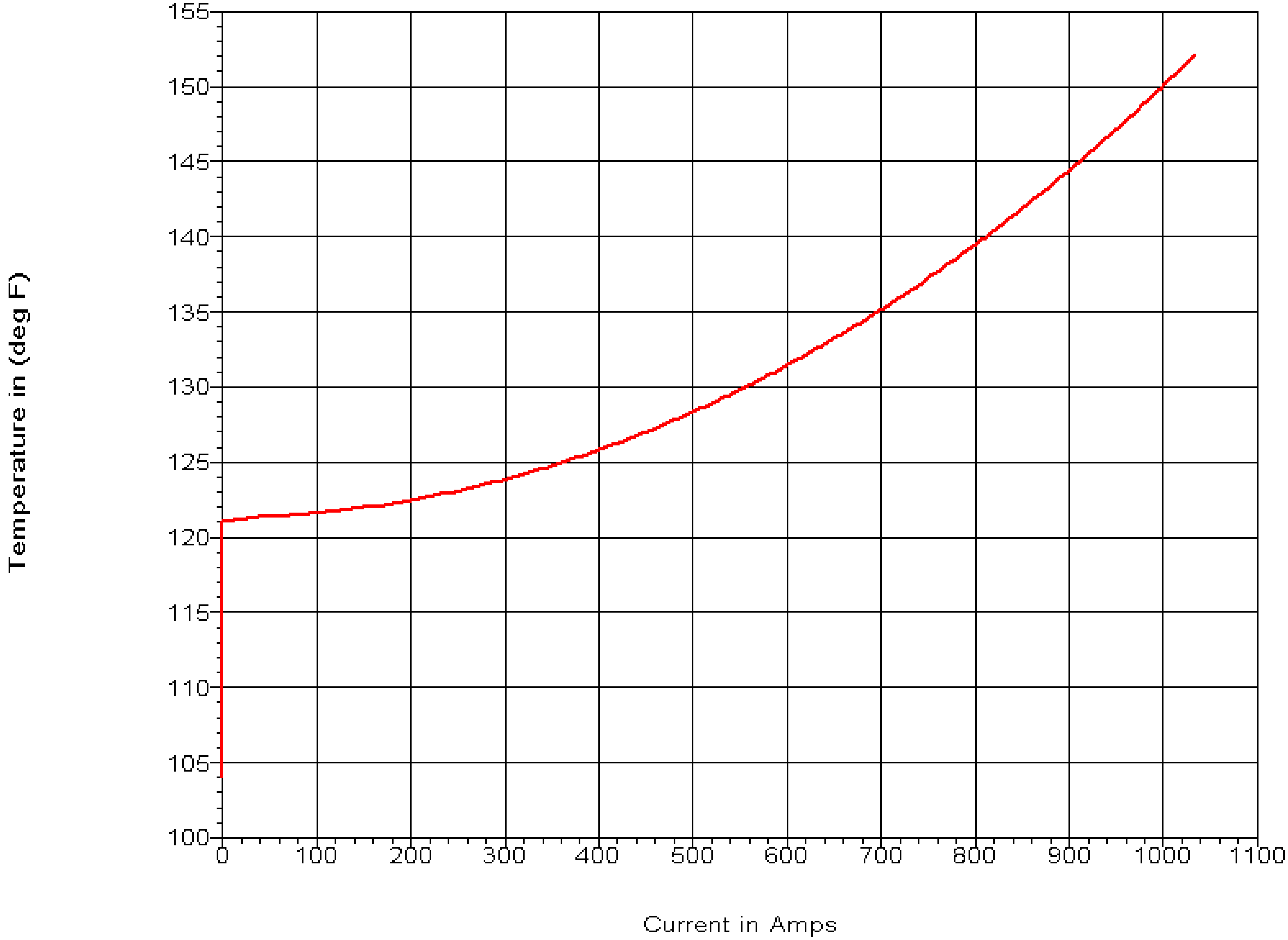
IEEE Std. 738-2006 method of calculation
NORMAL REGIME: I pole=3100 A; I conductor=I pole/3=1033.3 A

Air temperature is 104.00 (deg F)=40 (deg C)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 300 (ft)-at Mississippi River Crossing Span=4000 ft.
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2010) (day of the year with most solar heating)

Conductor description: ACCR-TW_1927-T13 Cumberland
Conductor diameter is 1.543 (in)
Conductor resistance is   0.0461 (Ohm/mile) at 68.0 (deg F)
                    and   0.0560 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   6.066 (Watt/ft) (corresponds to Global Solar Radiation of   94.350 (Watt/ft^2) - which was calculated)
Radiation cooling is   3.961 (Watt/ft)
Convective cooling is   13.129 (Watt/ft)

Given a constant dc current of 1033.3 amperes,
The conductor temperature is 152.1 (deg F)=67 (deg C)


Temperature in (deg F)
155
150
145
140
135
130
125
120
115
110
105
100
0
100
200
300
400
500
600
700
800
900
1000
1100
Current in Amps

Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\clean line_plains & eastern 600kv dc_segment 7.DON'

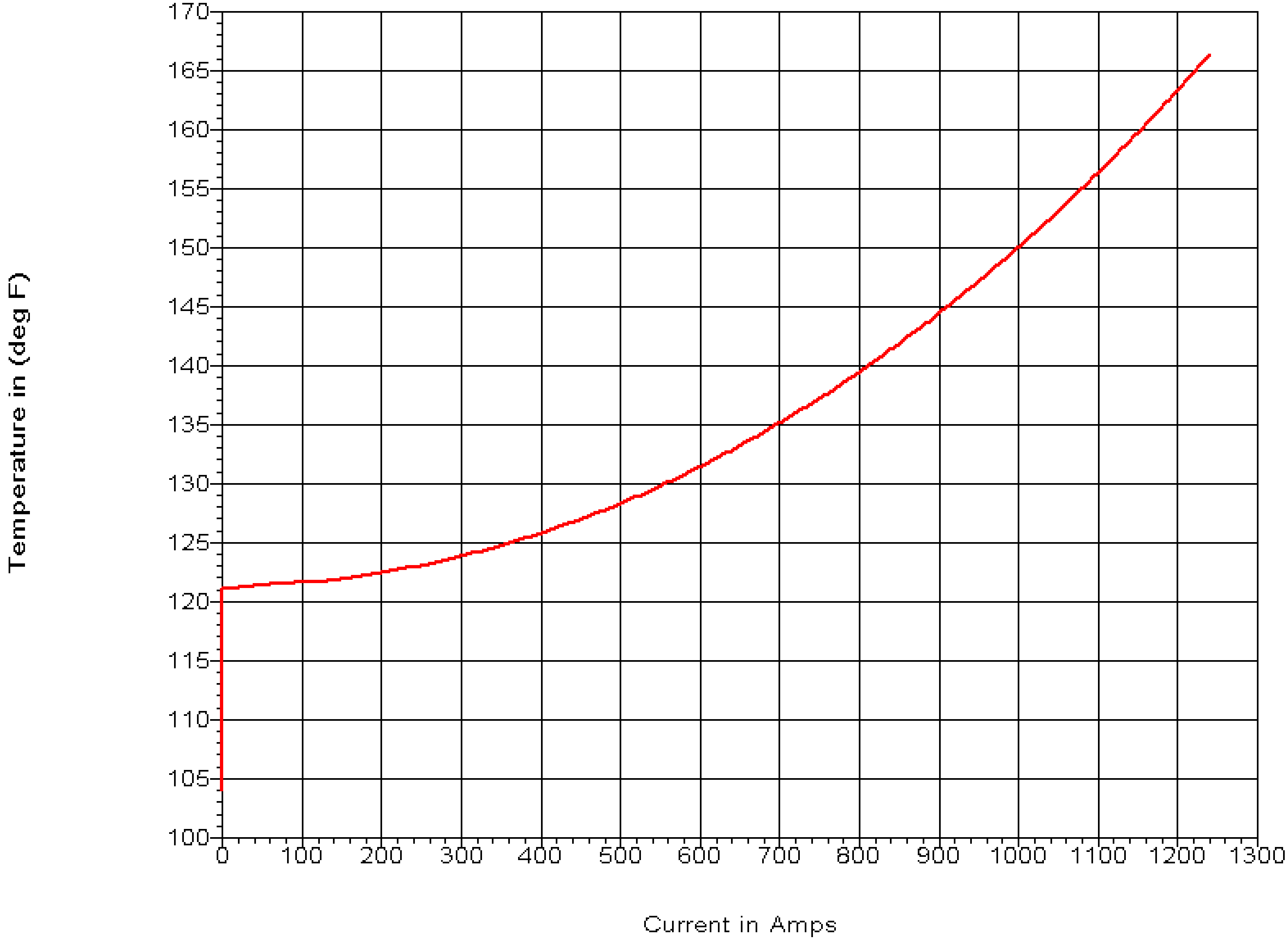
IEEE Std. 738-2006 method of calculation
EMERGENCY REGIME: I pole=3720 A; I conductor=I pole/3=1240 A
(20% over Normal Regime: I pole=3100 A; I condcutor=I pole/3=1033.3 A)

Air temperature is 104.00 (deg F)=40 (deg C)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 300 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2010) (day of the year with most solar heating)

Conductor description: ACCR-TW_1927-T13 Cumberland
Conductor diameter is 1.543 (in)
Conductor resistance is   0.0461 (Ohm/mile) at 68.0 (deg F)
                    and   0.0560 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   6.066 (Watt/ft) (corresponds to Global Solar Radiation of   94.350 (Watt/ft^2) - which was calculated)
Radiation cooling is   5.333 (Watt/ft)
Convective cooling is   17.021 (Watt/ft)

Given a constant dc current of 1240.0 amperes,
The conductor temperature is 166.4 (deg F)=74 (deg C)



170
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160
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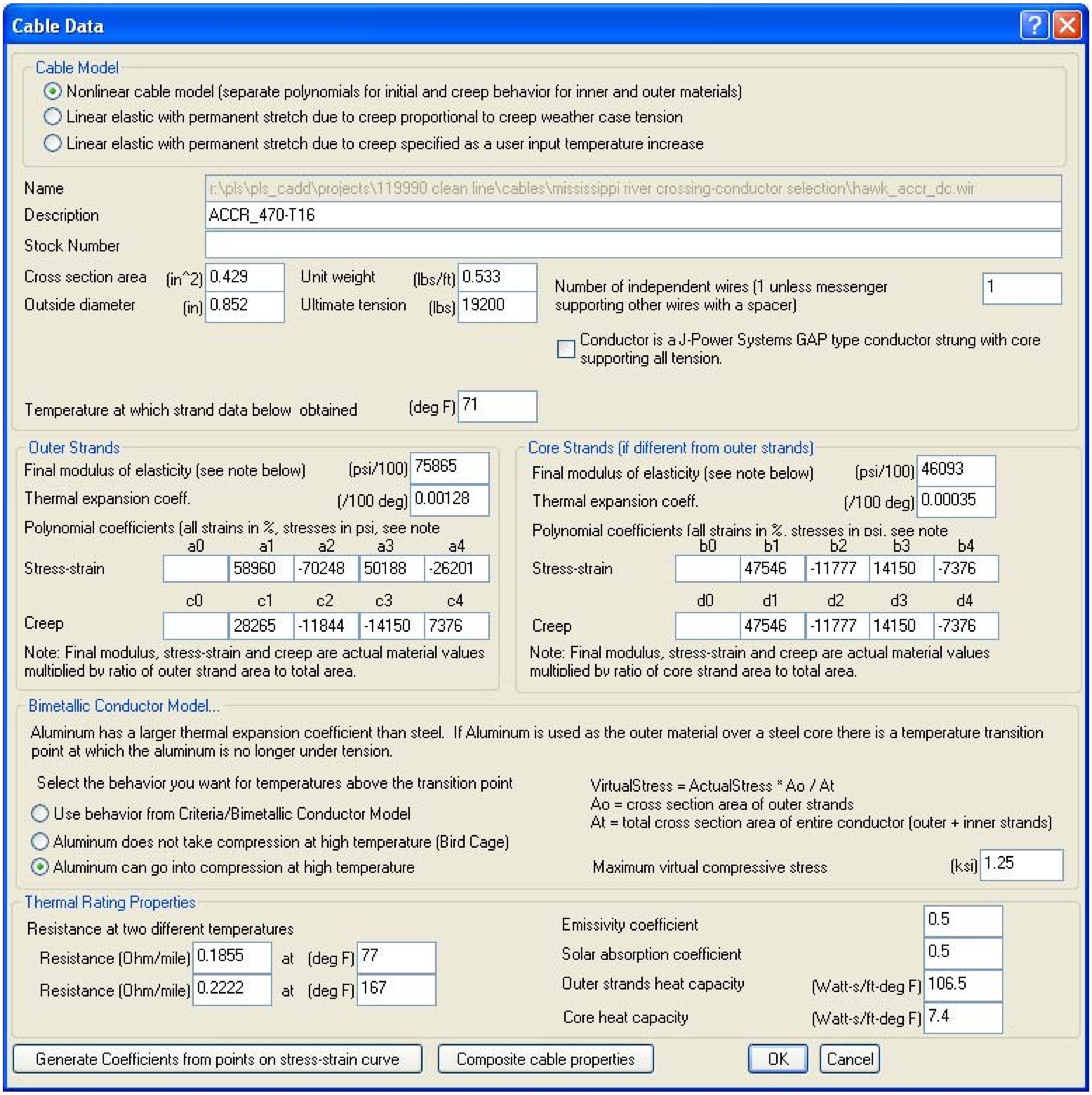
900
1000
1100
1200
1300
Temperature in (deg F)
Current in Amps

ACCR Hawk-with DC Resistances:



Cable Data

Cable Model

- (•) Nonlinear cable model (separate polynomials for initial and creep behavior for inner and outer materials)
- ( ) Linear elastic with permanent stretch due to creep proportional to creep weather case tension
- ( ) Linear elastic with permanent stretch due to creep specified as a user input temperature increase

Name: r:\pls\pls_cadd\projects\119990 clean line\cables\mississippi river crossing-conductor selection\hawk_accr_dc.wir

Description: ACCR_470-T16

Stock Number:

Cross section area (in^2) 0.429 | Unit weight (lbs/ft) 0.533

Outside diameter (in) 0.852 | Ultimate tension (lbs) 19200

Number of independent wires (1 unless messenger supporting other wires with a spacer) 1

[ ] Conductor is a J-Power Systems GAP type conductor strung with core supporting all tension.

Temperature at which strand data below obtained (deg F) 71

Outer Strands

Final modulus of elasticity (see note below) (psi/100) 75865

Thermal expansion coeff. (/100 deg) 0.00128

Polynomial coefficients (all strains in %, stresses in psi, see note

	a0	a1	a2	a3	a4
Stress-strain		58960	-70248	50188	-26201
	c0	c1	c2	c3	c4
Creep		28265	-11844	-14150	7376

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of outer strand area to total area.

Core Strands (if different from outer strands)

Final modulus of elasticity (see note below) (psi/100) 46093

Thermal expansion coeff. (/100 deg) 0.00035

Polynomial coefficients (all strains in %, stresses in psi, see note

	b0	b1	b2	b3	b4
Stress-strain		47546	-11777	14150	-7376
	d0	d1	d2	d3	d4
Creep		47546	-11777	14150	-7376

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of core strand area to total area.

Bimetallic Conductor Model...

Aluminum has a larger thermal expansion coefficient than steel. If Aluminum is used as the outer material over a steel core there is a temperature transition point at which the aluminum is no longer under tension.

Select the behavior you want for temperatures above the transition point

- ( ) Use behavior from Criteria/Bimetallic Conductor Model
- ( ) Aluminum does not take compression at high temperature (Bird Cage)
- (•) Aluminum can go into compression at high temperature

VirtualStress = ActualStress * Ao / At
Ao = cross section area of outer strands
At = total cross section area of entire conductor (outer + inner strands)

Maximum virtual compressive stress (ksi) 1.25

Thermal Rating Properties

Resistance at two different temperatures

Resistance (Ohm/mile) 0.1855 at (deg F) 77

Resistance (Ohm/mile) 0.2222 at (deg F) 167

Emissivity coefficient 0.5

Solar absorption coefficient 0.5

Outer strands heat capacity (Watt-s/ft-deg F) 106.5

Core heat capacity (Watt-s/ft-deg F) 7.4

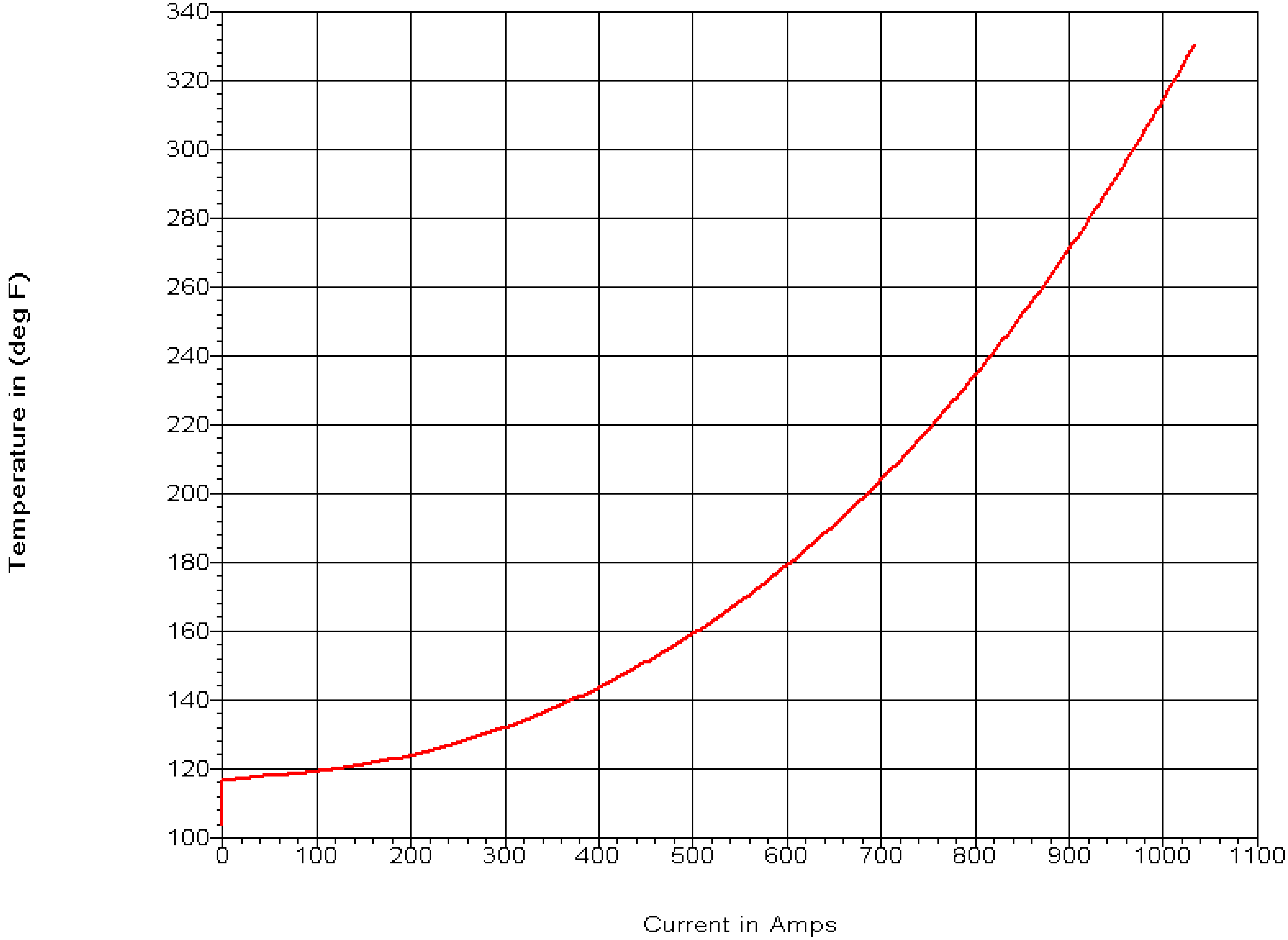
[Generate Coefficients from points on stress-strain curve] [Composite cable properties] [OK] [Cancel]

IEEE Std. 738-2006 method of calculation
NORMAL REGIME: I pole=3100 A; I conductor=I pole/3=1033.3 A
Air temperature is 104.00 (deg F)=40 (deg C)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 300 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2010) (day of the year with most solar heating)

Conductor description: ACCR_470-T16
Conductor diameter is 0.852 (in)
Conductor resistance is   0.1855 (Ohm/mile) at 77.0 (deg F)
                    and   0.2222 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   3.349 (Watt/ft) (corresponds to Global Solar Radiation of   94.350 (Watt/ft^2) - which was calculated)
Radiation cooling is   16.165 (Watt/ft)
Convective cooling is   45.606 (Watt/ft)

Given a constant dc current of 1033.3 amperes,
The conductor temperature is 330.6 (deg F)=166 (deg C)



340
320
300
280
260
240
220
200
180
160
140
120
100
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100
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700
800
900
1000
1100
Temperature in (deg F)
Current in Amps

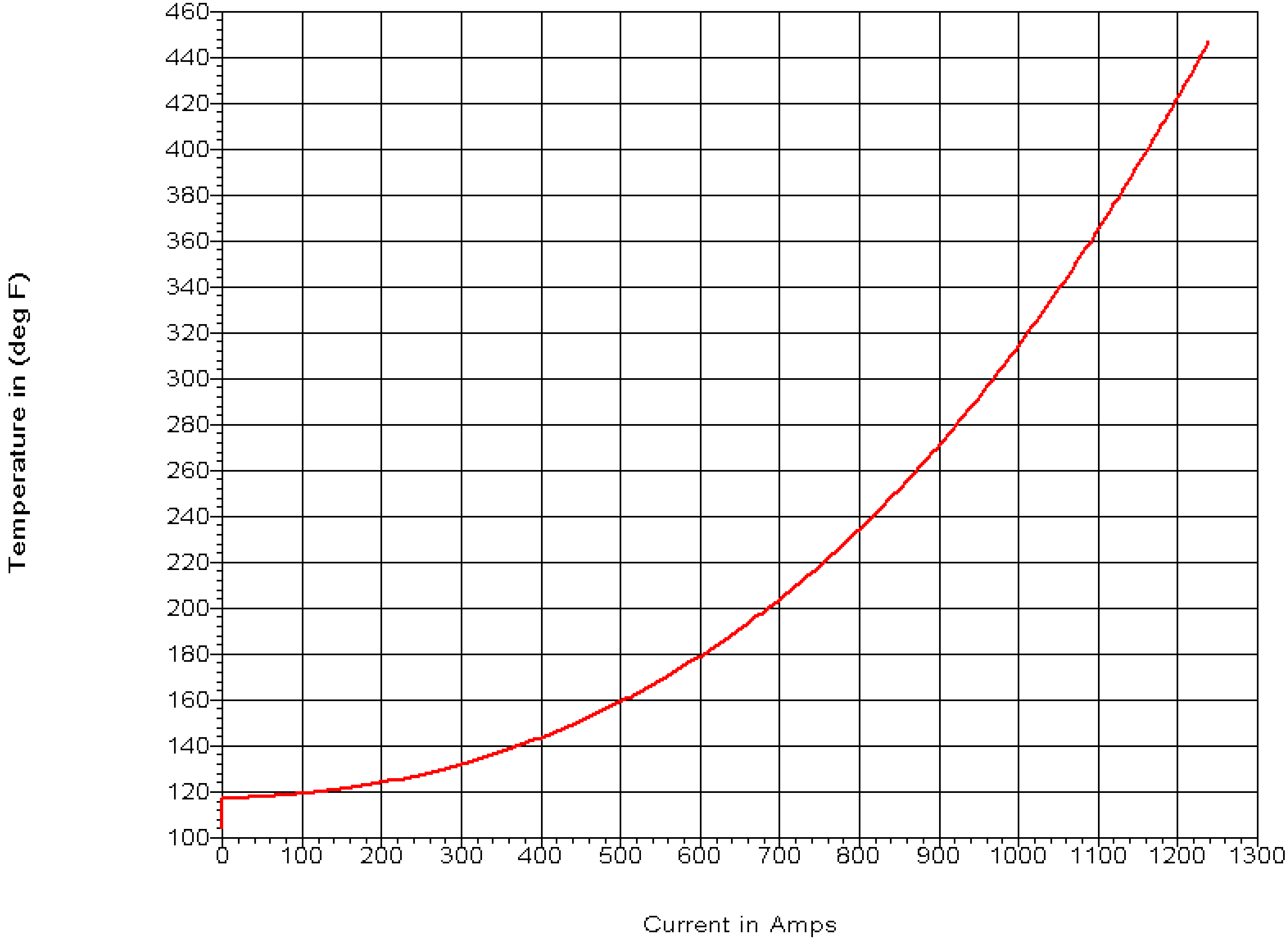
IEEE Std. 738-2006 method of calculation
EMERGENCY REGIME: I pole=3720 A ; I conductor=I pole/3=1240 A
(20% over Normal Regime: I pole=3100 A; I conductor=I pole/3=1033.3 A)

Air temperature is 104.00 (deg F)=40 9deg C)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 300 (ft)-at Mississippi River Crossing Span=4000 ft.
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2010) (day of the year with most solar heating)

Conductor description: ACCR_470-T16
Conductor diameter is 0.852 (in)
Conductor resistance is 0.1855 (Ohm/mile) at 77.0 (deg F)
and 0.2222 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 3.349 (Watt/ft) (corresponds to Global Solar Radiation of 94.350 (Watt/ft^2) - which was calculated)
Radiation cooling is 32.212 (Watt/ft)
Convective cooling is 69.134 (Watt/ft)

Given a constant dc current of 1240.0 amperes,
The conductor temperature is 447.3 (deg F)=231 C


Temperature in (deg F)
460
440
420
400
380
360
340
320
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280
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240
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200
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1000
1100
1200
1300
Current in Amps

ACCR Falcon-with DC Resistances

Cable Data

Cable Model

- (•) Nonlinear cable model (separate polynomials for initial and creep behavior for inner and outer materials)
- ( ) Linear elastic with permanent stretch due to creep proportional to creep weather case tension
- ( ) Linear elastic with permanent stretch due to creep specified as a user input temperature increase

Name: r:\pls\pls_cadd\projects\119990 clean line\cables\falcon_accr_dc.wir

Description: ACCR_Falcon_1594-T13

Stock Number:

Cross section area (in^2) 1.411 | Unit weight (lbs/ft) 1.745

Outside diameter (in) 1.547 | Ultimate tension (lbs) 53600.1

Number of independent wires (1 unless messenger supporting other wires with a spacer): 1

[ ] Conductor is a J-Power Systems GAP type conductor strung with core supporting all tension.

Temperature at which strand data below obtained (deg F) 71.0001

Outer Strands

Final modulus of elasticity (see note below) (psi/100) 73263

Thermal expansion coeff. (/100 deg) 0.00128

Polynomial coefficients (all strains in %, stresses in psi, see note

	a0	a1	a2	a3	a4
Stress-strain		48046	-26995.	-10555	5472.99

	c0	c1	c2	c3	c4
Creep		22920.9	-16104	4108	-2140.9

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of outer strand area to total area.

Core Strands (if different from outer strands)

Final modulus of elasticity (see note below) (psi/100) 39717.9

Thermal expansion coeff. (/100 deg) 0.00035

Polynomial coefficients (all strains in %, stresses in psi, see note

	b0	b1	b2	b3	b4
Stress-strain		41786	-8620	-4095	2134

	d0	d1	d2	d3	d4
Creep		41786	-8620	-4095	2134

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of core strand area to total area.

Bimetallic Conductor Model...

Aluminum has a larger thermal expansion coefficient than steel. If Aluminum is used as the outer material over a steel core there is a temperature transition point at which the aluminum is no longer under tension.

Select the behavior you want for temperatures above the transition point

- ( ) Use behavior from Criteria/Bimetallic Conductor Model
- ( ) Aluminum does not take compression at high temperature (Bird Cage)
- (•) Aluminum can go into compression at high temperature

VirtualStress = ActualStress * Ao / At
Ao = cross section area of outer strands
At = total cross section area of entire conductor (outer + inner strands)

Maximum virtual compressive stress (ksi) 1.25

Thermal Rating Properties

Resistance at two different temperatures

Resistance (Ohm/mile) 0.0558 at (deg F) 68

Resistance (Ohm/mile) 0.0679 at (deg F) 167

Emissivity coefficient 0.5

Solar absorption coefficient 0.5

Outer strands heat capacity (Watt-s/ft-deg F) 362.301

Core heat capacity (Watt-s/ft-deg F) 19.4999

[Generate Coefficients from points on stress-strain curve] [Composite cable properties] [OK] [Cancel]

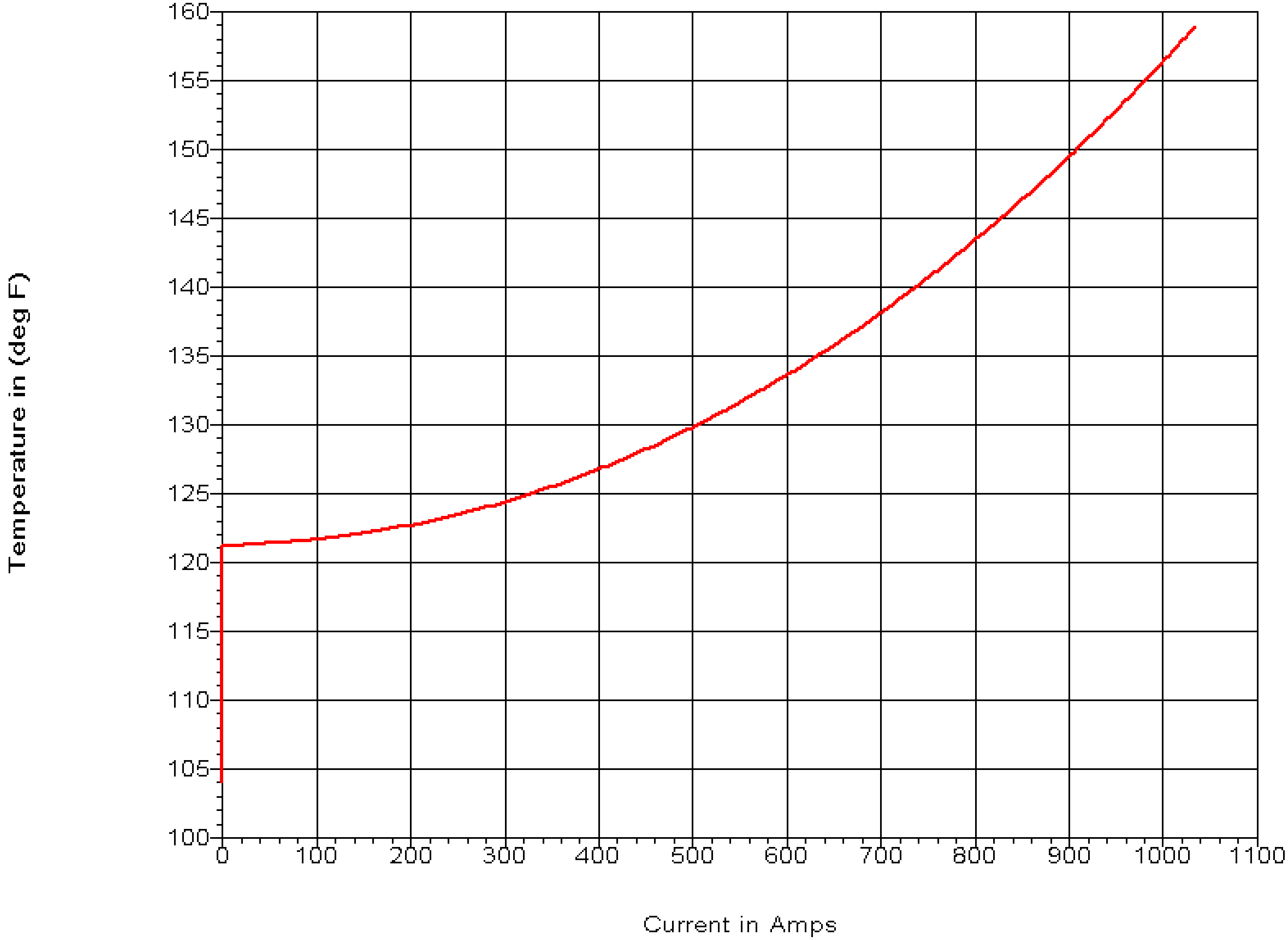
IEEE Std. 738-2006 method of calculation
NORMAL REGIME: I pole=3100 A; I cond=I pole/3=1033.3 A

Air temperature is 104.00 (deg F)=40 (deg C)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 300 (ft)-at Mississippi River Crossing Span=4000 ft.
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2010) (day of the year with most solar heating)

Conductor description: ACCR_Falcon_1594-T13
Conductor diameter is 1.547 (in)
Conductor resistance is   0.0558 (Ohm/mile) at 68.0 (deg F)
                    and   0.0679 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   6.082 (Watt/ft) (corresponds to Global Solar Radiation of   94.350 (Watt/ft^2) - which was calculated)
Radiation cooling is   4.613 (Watt/ft)
Convective cooling is   15.001 (Watt/ft)

Given a constant dc current of 1033.3 amperes,
The conductor temperature is 158.9 (deg F)=71 (deg C)


160
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Temperature in (deg F)
Current in Amps

Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\clean line_plains & eastern 600kv dc_segment 7.DON'

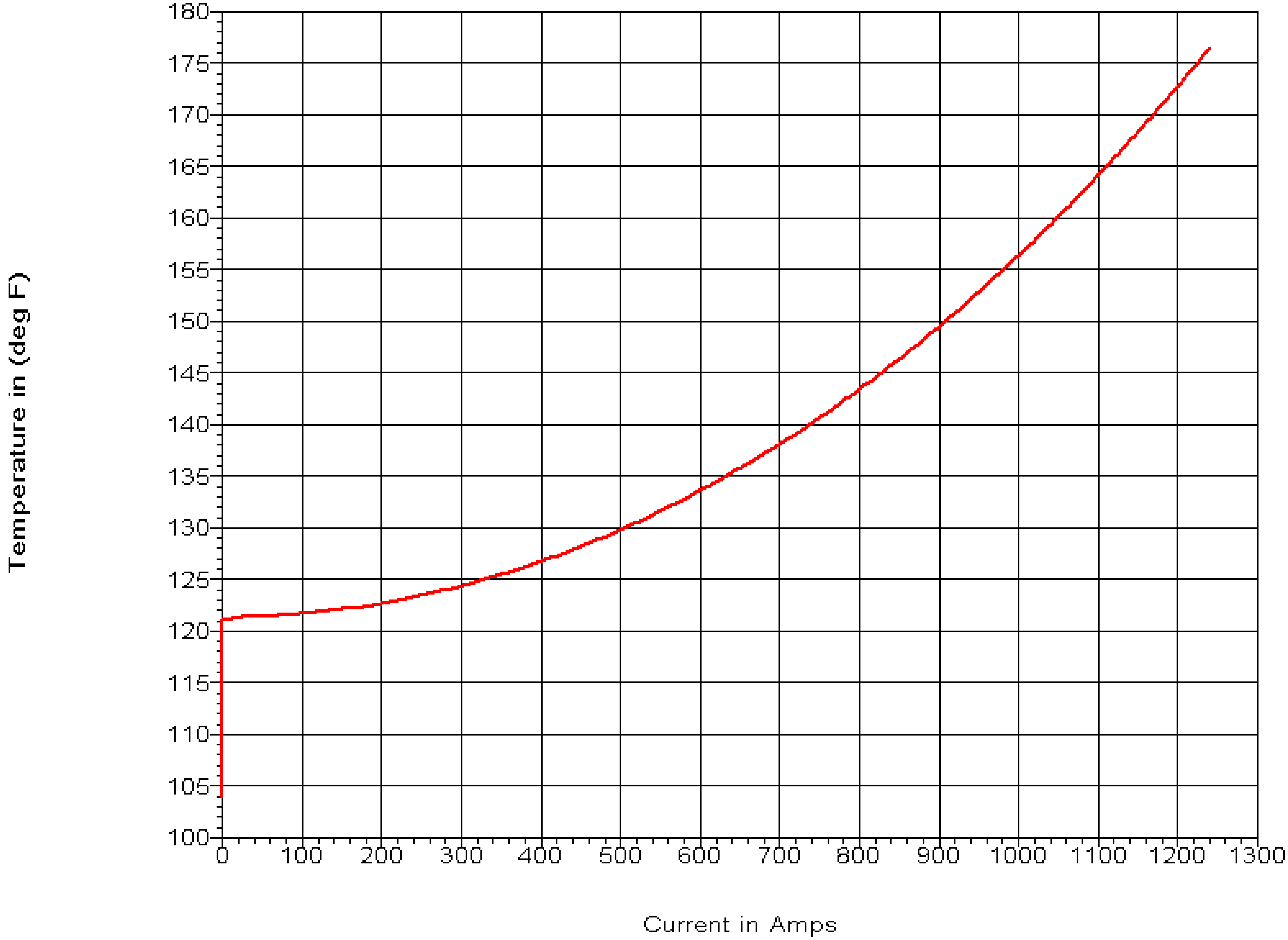
IEEE Std. 738-2006 method of calculation
EMERGENCY REGIME: I pole=3720 A; I conductor=I pole/3=1240 A
(20 % over Normal regime: I pole=3100 A; I conductor=I pole/3=1033.3 A)

Air temperature is 104.00 (deg F)=40 (deg C)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 300 (ft)- at Mississippi River Crossing Span=4000 ft.
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2010) (day of the year with most solar heating)

Conductor description: ACCR_Falcon_1594-T13
Conductor diameter is 1.547 (in)
Conductor resistance is   0.0558 (Ohm/mile) at 68.0 (deg F)
                    and   0.0679 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   6.082 (Watt/ft) (corresponds to Global Solar Radiation of   94.350 (Watt/ft^2) - which was calculated)
Radiation cooling is   6.383 (Watt/ft)
Convective cooling is   19.811 (Watt/ft)

Given a constant dc current of 1240.0 amperes,
The conductor temperature is 176.5 (deg F)=81 (deg C)



Temperature in (deg F)
180
175
170
165
160
155
150
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1100
1200
1300
Current in Amps

PLS-CADD Version 10.64x64 10:45:54 AM Monday, December 13, 2010
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\clean line_river crossing=4000 ft-opgw 49ay85acs-2c.loa'

Criteria notes:
River Crossing Span=4000 ft
NESC Heavy-Rule 250D-Initial @85% Controls (OPGW)

Section #1 '1:Back'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\49ay85acs-2c 1-1427.wir', Ruling span (ft) 4000
Sagging data: Catenary (ft) 7219.87, Horiz. Tension (lbs) 3415 Condition I Temperature (deg F) 60
Weather case for final after creep 60, Equivalent to 39.6 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B, Equivalent to 71.9 (deg F) temperature increase

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 Heavy-Rule 250B	0.53	1.15	1.57	10926	10453	43	6668	302.20	10926	10453	43	6668	302.20	10926	10453	43	6668	302.20	
2	NESC Rule 250D	1.06	3.33	3.50	21571	20357	85	5820	347.06	21571	20357	85	5820	347.06	21571	20357	85	5820	347.06	
3	32deg, .5", 0psf	0.00	1.15	1.15	8224	7885	32	6849	294.11	8222	7883	32	6847	294.18	8159	7817	32	6790	296.70	
4	60deg, 0", 97mph	1.20	0.47	1.29	9039	8653	36	6724	299.62	9039	8653	36	6724	299.62	8989	8601	35	6684	301.46	
5	60deg, 0", 12.2 psf	0.60	0.47	0.76	5595	5375	22	7030	286.43	5558	5338	22	6980	288.49	5513	5290	22	6918	291.11	
6	0deg, 0", 4psf	0.20	0.47	0.51	3894	3753	15	7325	274.73	3853	3711	15	7242	277.92	3818	3675	15	7172	280.69	
7	60deg, 0", 6psf	0.30	0.47	0.56	4152	3995	16	7163	281.03	4112	3953	16	7088	284.02	4076	3917	16	7022	286.73	
8	0	0.00	0.47	0.47	3608	3478	14	7354	273.64	3568	3437	14	7266	277.01	3535	3403	14	7194	279.79	
9	32	0.00	0.47	0.47	3575	3444	14	7282	276.39	3535	3403	14	7195	279.77	3504	3371	14	7126	282.50	
10	60	0.00	0.47	0.47	3547	3415	14	7220	278.78	3508	3375	14	7135	282.14	3478	3343	14	7067	284.88	
11	90	0.00	0.47	0.47	3518	3385	14	7156	281.32	3480	3345	14	7072	284.69	3450	3314	14	7007	287.37	
12	120	0.00	0.47	0.47	3489	3355	14	7092	283.87	3452	3317	14	7012	287.17	3423	3286	13	6947	289.89	MOT-OPGW
13	152	0.00	0.47	0.47	3460	3324	14	7028	286.51	3423	3286	13	6948	289.85	3395	3257	13	6885	292.53	MOT-Normal-Conductor
14	166	0.00	0.47	0.47	3447	3311	14	6999	287.70	3411	3273	13	6920	291.02	3383	3244	13	6859	293.66	MOT-Emergency-Conductor

(OPGW Sag @ 60 F, No wind, No ice, Final) / (Conductor ACCR-TW Cumberland Sag @ 60 F, No Wind, No Ice, Final)x100= 284.88' / 274.73' x 100= 103.7% > 85%, NOT OK.

(OPGW Sag @ 32 F, 0.5", No Wind, Final) / (Conductor ACCR-TW Cumberland Sag @ 32 F, No Wind, No Ice, Final)x100= 296.70' / 271.81' x 100= 109.15% > 95%, NOT OK.

PLS-CADD Version 10.64x64   10:32:44 AM Monday, December 27, 2010
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\cables\mississippi river crossing-conductor selection\clean line_river crossing=4000 ft-accr_tw pecos.loa'

Criteria notes:
River Crossing Span=4000 ft
NESC -Rule 250D- Extreme ice with Concurrent Wind-Initial @75% Controls (Conductor ACCR/TW Pecos)

Section #1 '1:Back'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\mississippi river crossing-conductor selection\pecos_accr_tw_dc.wir', Ruling span (ft) 4000
Sagging data: Catenary (ft) 7130.78, Horiz. Tension (lbs) 12650 Condition I Temperature (deg F) 60.0001
Weather case for final after creep 60, Equivalent to 44.8 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B, Equivalent to 42.7 (deg F) temperature increase

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 Heavy-Rule 250B	0.81	2.97	3.37	24559	23588	44	6992	287.99	24539	23567	44	6986	288.25	24559	23588	44	6992	287.99	
2	NESC Rule 250D	1.34	5.92	6.07	41616	39748	75	6549	307.76	41616	39748	75	6549	307.76	41616	39748	75	6549	307.76	
3	32deg, .5", 0psf	0.00	2.97	2.97	21607	20753	39	6997	287.78	21488	20629	39	6955	289.54	21505	20647	39	6961	289.28	
4	60deg, 0", 97mph	2.87	1.77	3.37	24203	23216	44	6882	292.68	24098	23106	43	6849	294.09	24117	23126	43	6855	293.83	
5	60deg, 0", 12.2 psf	1.44	1.77	2.29	16762	16109	30	7049	285.63	16573	15912	30	6963	289.21	16586	15926	30	6969	288.96	
6	0deg, 0", 4psf	0.47	1.77	1.84	13823	13314	25	7252	277.53	13664	13148	25	7162	281.08	13674	13158	25	7168	280.85	
7	60deg, 0", 6psf	0.71	1.77	1.91	14121	13580	25	7109	283.20	13930	13381	25	7005	287.46	13941	13392	25	7011	287.22	
8	0	0.00	1.77	1.77	13376	12885	24	7263	277.11	13216	12718	24	7169	280.80	13226	12728	24	7175	280.56	
9	32	0.00	1.77	1.77	13255	12759	24	7192	279.88	13079	12575	24	7088	284.03	13087	12584	24	7094	283.82	
10	60	0.00	1.77	1.77	13150	12650	24	7131	282.33	12962	12453	23	7020	286.84	12972	12464	23	7026	286.59	
11	90	0.00	1.77	1.77	13041	12536	23	7066	284.93	12840	12325	23	6948	289.85	12850	12336	23	6954	289.61	
12	120	0.00	1.77	1.77	12935	12425	23	7004	287.51	12722	12203	23	6879	292.81	12732	12213	23	6884	292.57	
13	160	0.00	1.77	1.77	12794	12278	23	6921	290.99	12569	12043	23	6789	296.75	12577	12051	23	6793	296.54	MOT-Normal
14	178	0.00	1.77	1.77	12732	12213	23	6884	292.57	12501	11971	23	6748	298.55	12511	11982	23	6754	298.28	MOT-Emergency

PLS-CADD Version 10.64x64   8:23:34 AM Monday, December 13, 2010
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\clean line_river crossing=4000 ft-acss_tw cumberland.loa'

Criteria notes:
River Crossing Span=4000 ft
0 deg F Final @25% Controls (Conductor ACCR/TW Cumberland)

Section #1 '1:Back'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\cumberland_acss_tw_dc.wir', Ruling span (ft) 4000
Sagging data: Catenary (ft) 4755.16, Horiz. Tension (lbs) 11750 Condition I Temperature (deg F) 60.0001
Weather case for final after creep 60, Equivalent to 0.2 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B, Equivalent to 94.4 (deg F) temperature increase

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 Heavy-Rule 250B	0.85	3.74	4.14	21189	19398	41	4688	433.11	21189	19398	41	4688	433.11	21189	19398	41	4688	433.11	
2	NESC Rule 250D	1.38	6.82	6.95	34343	31191	67	4485	453.36	34343	31191	67	4485	453.36	34343	31191	67	4485	453.36	
3	32deg, .5", 0psf	0.00	3.74	3.74	19200	17582	37	4698	432.19	19200	17582	37	4698	432.19	19105	17478	37	4670	434.84	
4	60deg, 0", 97mph	3.13	2.47	3.99	20338	18602	39	4666	435.23	20338	18602	39	4666	435.23	20248	18504	39	4641	437.63	
5	60deg, 0", 12.2 psf	1.57	2.47	2.93	15108	13851	29	4731	429.11	15108	13851	29	4731	429.11	14933	13659	29	4665	435.35	
6	0deg, 0", 4psf	0.51	2.47	2.52	13169	12101	26	4794	423.25	13168	12099	26	4794	423.31	13009	11924	25	4724	429.72	
7	60deg, 0", 6psf	0.77	2.47	2.59	13402	12295	26	4749	427.39	13402	12295	26	4749	427.39	13221	12095	26	4672	434.67	
8	0	0.00	2.47	2.47	12899	11854	25	4797	422.98	12898	11853	25	4797	423.03	12737	11675	25	4725	429.65	
9	32	0.00	2.47	2.47	12849	11799	25	4775	425.00	12848	11798	25	4775	425.05	12676	11608	25	4698	432.21	
10	60	0.00	2.47	2.47	12805	11750	25	4755	426.83	12805	11750	25	4755	426.83	12623	11549	24	4674	434.47	
11	90	0.00	2.47	2.47	12757	11697	25	4734	428.81	12745	11685	25	4729	429.29	12568	11488	24	4649	436.86	
12	120	0.00	2.47	2.47	12709	11644	25	4712	430.82	12687	11620	25	4702	431.76	12515	11430	24	4626	439.16	
13	152	0.00	2.47	2.47	12657	11587	25	4689	433.04	12627	11554	24	4676	434.30	12455	11363	24	4599	441.82	MOT-Normal
14	166	0.00	2.47	2.47	12634	11562	24	4679	434.00	12600	11524	24	4664	435.46	12430	11336	24	4588	442.91	MOT-Emergency

PLS-CADD Version 10.64x64 3:03:14 PM Friday, December 10, 2010
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\clean line_river crossing=4000 ft-accr_tw cumberland.LOA'

Criteria notes:
River Crossing Span=4000 ft
0 deg F Final @25% Controls (Conductor ACCR/TW Cumberland)

Section #1 '1:Back'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\cumberland_accr_tw_dc.wir', Ruling span (ft) 4000
Sagging data: Catenary (ft) 7437.05, Horiz. Tension (lbs) 15655 Condition I Temperature (deg F) 60.0001
Weather case for final after creep 60, Equivalent to 47.3 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B, Equivalent to 40.3 (deg F) temperature increase

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.	Vert	Res.	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)	
		-----Load----- ---(lbs/ft)---																		
1	NESC Heavy-Rule 250B	0.85	3.38	3.78	28649	27607	44	7303	275.57	28579	27534	44	7284	276.30	28649	27607	44	7303	275.57	
2	NESC Rule 250D	1.38	6.45	6.59	47068	45128	72	6845	294.27	47068	45128	72	6845	294.27	47068	45128	72	6845	294.27	
3	32deg, .5", 0psf	0.00	3.38	3.38	25568	24637	39	7299	275.72	25386	24448	39	7243	277.88	25447	24511	39	7262	277.15	
4	60deg, 0", 97mph	3.12	2.11	3.77	28106	27049	43	7180	280.37	27929	26865	43	7131	282.31	27995	26935	43	7149	281.58	
5	60deg, 0", 12.2 psf	1.57	2.11	2.63	20025	19307	31	7354	273.63	19759	19030	30	7249	277.66	19807	19080	30	7268	276.92	
6	0deg, 0", 4psf	0.51	2.11	2.17	16991	16415	26	7575	265.55	16764	16180	26	7467	269.46	16805	16223	26	7487	268.74	
7	60deg, 0", 6psf	0.77	2.11	2.24	17232	16624	26	7415	271.36	16964	16345	26	7291	276.05	17004	16387	26	7309	275.33	
8	0	0.00	2.11	2.11	16528	15970	25	7587	265.15	16300	15733	25	7474	269.19	16341	15776	25	7494	268.45	
9	32	0.00	2.11	2.11	16365	15801	25	7506	268.03	16114	15541	25	7383	272.56	16156	15583	25	7403	271.81	
10	60	0.00	2.11	2.11	16224	15654	25	7437	270.56	15958	15379	24	7306	275.47	15998	15419	24	7325	274.73	
11	90	0.00	2.11	2.11	16077	15502	25	7364	273.25	15795	15208	24	7225	278.59	15832	15247	24	7243	277.88	
12	120	0.00	2.11	2.11	15933	15352	24	7293	275.95	15637	15044	24	7147	281.67	15676	15084	24	7166	280.92	
13	152	0.00	2.11	2.11	15783	15196	24	7219	278.82	15474	14874	24	7066	284.93	15509	14911	24	7084	284.22	MOT-Normal
14	166	0.00	2.11	2.11	15718	15128	24	7187	280.09	15403	14800	24	7031	286.39	15438	14837	24	7048	285.67	MOT-Emergency

PLS-CADD Version 10.64x64   11:41:22 AM Thursday, December 16, 2010
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\cables\mississippi river crossing-conductor selection\clean line_river crossing=4000 ft-accr hawk.loa'

Criteria notes:
  River Crossing Span=4000 ft
  NESC -Rule 250D- Extreme ice with Concurrent Wind-Initial @75% Controls (OPGW)

Section #1 '1:Back'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\mississippi river crossing-conductor selection\hawk_accr_dc.wir', Ruling span (ft) 4000
Sagging data: Catenary (ft) 2973.73, Horiz. Tension (lbs) 1585 Condition I Temperature (deg F) 60.0001
Weather case for final after creep 60, Equivalent to 26.2 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B, Equivalent to 39.2 (deg F) temperature increase

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	Res.	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-Rule 250B	0.62	1.37	1.81	6615	5348	34	2961	701.40	6615	5348	34	2961	701.40	6615	5348	34	2961	701.40	
2	NESC Rule 250D	1.15	3.80	3.97	14405	11575	75	2916	713.16	14405	11575	75	2916	713.16	14405	11575	75	2916	713.16	
3	32deg, .5", 0psf	0.00	1.37	1.37	5034	4072	26	2964	700.69	5034	4072	26	2964	700.73	5031	4068	26	2961	701.47	
4	60deg, 0", 97mph	1.73	0.53	1.81	6602	5331	34	2952	703.75	6602	5331	34	2952	703.75	6599	5327	34	2950	704.30	
5	60deg, 0", 12.2 psf	0.87	0.53	1.02	3728	3016	19	2965	700.45	3727	3014	19	2964	700.88	3724	3010	19	2960	701.83	
6	0deg, 0", 4psf	0.28	0.53	0.60	2221	1801	12	2982	696.26	2220	1799	12	2979	696.92	2219	1798	12	2976	697.65	
7	60deg, 0", 6psf	0.43	0.53	0.68	2504	2027	13	2971	699.00	2502	2025	13	2968	699.79	2501	2023	13	2965	700.58	
8	0	0.00	0.53	0.53	1961	1590	10	2983	696.02	1960	1589	10	2982	696.25	1959	1587	10	2978	697.13	
9	32	0.00	0.53	0.53	1959	1587	10	2977	697.46	1958	1586	10	2975	697.92	1957	1584	10	2972	698.66	
10	60	0.00	0.53	0.53	1957	1585	10	2973	698.47	1955	1583	10	2969	699.45	1954	1581	10	2966	700.20	
11	90	0.00	0.53	0.53	1955	1582	10	2968	699.84	1954	1580	10	2965	700.59	1952	1578	10	2961	701.61	
12	120	0.00	0.53	0.53	1953	1579	10	2963	701.08	1951	1577	10	2958	702.27	1949	1575	10	2954	703.29	
13	331	0.00	0.53	0.53	1943	1566	10	2938	707.30	1943	1566	10	2938	707.30	1943	1566	10	2938	707.30	MOT-Normal
14	447	0.00	0.53	0.53	1940	1562	10	2930	709.41	1940	1562	10	2930	709.41	1940	1562	10	2930	709.41	MOT-Emergency

PLS-CADD Version 10.64x64   2:56:10 PM Friday, December 10, 2010
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\clean line_river crossing=4000 ft-accr falcon.LOA'

Criteria notes:
  River Crossing Span=4000 ft
  NESC Heavy-Rule 250D-Initial @75% Controls (Conductor ACCR Falcon)

Section #1 '1:Back'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\falcon_accr_dc.wir', Ruling span (ft) 4000
Sagging data: Catenary (ft) 6561.6, Horiz. Tension (lbs) 11450 Condition I Temperature (deg F) 60.0001
Weather case for final after creep 60, Equivalent to 42.0 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B, Equivalent to 42.0 (deg F) temperature increase

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 Heavy-Rule 250B	0.85	3.02	3.43	23242	22169	43	6454	312.37	23239	22166	43	6453	312.41	23242	22169	43	6454	312.37	
2	NESC Rule 250D	1.38	6.09	6.25	40177	38110	75	6100	330.83	40177	38110	75	6100	330.83	40177	38110	75	6100	330.83	
3	32deg, .5", 0psf	0.00	3.02	3.02	20424	19482	38	6456	312.29	20343	19396	38	6427	313.69	20346	19399	38	6428	313.64	
4	60deg, 0", 97mph	3.13	1.74	3.59	23902	22763	45	6348	317.68	23848	22706	44	6332	318.48	23852	22710	44	6333	318.43	
5	60deg, 0", 12.2 psf	1.57	1.74	2.35	15976	15246	30	6490	310.62	15840	15104	30	6429	313.59	15842	15105	30	6430	313.56	
6	0deg, 0", 4psf	0.52	1.74	1.82	12663	12112	24	6656	302.73	12548	11992	23	6590	305.81	12549	11992	23	6591	305.80	
7	60deg, 0", 6psf	0.77	1.74	1.91	13075	12487	24	6542	308.10	12936	12341	24	6466	311.80	12936	12341	24	6466	311.80	
8	0	0.00	1.74	1.74	12159	11631	23	6666	302.31	12046	11512	22	6597	305.48	12046	11513	22	6598	305.46	
9	32	0.00	1.74	1.74	12066	11534	23	6610	304.89	11939	11401	22	6533	308.52	11940	11401	22	6534	308.50	
10	60	0.00	1.74	1.74	11986	11450	22	6561	307.18	11850	11307	22	6479	311.12	11850	11307	22	6480	311.11	
11	90	0.00	1.74	1.74	11902	11361	22	6511	309.61	11755	11208	22	6423	313.92	11757	11209	22	6424	313.88	
12	120	0.00	1.74	1.74	11817	11273	22	6460	312.07	11662	11109	22	6366	316.76	11665	11112	22	6368	316.67	
13	159	0.00	1.74	1.74	11711	11161	22	6396	315.24	11546	10987	22	6296	320.33	11546	10987	22	6297	320.32	MOT-Normal
14	177	0.00	1.74	1.74	11663	11111	22	6367	316.71	11494	10932	21	6265	321.97	11494	10932	21	6265	321.96	MOT-Emergency

PLS-CADD Version 10.64x64   8:42:50 AM Wednesday, December 15, 2010
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\clean line_river crossing=4000 ft-opgw 161acs-2c.loa'

Criteria notes:
River Crossing Span=4000 ft
NESC -Rule 250D- Extreme ice with Concurrent Wind-Initial @75% Controls (OPGW)

Section #1 '1:Back'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\mississippi river crossing-conductor selection\brugg_161acs-2c 1-1140.wir', Ruling span (ft) 4000
Sagging data: Catenary (ft) 9262.54, Horiz. Tension (lbs) 6280 Condition I Temperature (deg F) 60.0001
Weather case for final after creep 60, Equivalent to 47.3 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B, Equivalent to 26.5 (deg F) temperature increase

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)	After Creep Hori. Tens. (lbs)	After Creep Max Ten %UL	After Creep C (ft)	After Creep R.S. Sag (ft)	R.S. Final Cond. After Load Max. Tens. (lbs)	After Load Hori. Tens. (lbs)	After Load Max Ten %UL	After Load C (ft)	After Load R.S. Sag (ft)	
1	NESC Heavy-Rule 250B	0.55	1.39	1.79	15580	15153	41	8442	238.01	15480	15050	41	8385	239.66	15580	15153	41	8442	238.01	
2	NESC Rule 250D	1.07	3.63	3.78	28550	27504	75	7274	276.70	28550	27504	75	7274	276.70	28550	27504	75	7274	276.70	
3	32deg, .5", 0psf	0.00	1.39	1.39	12384	12062	33	8674	231.59	12248	11922	32	8574	234.34	12333	12010	32	8637	232.61	
4	60deg, 0", 97mph	1.31	0.68	1.47	12905	12558	34	8523	235.74	12775	12424	34	8432	238.31	12860	12511	34	8492	236.62	
5	60deg, 0", 12.2 psf	0.66	0.68	0.94	8694	8483	23	8987	223.47	8556	8341	22	8837	227.29	8621	8409	23	8908	225.46	
6	0deg, 0", 4psf	0.22	0.68	0.71	6887	6736	18	9469	211.99	6754	6600	18	9278	216.41	6812	6659	18	9361	214.46	
7	60deg, 0", 6psf	0.32	0.68	0.75	7062	6897	19	9184	218.63	6934	6766	18	9010	222.90	6990	6824	18	9086	221.01	
8	0	0.00	0.68	0.68	6591	6448	17	9510	211.08	6460	6314	17	9313	215.59	6516	6371	17	9397	213.63	
9	32	0.00	0.68	0.68	6502	6357	17	9376	214.13	6376	6228	17	9186	218.59	6430	6283	17	9268	216.64	
10	60	0.00	0.68	0.68	6427	6280	17	9262	216.77	6305	6155	17	9078	221.20	6357	6209	17	9157	219.27	
11	90	0.00	0.68	0.68	6350	6201	17	9146	219.55	6232	6080	16	8968	223.95	6282	6132	16	9044	222.05	
12	120	0.00	0.68	0.68	6275	6125	16	9033	222.31	6161	6007	16	8860	226.70	6209	6057	16	8933	224.83	MOT-OPGW
13	152	0.00	0.68	0.68	6198	6045	16	8916	225.26	6088	5932	16	8749	229.59	6135	5980	16	8820	227.72	MOT-Normal-Conductor ACCR/TW Cumberland
14	166	0.00	0.68	0.68	6165	6012	16	8867	226.52	6056	5900	16	8702	230.85	6102	5947	16	8772	229.00	MOT-Emergency-Conductor ACCR/TW Cumberland

(OPGW Sag @ 60 F, No Ice , No Wind, Final)/(Conductor ACCR/TW Cumberland Sag @ 60 F, No Ice, No Wind, Final)x100= 221.20/275.47x100=80.3% <=85%, OK

(OPGW Sag @ 32 F, 0.5" Ice, No Wind, Final)/(Conductor ACCR/TW Cumberland Sag @ 32 F, No Ice, No Wind, Final)x100= 234.34/272.56x100=85.9% <=95%, OK

(OPGW Sag @ 60 F, No Ice , No Wind, Final)/(Conductor ACCR/TW Pecos Sag @ 60 F, No Ice, No Wind, Final)x100= 221.20/286.84x100=77.1% <=85%, OK

(OPGW Sag @ 32 F, 0.5" Ice, No Wind, Final)/(Conductor ACCR/TW Pecos Sag @ 32 F, No Ice, No Wind, Final)x100= 234.34/284.03x100=82.5% <=95%, OK

Note: Appendix G is using Power & Ampacity from conceptual design Rev.D, however the conclusions are still valid for the updated performance requirements.

POWER ENGINEERS

Appendix G1

Clean Line Energy-Plains & Eastern +/- 600 kV HVDC Line

Mississippi River Crossing Span=4000 Ft

Metal Return Conductor (MRC)- Comparison and Selection

Conductor Type	**Normal Regime** I pole=3100 A; I metal return conductor=I pole/2=1550 A	**Emergency Regime** **(20% over Normal regime)** I pole=3720 A; I metal return conductor=I pole/2=1680 A
ACSR CHUCKAR $3.35/ft	MOT=200 F (93 C): Final Sag @ MOT: 372.35' NESC Rule 250D-Initial Controls @ 75%RBS	MOT=238 F (114 C): Final Sag @ MOT: 376.03' NESC Rule 250D-Initial Controls @ 75%RBS
ACCR/TW PECOS **$24.16/ft** **(selected)**	MOT=216 F (102 C): Final Sag @ MOT: 302.24' NESC Rule 250D- Initial Controls @ 75%RBS	MOT=263 F (128 C): **Final Sag @ MOT: 304.83'** NESC Rule 250D- initial Controls @ 75%RBS

Notes:

1. It was chosen as Metallic Return Conductor for Mississippi River Crossing the ACCR/TW Pecos because even if this will mean an additional cost of about $262K for the 3 spans of the Mississippi River Crossing Section (being $20.81/ ft more expensive), the fact that the tower height will be reduced by about 71.2' (due to the difference in final sags @ MOT), will provide savings (tower, foundation, erection, etc.) higher than the additional $262K put in the MRC.

2. In the Mississippi River Crossing, ACCR/TW Pecos it is used as **both** Pole Conductor and Metal Return Conductor (MRC):
   - When used as **Pole Conductor**:
     - Normal Regime:
     - I pole conductor=I pole/3=3100 A/3=**1033.3 A**, with corresponding:
       - **MOT=160 F (71 C),** and final sag=**297.07'**
     - Emergency Regime:
     - I pole conductor=I pole/3=3720 A/3=**1240 A**, with corresponding:
       - **MOT=178 F (81 C),** and final sag=**299.71'**
   - When used as **Metal Return Conductor**:
     - Normal Regime:
     - I pole conductor=I pole/2=3100 A/2=**1550 A**, with corresponding:
       - **MOT=216 F (102 C),** and final sag=**302.24'**
     - Emergency Regime:
     - I pole conductor=I pole/2=3720 A/2=**1860 A**, with corresponding:
       - **MOT=263 F (128 C**), and final sag=**304.83'**

ACCR/TW Pecos-with DC Resistances:

Cable Data

Cable Model

- (•) Nonlinear cable model (separate polynomials for initial and creep behavior for inner and outer materials)
- ( ) Linear elastic with permanent stretch due to creep proportional to creep weather case tension
- ( ) Linear elastic with permanent stretch due to creep specified as a user input temperature increase

Name: r:\pls\pls_cadd\projects\119990 clean line\cables\mississippi river crossing-conductor selection\pecos_acss_tw_dc.wir

Description: ACCR-TW_1622-T13 PECOS

Stock Number:

Cross section area (in^2) 1.437 | Unit weight (lbs/ft) 1.774

Outside diameter (in) 1.417 | Ultimate tension (lbs) 55500

Number of independent wires (1 unless messenger supporting other wires with a spacer): 1

[ ] Conductor is a J-Power Systems GAP type conductor strung with core supporting all tension.

Temperature at which strand data below obtained (deg F) 71

Outer Strands

Final modulus of elasticity (see note below) (psi/100) 73166

Thermal expansion coeff. (/100 deg) 0.00128

Polynomial coefficients (all strains in %, stresses in psi, see note

	a0	a1	a2	a3	a4
Stress-strain		47982	-26959	-10541	5466
	c0	c1	c2	c3	c4
Creep		22891	-16083	4103	-2138

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of outer strand area to total area.

Core Strands (if different from outer strands)

Final modulus of elasticity (see note below) (psi/100) 40134

Thermal expansion coeff. (/100 deg) 0.00035

Polynomial coefficients (all strains in %, stresses in psi, see note

	b0	b1	b2	b3	b4
Stress-strain		42224	-8710	-4138	2156
	d0	d1	d2	d3	d4
Creep		42224	-8710	-4138	2156

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of core strand area to total area.

Bimetallic Conductor Model...

Aluminum has a larger thermal expansion coefficient than steel. If Aluminum is used as the outer material over a steel core there is a temperature transition point at which the aluminum is no longer under tension.

Select the behavior you want for temperatures above the transition point

- ( ) Use behavior from Criteria/Bimetallic Conductor Model
- ( ) Aluminum does not take compression at high temperature (Bird Cage)
- (•) Aluminum can go into compression at high temperature

VirtualStress = ActualStress * Ao / At
Ao = cross section area of outer strands
At = total cross section area of entire conductor (outer + inner strands)

Maximum virtual compressive stress (ksi) 1.25

Thermal Rating Properties

Resistance at two different temperatures

Resistance (Ohm/mile) 0.0547 at (deg F) 68

Resistance (Ohm/mile) 0.0666 at (deg F) 167

Emissivity coefficient 0.5

Solar absorption coefficient 0.5

Outer strands heat capacity (Watt-s/ft-deg F) 367.7

Core heat capacity (Watt-s/ft-deg F) 20.1

[Generate Coefficients from points on stress-strain curve] [Composite cable properties] [OK] [Cancel]

POWER ENGINEERS

PROJECT: 119990 CLEAN LINE - EASTERN PLAINS ± 600 kV DC | PROJECT NUMBER: 119990

SUBJECT: DC Resistance Calculation for 3M's CONDUCTOR ACCR/TW PECOS | BY: CRISTIAN MILITARU | DATE: 12/27/2010

CHECKED BY: | DATE:

3M's WEBSITE CATALOG: ACCR/TW PECOS:

$R_{dc\,@20°C=68°F} = 0.0547\ \Omega/mile$

$R_{ac\,@25°C=77°F} = 0.0560\ \Omega/mile$

$R_{ac\,@75°C=167°F} = 0.0671\ \Omega/mile$

$\Rightarrow R_{ac\,@75°C} = R_{ac\,@25°C} \cdot [1 + CTR \cdot (75° - 25°)]$

$$\Rightarrow CTR = \left(\frac{R_{ac\,@75°C}}{R_{ac\,@25°C}} - 1\right) \Big/ (75° - 25°) = \left(\frac{0.0671}{0.0560} - 1\right) \Big/ (75° - 25°) = \underline{0.00396}\ [1/°C]$$

$$R_{dc\,@75°C} = R_{dc\,@20°C} \cdot [1 + CTR \cdot (75° - 20°)] = 0.0547 \cdot [1 + 0.00396 \cdot (75° - 20°)] = \underline{0.0666\ \Omega/mile}$$

created accr_tw_pecos_dc.wir with:

$R_{dc\,@20°C=68°F} = \underline{0.0547\ \Omega/mile}$

$R_{dc\,@75°C=167°F} = \underline{0.0666\ \Omega/mile}$

Using PLS-CADD, IEEE-738 Method and running sag/tension in PLS-CADD LITE:

ACCR/TW PECOS: USED AS [POLE CONDUCTOR] in RIVER CROSSING:

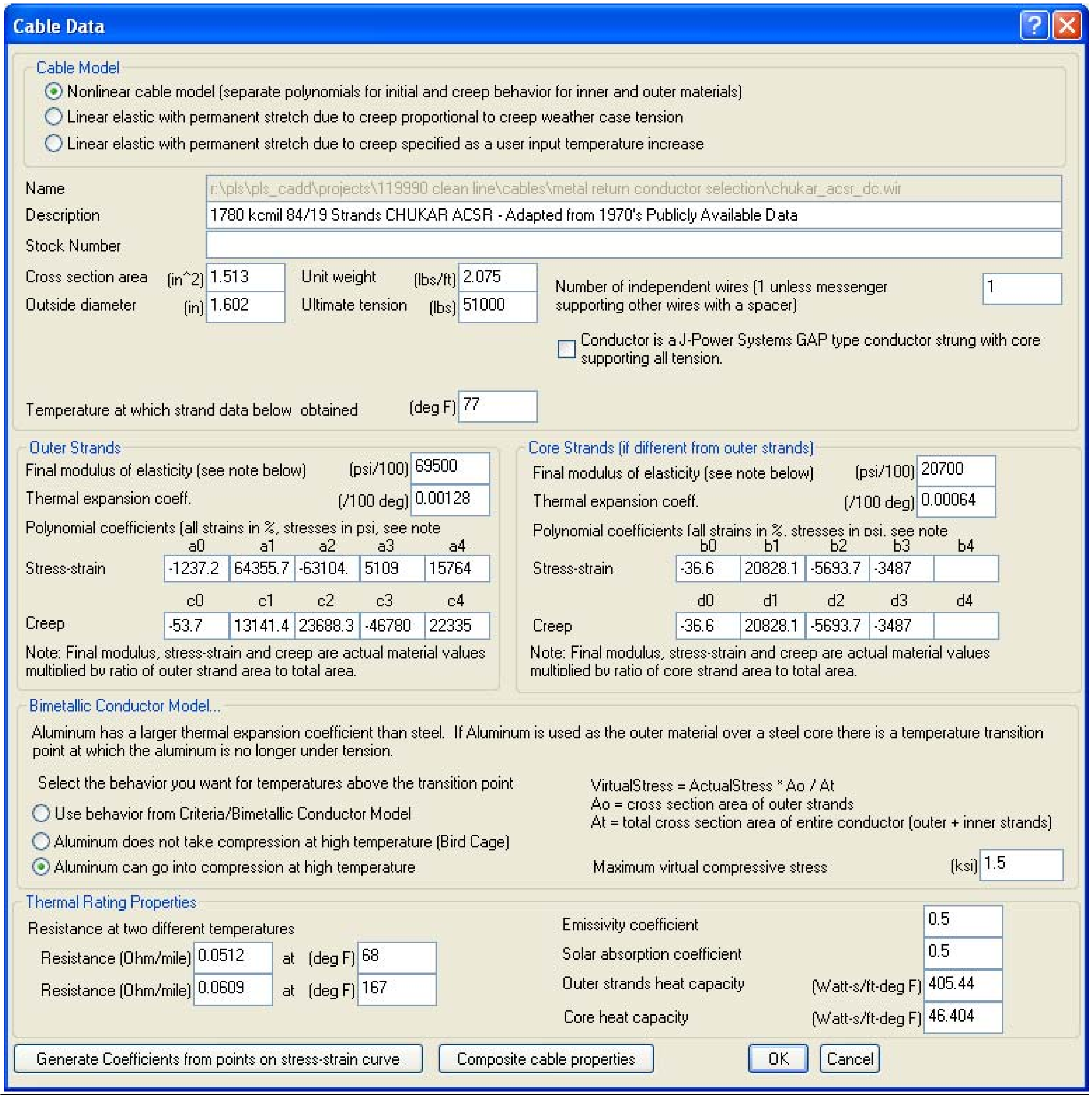
Conductor Type	Normal Regime $I_{pole} = 3100A$; $I_{cond} = I_{pole}/3 = 1033.3A$	Emergency Regime (20% over Normal Regime) $I_{pole} = 3720A$; $I_{cond} = I_{pole}/3 = 1240A$
ACCR/TW PECOS	MOT = 160°F = 71°C River Crossing Span = 4000 ft Final Sag @ MOT = 296.75'	MOT = 178°F = 81°C River Crossing Span = 4000 ft Final Sag @ MOT = 298.55'

ACCR/TW PECOS USED AS [METAL RETURN CONDUCTOR] IN RIVER CROSSING

Conductor Type	Normal Regime $I_{pole} = 3100A$; $I_{metal\,return} = I_{pole}/2 = 1550A$	Emergency Regime (20% over Normal Regime) $I_{pole} = 3720A$; $I_{metal\,return} = I_{pole}/2 = 1860A$
ACCR/TW PECOS	MOT = 216°F = 102°C River Crossing Span = 4000 ft Final Sag @ MOT = 302.24'	MOT = 263°F = 128°C River Crossing Span = 4000 ft Final Sag @ MOT = 304.83'

ACSR CHUCKAR wire File with DC Resistances

acsr_chuckar_dc.wir



POWER ENGINEERS

SHEET NUMBER: 1 OF 1

PROJECT: CLEAN LINE: ± 600kVDC

PROJECT NUMBER: 119940

SUBJECT: ACSR CHUKAR - DC RESISTANCES CALCULATION

BY: CRISTIAN MILITARU DATE: 01/19/2011

CHECKED BY: DATE:

1780 kcmil ACSR CHUKAR: Per Southwire's Catalog:

$$\begin{cases} R_{dc@20°C=68°F} = 0.0512\ \Omega/mile \\ R_{ac@25°C=77°F} = 0.0561\ \Omega/mile \\ R_{ac@75°C=167°F} = 0.0658\ \Omega/mile \end{cases} \Rightarrow R_{ac@75°C} = R_{ac25°C} \cdot [1 + CTR \cdot (75° - 25°)] \Rightarrow$$

$$\Rightarrow CTR = \left(\frac{R_{ac@75°C}}{R_{ac@25°C}} - 1\right) / (75° - 25°) = \left(\frac{0.0658}{0.0561} - 1\right) / (75° - 25°) = 0.00346\ [1/deg\ C]$$

$$\Rightarrow R_{dc@75°C} = R_{dc@20°C} \cdot [1 + CTR \cdot (75° - 20°)] = 0.0512 \cdot [1 + 0.00346 \cdot (75 - 20)] = 0.0609\ \Omega/mile$$

I created acsr_chukar_dc.wir with:

$$\begin{cases} R_{dc@20°C=68°F} = 0.0512\ \Omega/mile \\ R_{dc@75°C=167°F} = 0.0609\ \Omega/mile \end{cases}$$

Using PLS-CADD - IEEE 738 Method: I = 1860 A (emergency regime). MOT = 238 F = 114°C.

POWER ENGINEERS

SHEET NUMBER: 1 OF 1

PROJECT: CLEAN LINE : ±600kV DC

PROJECT NUMBER: 118990

SUBJECT: ACSR LAPWING - DC RESISTANCES CALCULATION

BY: CRISTIAN MILITARU DATE: 01/20/2011

CHECKED BY: DATE:

1590kcmil ACSR LAPWING: Per Southwire's Catalog:

$$\begin{cases} R_{dc@20^\circ C=68^\circ F} = 0.0572 \ \Omega/mile \\ R_{ac@25^\circ C=77^\circ F} = 0.0620 \ \Omega/mile \\ R_{ac@75^\circ C=167^\circ F} = 0.0733 \ \Omega/mile \end{cases} \Rightarrow R_{ac\,75^\circ C} = R_{ac\,25^\circ C} \cdot [1 + CTR \cdot (75-25)] \Rightarrow$$

$$\Rightarrow CTR = \left(\frac{R_{ac@75^\circ C}}{R_{ac@25^\circ C}} - 1\right) / (75^\circ - 25^\circ) = \left(\frac{0.0733}{0.0620} - 1\right) / (75^\circ - 25^\circ) = 0.00364 \ [1/deg\,C]$$

$$\Rightarrow R_{dc@75^\circ C} = R_{dc@20^\circ C} \cdot [1 + CTR \cdot (75^\circ - 20^\circ)] = 0.0572\,[1 + 0.00364 \cdot (75^\circ - 20^\circ)] = 0.0687 \ \Omega/mile$$

I created acsr_lapwing_dc.wir units:

$$\begin{cases} R_{dc@20^\circ C=68^\circ F} = 0.0572 \ \Omega/mile \\ R_{dc@75^\circ C=167^\circ F} = 0.0687 \ \Omega/mile \end{cases}$$

Using PLS-CADD IEEE 738 Method: I = 1860A (emergency regime): MOT = 281°F = 127°C

$$\begin{cases} m_{AL} = 1.4981 \ lbs/Ft \\ m_{ST} = 0.2922 \ lbs/Ft \\ m_{total} = 1.7903 \ lbs/Ft \end{cases} \quad \begin{cases} A_{AL} = 1.2492 \ sq.in. \\ A_{ST} = 0.0863 \ sq.in. \\ A_{total} = 1.3355 \ sq.in. \end{cases} \quad \begin{cases} c_{P_{AL}} = 433 \ W \cdot sec/lbs \cdot ^\circ C \\ c_{P_{ST}} = 216 \ W \cdot sec/lbs \cdot ^\circ C \\ \boxed{1.8\,[1/^\circ C] = 1\,[1/^\circ F]} \end{cases}$$

OUTER STRANDS: $m_{AL} \cdot c_{P_{AL}} = 1.4981 \ lbs/Ft \cdot 433 \ W \cdot sec/lbs \cdot ^\circ C = 648.6773 \ W \cdot sec/Ft \cdot ^\circ C = \underline{360.376} \ [W \cdot sec/Ft \cdot ^\circ F]$

CORE: $m_{ST} \cdot c_{P_{ST}} = 0.2922 \ lbs/Ft \cdot 216 \ W \cdot sec/lbs \cdot ^\circ C = 63.1152 \ W \cdot sec/Ft \cdot ^\circ C = \underline{35.064} \ [W \cdot sec/Ft \cdot ^\circ F]$

POWER ENGINEERS

SHEET NUMBER: 1 OF

PROJECT: CLEAN LINE ± 600 kV DC: PLAINS & EASTERN

PROJECT NUMBER: 119990

SUBJECT: METAL RETURN INSULATION CALCULATION

BY: CRISTIAN MILITARU

DATE: 01/19/2011

CHECKED BY:

DATE:

For 2 ACSR Bluebird, that take total 3720A, each one taking 1860A, [2 ACSR Chukar]

the corresponding optimum voltage it is:

$V_{metal\ return} = \pm 43\ kV\ d.c.$ [±53 kV]

Specific Leakage Distance = 34.6 mm/kV (medium contamination)

Total Leakage Distance = 34.6 mm/kV · 43 kV = 1488 mm = 58.58 inches (medium contamination) [53 kV, 1834 mm = 72.20 inches]

To be Used: Sediver's Toughened Glass DC Fog Type | N 180 P/C 171 DR 180kN (40 kips)

latest DC Insulator Catalog

M&E Strength = 180 kN = 40 kips
Spacing = 171 mm = 6.75"
Diameter = 330 mm = 13"
Leakage Distance = 550 mm / bell

Necessary Number of Bells = $\frac{\text{Total Leakage Distance}}{\text{Insulator Leakage Distance per Bell}} = \frac{1488\ mm}{550\ mm/bell} = 2.7 \approx 3$ bells [1834 mm, 3.33 ≈ 4 bells]

Necessary Insulator Length = Spacing · Number of Bells = 171 mm · 3 bells = 513 mm ≅ 1.7 ft [4 bells, 684 mm ≈ 2.24 ft]

Insulator Hardware Length = 0.9 ft (both sides of the insulator string)

Total Necessary Insulator Length = 3 Bells + Hardware = 1.7 ft + 0.9 ft = 2.6 ft = 0.91 m [2.24, = 3.14 ft = 0.95 m]

PLS-CADD Version 10.76x64   8:57:28 AM Wednesday, May 25, 2011
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\clean line_plains & eastern 600kv dc_segment 7.DON'
Line Title: 'Lattice Tower (Design Span=1500')'

METAL RETURN CONDUCTOR

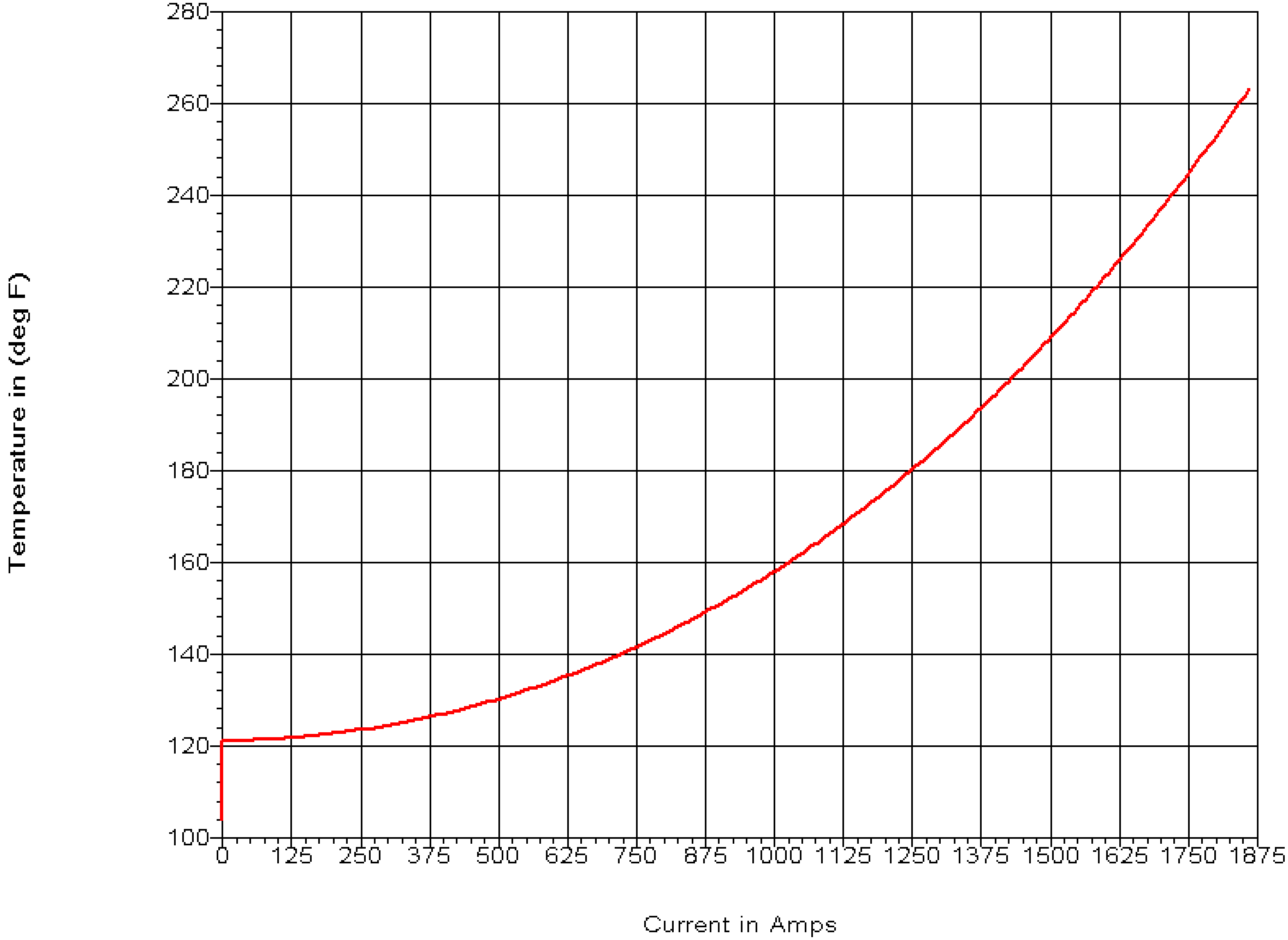
IEEE Std. 738-2006 method of calculation
EMERGENCY REGIME: I pole=3720 A; I metal return conductor=3720 A/2=1860 A
(20% over Normal Regime: I pole=3100 A)

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 1000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2011) (day of the year with most solar heating)

Conductor description: ACCR-TW_1622-T13 PECOS
Conductor diameter is 1.417 (in)
Conductor resistance is   0.0547 (Ohm/mile) at 68.0 (deg F)
                    and   0.0666 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   5.700 (Watt/ft) (corresponds to Global Solar Radiation of   96.549 (Watt/ft^2) - which was calculated)
Radiation cooling is   15.974 (Watt/ft)
Convective cooling is   40.921 (Watt/ft)

Given a constant ac current of 1860.0 amperes,
The conductor temperature is 263.0 (deg F)



280
260
240
220
200
180
160
140
120
100
Temperature in (deg F)
0 125 250 375 500 625 750 875 1000 1125 1250 1375 1500 1625 1750 1875
Current in Amps

METAL RETURN CONDUCTOR

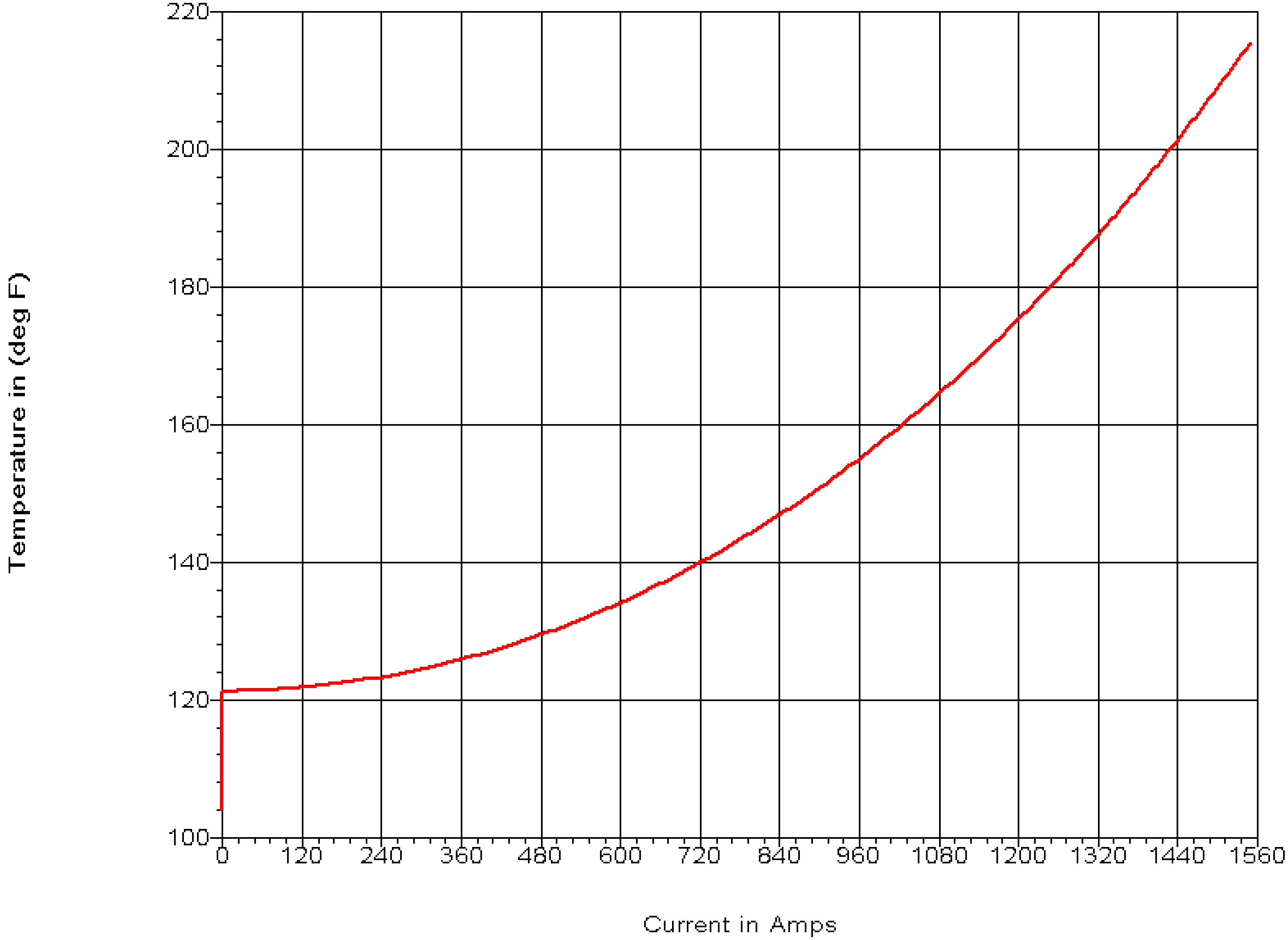
IEEE Std. 738-2006 method of calculation
NORMAL REGIME: I pole=3100 A; I metal return conductor=3100/2=1550 A

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 1000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2011) (day of the year with most solar heating)

Conductor description: ACCR-TW_1622-T13 PECOS
Conductor diameter is 1.417 (in)
Conductor resistance is   0.0547 (Ohm/mile) at 68.0 (deg F)
                    and   0.0666 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   5.700 (Watt/ft) (corresponds to Global Solar Radiation of   96.549 (Watt/ft^2) - which was calculated)
Radiation cooling is   9.936 (Watt/ft)
Convective cooling is   28.721 (Watt/ft)

Given a constant ac current of 1550.0 amperes,
The conductor temperature is 215.5 (deg F)



220
200
180
160
140
120
100
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440
1560
Temperature in (deg F)
Current in Amps

METAL RETURN CONDUCTOR

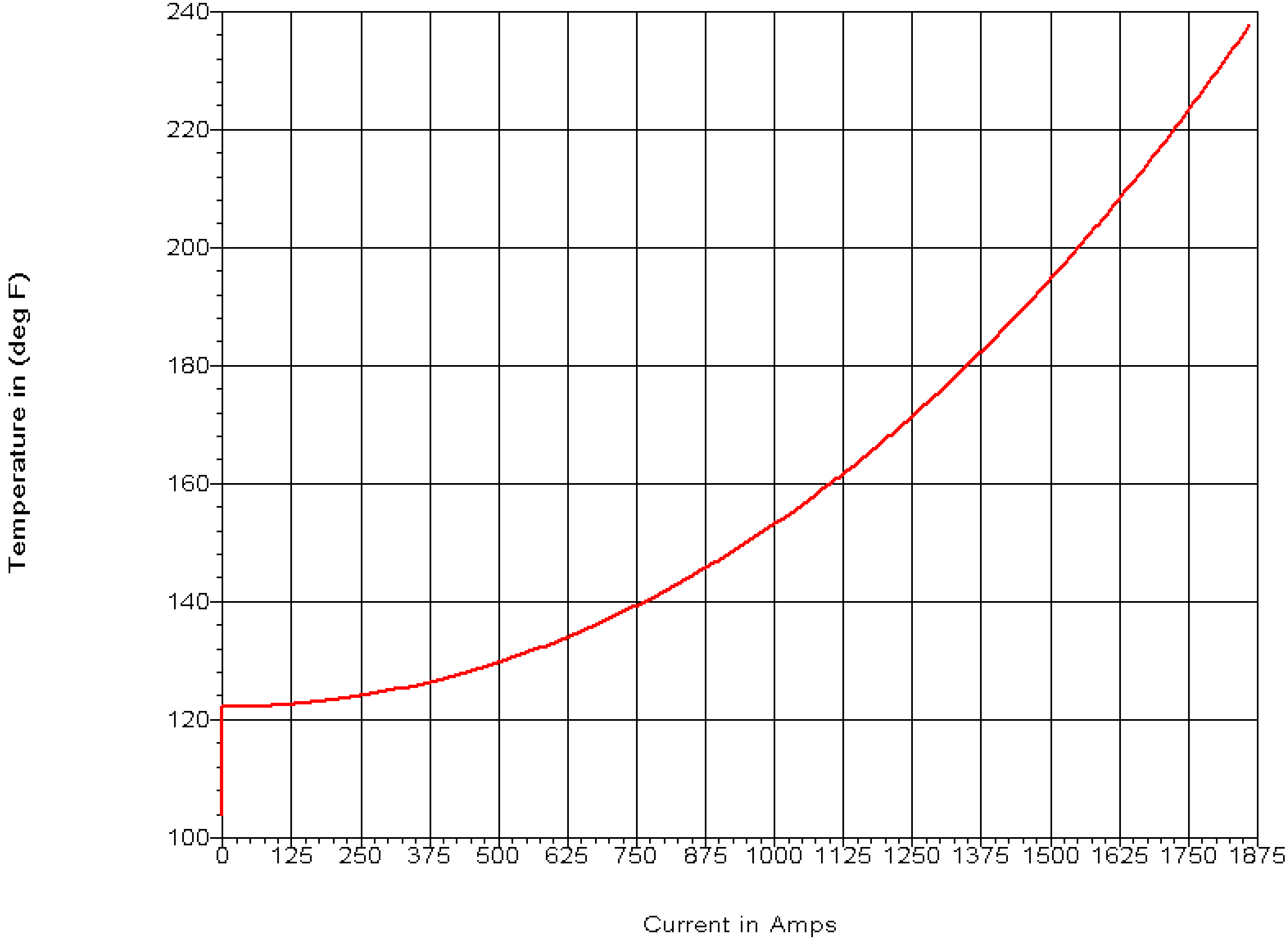
IEEE Std. 738-2006 method of calculation
EMERGENCY REGIME: I pole=3720 A; I metal return conductor=3720/2=1860 A
(20% over Normal regime: I pole=3100 A)

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 1000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2011) (day of the year with most solar heating)

Conductor description: 1780 kcmil 84/19 Strands CHUKAR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.602 (in)
Conductor resistance is   0.0512 (Ohm/mile) at 68.0 (deg F)
                    and   0.0609 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   6.445 (Watt/ft) (corresponds to Global Solar Radiation of   96.549 (Watt/ft^2) - which was calculated)
Radiation cooling is   14.245 (Watt/ft)
Convective cooling is   36.636 (Watt/ft)

Given a constant dc current of 1860.0 amperes,
The conductor temperature is 237.6 (deg F)



Temperature in (deg F)
240
220
200
180
160
140
120
100
0 125 250 375 500 625 750 875 1000 1125 1250 1375 1500 1625 1750 1875
Current in Amps

METAL RETURN CONDUCTOR

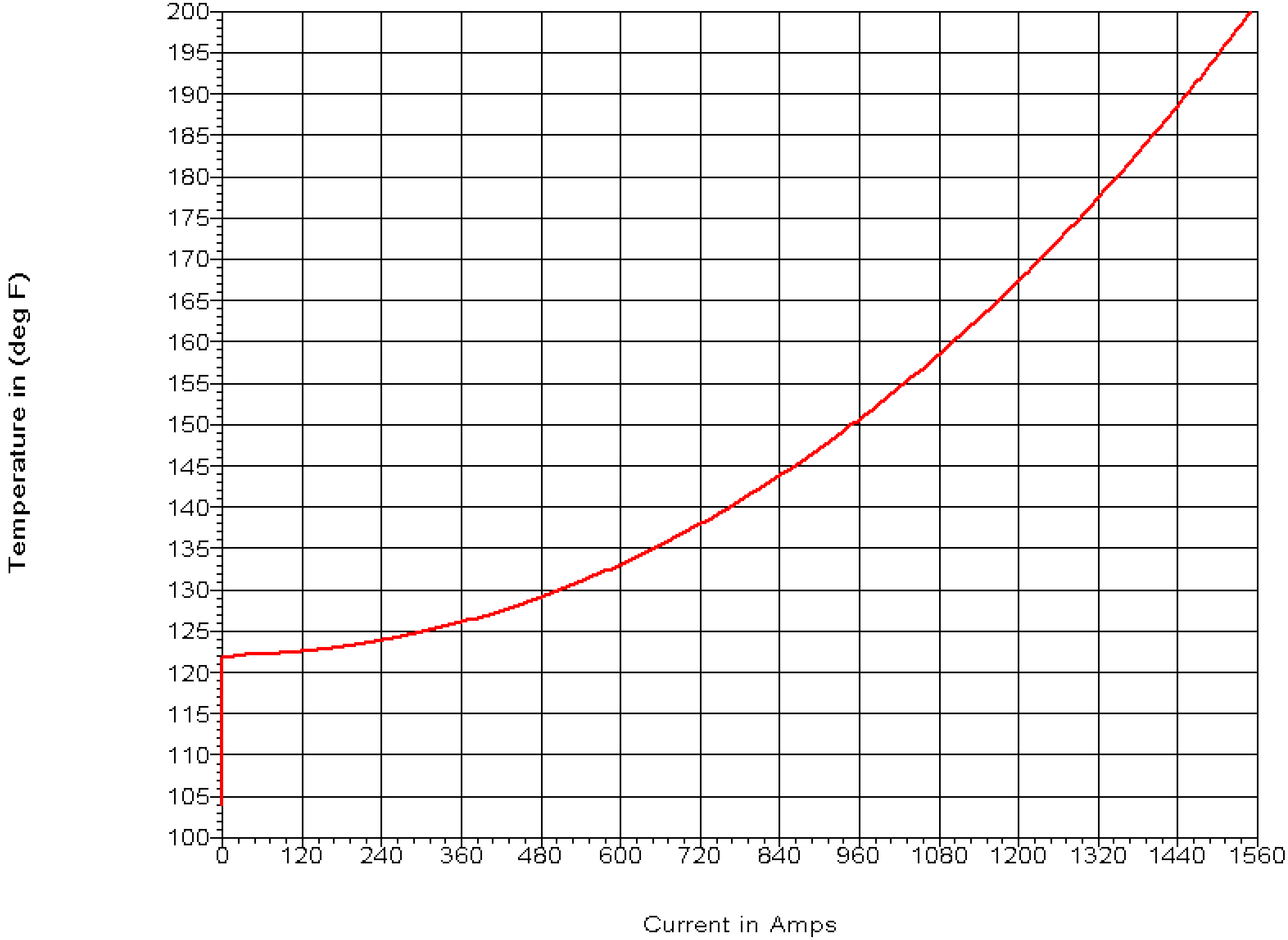
IEEE Std. 738-2006 method of calculation
NORMAL REGIME: I pole=3100 A; I metal return ondutor=3100/2=1550 A

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 1000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2011) (day of the year with most solar heating)

Conductor description: 1780 kcmil 84/19 Strands CHUKAR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.602 (in)
Conductor resistance is   0.0512 (Ohm/mile) at 68.0 (deg F)
                    and   0.0609 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   6.445 (Watt/ft) (corresponds to Global Solar Radiation of   96.549 (Watt/ft^2) - which was calculated)
Radiation cooling is   9.294 (Watt/ft)
Convective cooling is   26.333 (Watt/ft)

Given a constant ac current of 1550.0 amperes,
The conductor temperature is 200.0 (deg F)


Temperature in (deg F)
200
195
190
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
105
100
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440
1560
Current in Amps

PLS-CADD Version 10.76x64   10:17:07 AM Wednesday, May 25, 2011
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\cables\mississippi river crossing-conductor selection\clean line_river crossing=4000 ft-mrc_accr_tw pecos.LOA'

Criteria notes:
River Crossing Span=4000 ft- ACCR/TW Pecos used as METAL RETURN CONDUCTOR : I mrc=I pole/2: 1550 A (Normal); 1860 A (Emergency)
NESC Rule 250D-Extreme Ice with Concurrent Wind-Initial @ 75% Controls (Conductor ACCR/TW Pecos)

Section #1 '1:Back'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\pecos_accr_tw_dc.wir', Ruling span (ft) 4000
Sagging data: Catenary (ft) 7130.78, Horiz. Tension (lbs) 12650 Condition I Temperature (deg F) 60.0001
Weather case for final after creep 60, Equivalent to 44.8 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B, Equivalent to 42.7 (deg F) temperature increase

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	Res.	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-Rule 250B	0.81	2.97	3.37	24559	23588	44	6992	287.99	24539	23567	44	6986	288.25	24559	23588	44	6992	287.99	
2	NESC Rule 250D	1.34	5.92	6.07	41616	39748	75	6549	307.76	41616	39748	75	6549	307.76	41616	39748	75	6549	307.76	
3	32deg, .5", 0psf	0.00	2.97	2.97	21607	20753	39	6997	287.78	21488	20629	39	6955	289.54	21505	20647	39	6961	289.28	
4	60deg, 0", 97mph	2.87	1.77	3.37	24203	23216	44	6882	292.68	24098	23106	43	6849	294.09	24117	23126	43	6855	293.83	
5	60deg, 0", 12.2 psf	1.44	1.77	2.29	16762	16109	30	7049	285.63	16573	15912	30	6963	289.21	16586	15926	30	6969	288.96	
6	0deg, 0", 4psf	0.47	1.77	1.84	13823	13314	25	7252	277.53	13664	13148	25	7162	281.08	13674	13158	25	7168	280.85	
7	60deg, 0", 6psf	0.71	1.77	1.91	14121	13580	25	7109	283.20	13930	13381	25	7005	287.46	13941	13392	25	7011	287.22	
8	0	0.00	1.77	1.77	13376	12885	24	7263	277.11	13216	12718	24	7169	280.80	13226	12728	24	7175	280.56	
9	32	0.00	1.77	1.77	13255	12759	24	7192	279.88	13079	12575	24	7088	284.03	13087	12584	24	7094	283.82	
10	60	0.00	1.77	1.77	13150	12650	24	7131	282.33	12962	12453	23	7020	286.84	12972	12464	23	7026	286.59	
11	90	0.00	1.77	1.77	13041	12536	23	7066	284.93	12840	12325	23	6948	289.85	12850	12336	23	6954	289.61	
12	120	0.00	1.77	1.77	12935	12425	23	7004	287.51	12722	12203	23	6879	292.81	12732	12213	23	6884	292.57	
13	216	0.00	1.77	1.77	12604	12079	23	6809	295.84	12364	11827	22	6667	302.24	12372	11837	22	6672	302.00	MOT-Normal
14	263	0.00	1.77	1.77	12449	11917	22	6717	299.94	12269	11728	22	6611	304.83	12269	11728	22	6611	304.83	MOT-Emergency

PLS-CADD Version 10.76x64   11:29:18 AM Wednesday, May 25, 2011
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\pls cadd lite\clean line_river crossing=4000 ft-acsr chuckar.loa'

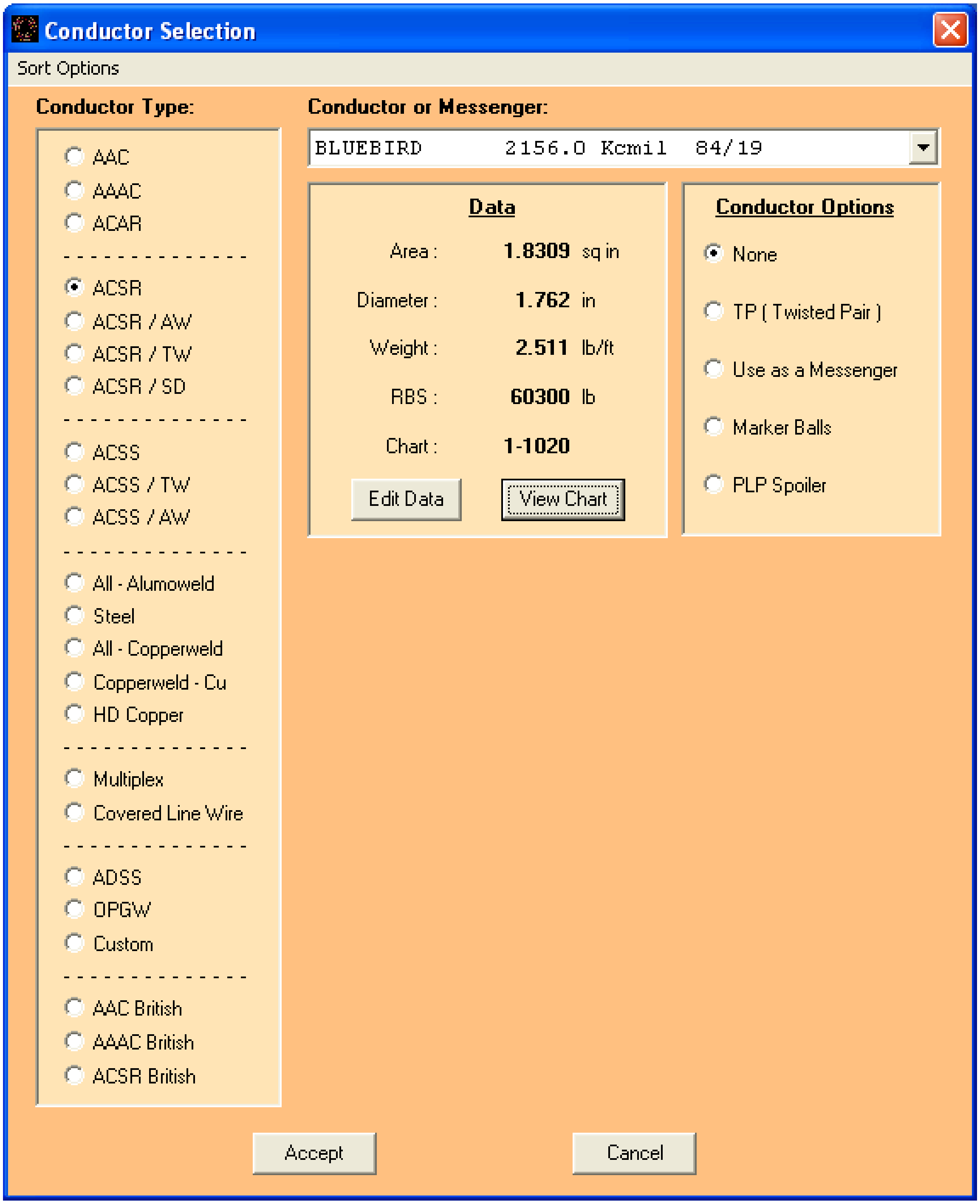
Criteria notes:
River Crossing Span=4000 ft- ACSR Chuckar used as METAL RETURN CONDUCTOR: I mrc=I pole/2: 1550 A (Normal); 1860 A (Emergency)
NESC-Rule 250D-Extreme Ice with Concurrent Wind-Initial @75% Controls (Conductor ACSR Chuckar)

Section #1 '1:Back'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\metal return conductor selection\chukar_acsr_dc.wir', Ruling span (ft) 4000
Sagging data: Catenary (ft) 5783.13, Horiz. Tension (lbs) 12000 Condition I Temperature (deg F) 60.0001
Weather case for final after creep 60, Equivalent to 94.2 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B, Equivalent to 34.3 (deg F) temperature increase

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**	**Res.**	**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-Rule 250B	0.87	3.38	3.79	23026	21687	45	5720	353.23	22696	21334	45	5627	359.20	23026	21687	45	5720	353.23	
2	NESC Rule 250D	1.40	6.51	6.66	38335	35832	75	5382	375.88	38335	35832	75	5382	375.88	38335	35832	75	5382	375.88	
3	32deg, .5", 0psf	0.00	3.38	3.38	20516	19320	40	5713	353.69	20167	18947	40	5602	360.80	20460	19259	40	5695	354.82	
4	60deg, 0", 97mph	3.24	2.08	3.85	23067	21685	45	5631	358.92	22723	21317	45	5536	365.25	23045	21661	45	5625	359.32	
5	60deg, 0", 12.2 psf	1.63	2.08	2.64	16061	15132	31	5737	352.18	15731	14780	31	5603	360.76	15959	15023	31	5695	354.80	
6	0deg, 0", 4psf	0.53	2.08	2.14	13320	12583	26	5873	343.86	13020	12264	26	5724	352.99	13216	12472	26	5821	346.97	
7	60deg, 0", 6psf	0.80	2.08	2.22	13615	12836	27	5771	350.03	13314	12515	26	5627	359.22	13507	12721	26	5719	353.27	
8	0	0.00	2.08	2.08	12911	12199	25	5879	343.50	12618	11886	25	5728	352.70	12807	12088	25	5826	346.70	
9	32	0.00	2.08	2.08	12811	12092	25	5827	346.59	12521	11782	25	5678	355.89	12706	11980	25	5773	349.90	
10	60	0.00	2.08	2.08	12724	12000	25	5783	349.31	12438	11693	24	5635	358.64	12619	11887	25	5729	352.68	
11	90	0.00	2.08	2.08	12635	11904	25	5737	352.17	12350	11599	24	5590	361.61	12528	11790	25	5682	355.65	
12	120	0.00	2.08	2.08	12547	11810	25	5692	355.03	12263	11507	24	5545	364.59	12438	11694	24	5636	358.63	
13	200	0.00	2.08	2.08	12319	11567	24	5574	362.65	12045	11272	24	5432	372.35	12210	11449	24	5518	366.46	MOT-Normal
14	238	0.00	2.08	2.08	12215	11455	24	5521	366.26	11944	11164	23	5380	376.03	12105	11337	24	5464	370.15	MOT-Emergency

APPENDIX I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Conductor Type:
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ACSR
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ACSR / TW
ACSR / SD
ACSS
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ACSS / AW
All - Alumoweld
Steel
All - Copperweld
Copperweld - Cu
HD Copper
Multiplex
Covered Line Wire
ADSS
OPGW
Custom
AAC British
AAAC British
ACSR British
Conductor or Messenger:
BLUEBIRD 2156.0 Kcmil 84/19
Data
Area : 1.8309 sq in
Diameter : 1.762 in
Weight : 2.511 lb/ft
RBS : 60300 lb
Chart : 1-1020
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View Chart
Conductor Options
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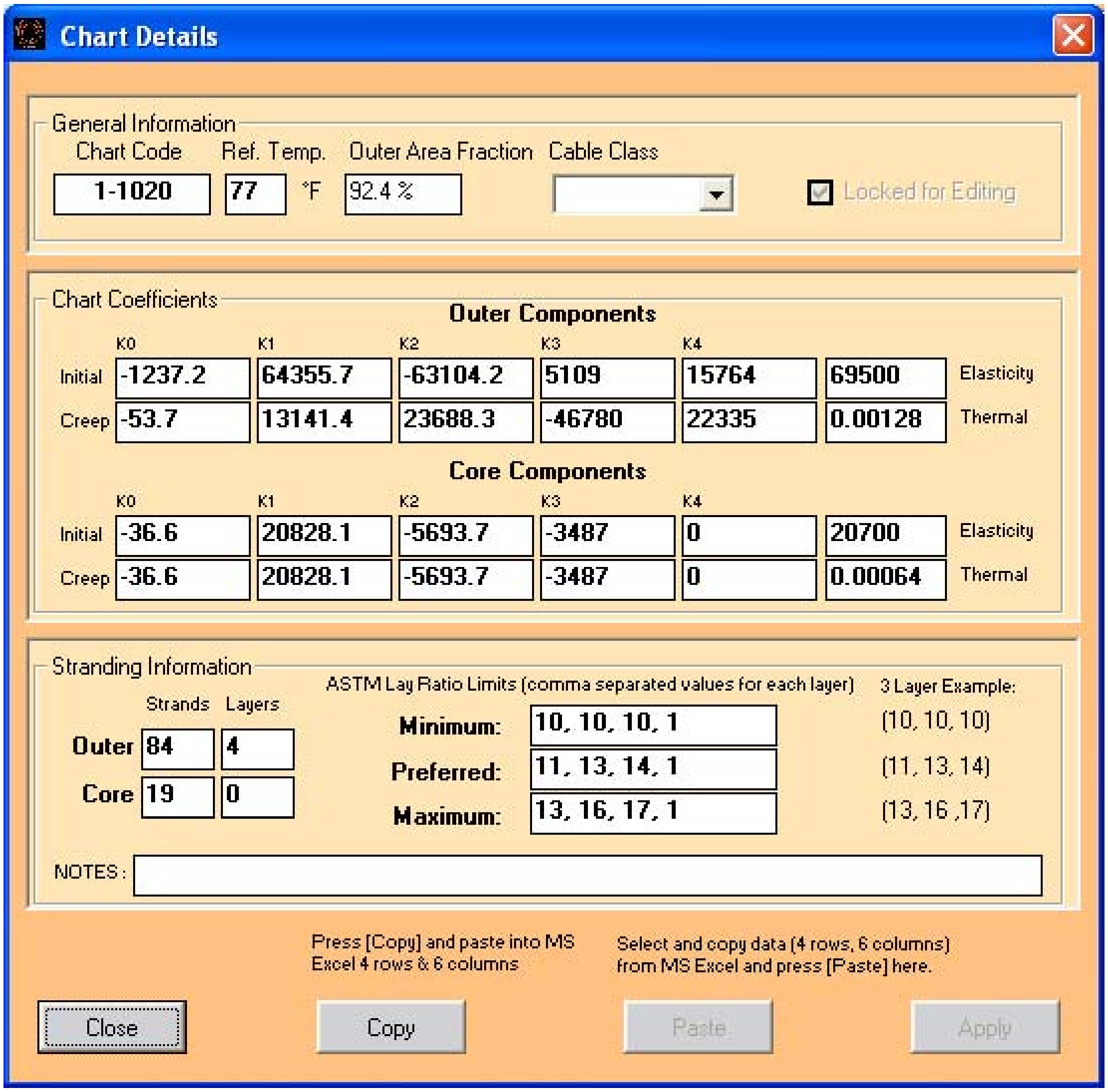
TP (Twisted Pair)
Use as a Messenger
Marker Balls
PLP Spoiler
Accept
Cancel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General Information
Chart Code
Ref. Temp.
Outer Area Fraction
Cable Class
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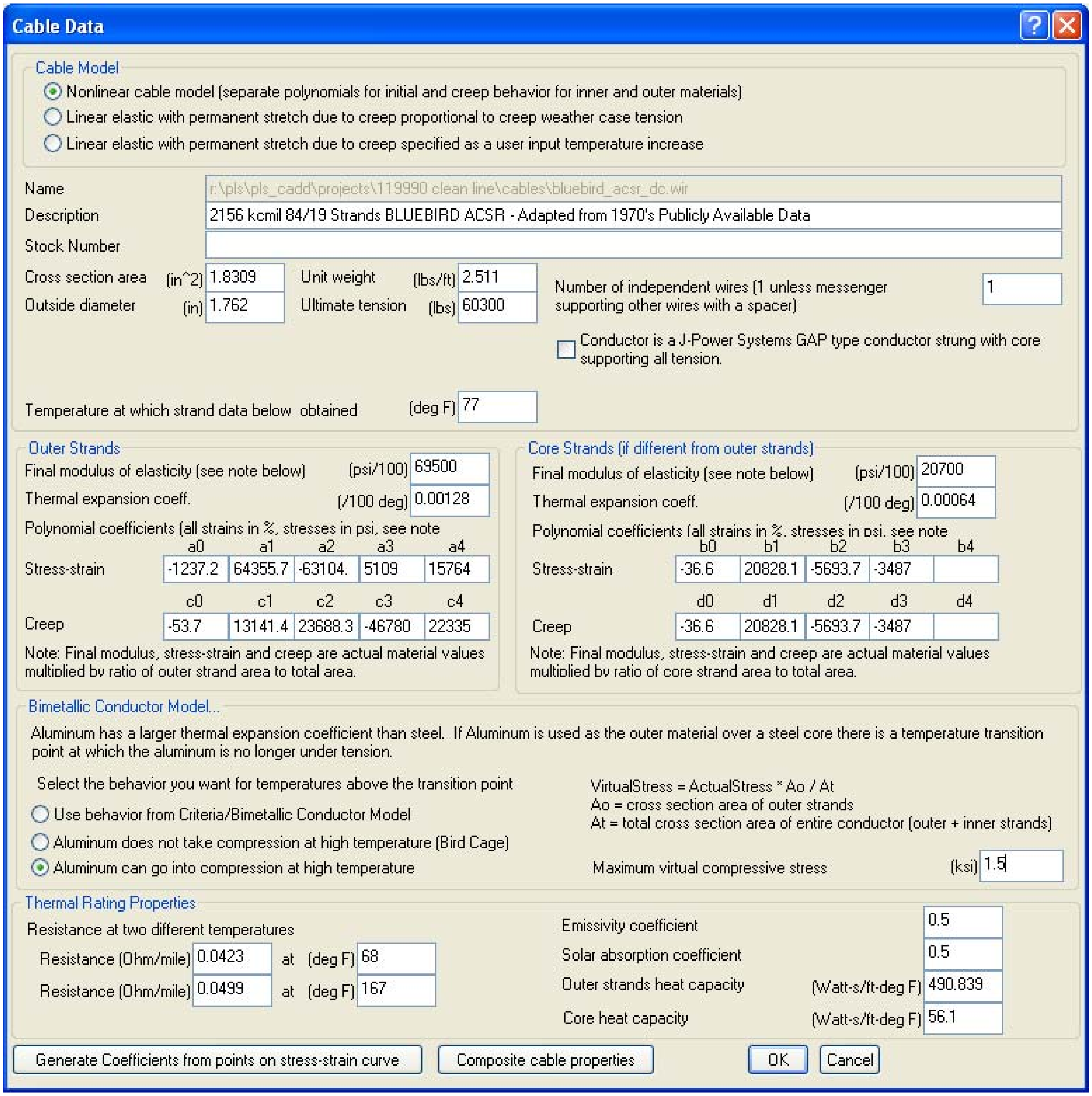
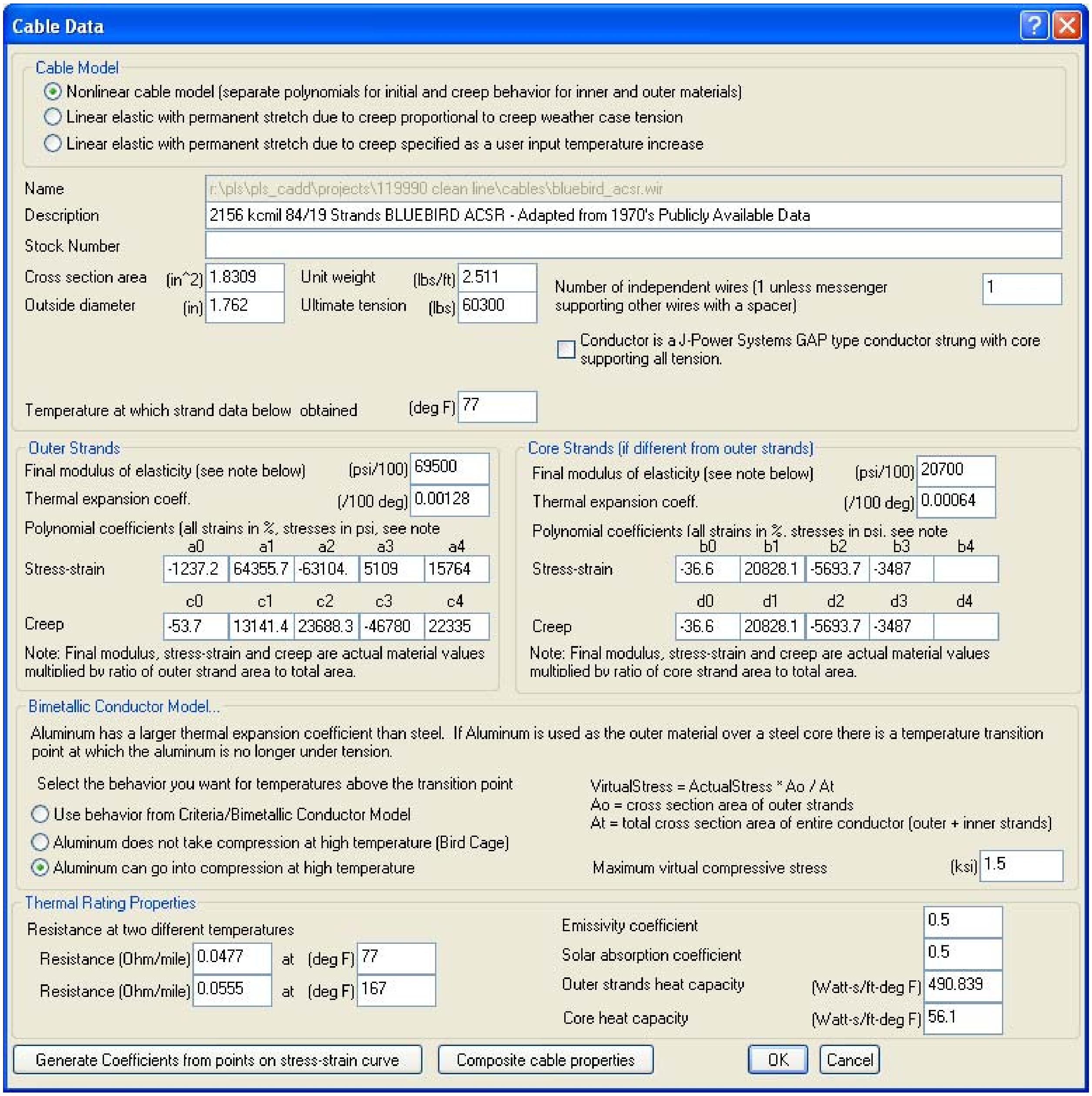
77
°F
92.4 %
Locked for Editing
Chart Coefficients
Outer Components
K0
K1
K2
K3
K4
Initial
-1237.2
64355.7
-63104.2
5109
15764
69500
Elasticity
Creep
-53.7
13141.4
23688.3
-46780
22335
0.00128
Thermal
Core Components
K0
K1
K2
K3
K4
Initial
-36.6
20828.1
-5693.7
-3487
0
20700
Elasticity
Creep
-36.6
20828.1
-5693.7
-3487
0
0.00064
Thermal
Stranding Information
Strands
Layers
Outer
84
4
Core
19
0
ASTM Lay Ratio Limits (comma separated values for each layer)
Minimum:
10, 10, 10, 1
Preferred:
11, 13, 14, 1
Maximum:
13, 16, 17, 1
3 Layer Example:
(10, 10, 10)
(11, 13, 14)
(13, 16 ,17)
NOTES :
Press [Copy] and paste into MS Excel 4 rows & 6 columns
Select and copy data (4 rows, 6 columns) from MS Excel and press [Paste] here.
Close
Copy
Paste
Apply

acsr_bluebird_dc.wir: the resistances values in this table are DC Resistances:



acsr_bluebird.wir: the resistances values in this table are AC Resistances:



Cable Data

Cable Model

- (•) Nonlinear cable model (separate polynomials for initial and creep behavior for inner and outer materials)
- ( ) Linear elastic with permanent stretch due to creep proportional to creep weather case tension
- ( ) Linear elastic with permanent stretch due to creep specified as a user input temperature increase

Name: r:\pls\pls_cadd\projects\119990 clean line\cables\bluebird_acsr.wir

Description: 2156 kcmil 84/19 Strands BLUEBIRD ACSR - Adapted from 1970's Publicly Available Data

Stock Number:

Cross section area (in^2) 1.8309 | Unit weight (lbs/ft) 2.511

Outside diameter (in) 1.762 | Ultimate tension (lbs) 60300

Number of independent wires (1 unless messenger supporting other wires with a spacer) 1

[ ] Conductor is a J-Power Systems GAP type conductor strung with core supporting all tension.

Temperature at which strand data below obtained (deg F) 77

Outer Strands

Final modulus of elasticity (see note below) (psi/100) 69500

Thermal expansion coeff. (/100 deg) 0.00128

Polynomial coefficients (all strains in %, stresses in psi, see note

	a0	a1	a2	a3	a4
Stress-strain	-1237.2	64355.7	-63104.	5109	15764

	c0	c1	c2	c3	c4
Creep	-53.7	13141.4	23688.3	-46780	22335

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of outer strand area to total area.

Core Strands (if different from outer strands)

Final modulus of elasticity (see note below) (psi/100) 20700

Thermal expansion coeff. (/100 deg) 0.00064

Polynomial coefficients (all strains in %, stresses in psi, see note

	b0	b1	b2	b3	b4
Stress-strain	-36.6	20828.1	-5693.7	-3487	

	d0	d1	d2	d3	d4
Creep	-36.6	20828.1	-5693.7	-3487	

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of core strand area to total area.

Bimetallic Conductor Model...

Aluminum has a larger thermal expansion coefficient than steel. If Aluminum is used as the outer material over a steel core there is a temperature transition point at which the aluminum is no longer under tension.

Select the behavior you want for temperatures above the transition point

- ( ) Use behavior from Criteria/Bimetallic Conductor Model
- ( ) Aluminum does not take compression at high temperature (Bird Cage)
- (•) Aluminum can go into compression at high temperature

VirtualStress = ActualStress * Ao / At
Ao = cross section area of outer strands
At = total cross section area of entire conductor (outer + inner strands)

Maximum virtual compressive stress (ksi) 1.5

Thermal Rating Properties

Resistance at two different temperatures

Resistance (Ohm/mile) 0.0477 at (deg F) 77

Resistance (Ohm/mile) 0.0555 at (deg F) 167

Emissivity coefficient 0.5

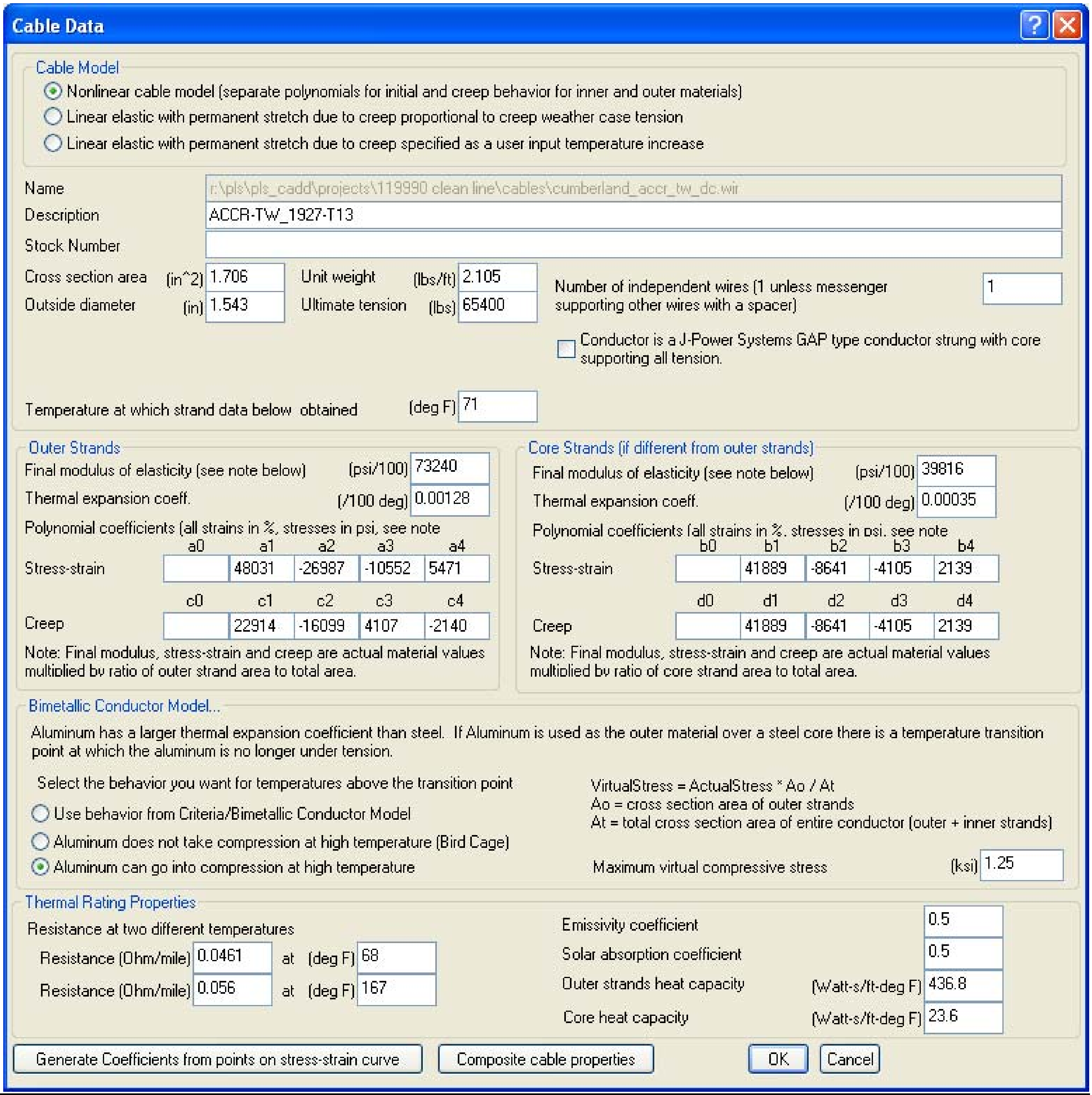
Solar absorption coefficient 0.5

Outer strands heat capacity (Watt-s/ft-deg F) 490.839

Core heat capacity (Watt-s/ft-deg F) 56.1

[Generate Coefficients from points on stress-strain curve] [Composite cable properties] [OK] [Cancel]

ACCR/TW Cumberland- with DC Resistances:



APPENDIX P – METAL RETURN CLEARANCES TABLES

Comparison of Clearances for Clean Line +/- 600 kV Project Plains & Eastern

Case	**NESC- DC** V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	**NESC- AC Equivalent** V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230 H V max=68 KV (5% over V nom)	**EPRI** T/L Reference Book HVDC Lines	**MAD* for Tools** (IEEE 516-2009) **+ Working Space** (NESC Rule 236& 237)	**Conclusion**: Values used in design
Conductor to Ground:	V max=56 KV dc pole to ground < 139 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	Rule 232 B and 232 C:	Not addressed.	N/A	
a. Track rails of railroads		27.07’ (bare) 27’ (rounded to 0.5’) 28’ (w/1’ buffer)			**28’**
b. Streets, Alleys, roads, driveways, and parking lots		19.07’ (bare) 19’ (rounded to 0.5’) 20’ (w/1’ buffer)			**20’**
c. Spaces and ways subject to pedestrians or restricted traffic:		15.07’ (bare) 15’ (rounded to 0.5’) 16’ (w/1’ buffer)			**16’**
d. Vehicular areas		19.07’ (bare) 19’ (rounded) 20’ (w/1’ buffer)			**20’**
Conductor to Water:	V max=56 KV dc pole to ground < 139 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	Rule 232, Table 232-1:	Not addressed.	N/A	
e. Water areas not suitable for sail boating or where sail boating is prohibited		17.57’ (bare) 17.5’ (rounded to 0.5’) 18.5’ (w/1’ buffer)			**18.5’**
f. Water areas suitable for sail boating, including rivers, lakes, ponds, canals with unobstructed surface area:					
1) less than 0.08 km^2 (20 acres)		21.07’ (bare) 21’ (rounded to 0.5’) 22’ (w/1’ buffer)			**22’**
(2) over 0.08 to 0.8 km^2 (20 to 200 acres)		29.07’ (bare) 29’ (rounded to 0.5’) 30’ (w/1’ buffer)			**30’**
3) over 0.8 to 8 km^2 (200 to 2000 acres)		35.07’ (bare) 35’ (rounded to 0.5’) 36’ (w/1’ buffer)			**36’**
(4) over 8 km^2 (2000 acres) Mississippi River Crossing		41.07’ (bare) 41’ (rounded to 0.5’) 42’ (w/1’ buffer)			**42’**

Case	**NESC- DC** V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	**NESC- AC Equivalent** V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230 H V max=68 KV (5% over V nom)	**EPRI** T/L Reference Book HVDC Lines	**MAD* for Tools** (IEEE 516-2009) **+ Working Space** (NESC Rule 236& 237)	**Conclusion**: Values used in design
Conductor to Own Structure No Wind	V max=56 KV dc pole to ground < 139 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	1.217’ (bare) 1.5’ (rounded tp 0.5’) 2’ (w/0.5’ buffer) Rule 235E, Table 235-6, item 4b	1’ No Wind Case corresponds to Lightning Impulse, required clearance from Figure 10-13, page 150. Lightning Surge will be at least 30% higher than Switching Surge: 96*1.3=125 kV Surge Factor: Ti=1.8	N/A	**2’**
Conductor to Own Structure Medium Wind 6 psf	V max=56 KV dc pole to ground < 139 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	1.217’ (bare) 1.5’ (rounded to 0.5’) 2’ (w/0.5’ buffer) Rule 235E, Table 235-6, item 4b	0.82’ Medium Wind Case corresponds to Switching Impulse, required clearance from Figure 10-13, page 150 Switching Surge=1.8*53 =96 kV Surge Factor: Ti=1.8	N/A	**2’**
Conductor to Own Structure Extreme Wind 24.3 psf	Not addressed	Not addressed	0.5’ (no buffer) 0.75’ (w/0.25’ buffer) Extreme Wind corresponds to Steady State required clearance from Fig.10-3 , Page 145 and Fig.10-4, Page 146.	Not addressed	**0.75’**

*MAD=Minimum Approach Distance.

NESC-Clearance Conductor to Ground calculation:

NESC- DC: V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	**NESC- AC Equiv** V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230 H V max=68 KV (5% over V nom)
V max=56 KV dc pole to ground < 139 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	Equivalent max ac system voltage=65*1.05=68 KV Equivalent max ac system voltage, phase-to-ground=68/sqrt(3)=39 kV NESC Rule 232, Table 232-1, open supply conductor up to 22 kv: a. Track rails of railroads: H basic=26.5’ b. Streets, Alleys, roads, driveways, and parking lots: H basic=18.5’ c. Spaces and ways subject to pedestrians or restricted traffic: H basic=14.5’ d. Vehicular areas: H basic=18.5’ Voltage Adder: C adder=(39-22)*0.4”/12=0.57’ Altitude adder : zero a. Track rails of railroads: C total=H basic + C adder= 26.5’ + 0.57’=**27.07’ (bare)** **27’ (rounded to nearest 0.5’)** **28’ (w/1’ buffer)** **CHOSEN** b. Streets, Alleys, roads, driveways, and parking lots: C total=H basic + C adder= 18.5’ + 0.57’=**19.07’ (bare)** **19’ (rounded to nearest 0.5’)** **20’ (w/1’ buffer)** **CHOSEN** c. Spaces and ways subject to pedestrians or restricted traffic : C total=H basic + C adder= 14.5’ + 0.57’=**15.07’ (bare)** **15.5’ (rounded to nearest 0.5’)** **16.5’ (w/1’ buffer)** **CHOSEN** d. Vehicular Areas: C total=H basic + C adder= 18.5’ + 0.57’=**19.07’ (bare)** **19’ (rounded)** **20’ (w/1’ buffer)** **CHOSEN**

NESC- Clearance Conductor-to-Own Structure calculation

for Cases: Medium Wind (6 psf) and No Wind:

NESC- DC:	NESC- AC Equiv
V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230H V max=68 KV (5% over V nom)
V max=56 KV dc pole to ground < 139 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	Equivalent max ac system voltage=65*1.05=68 KV Equivalent max ac system voltage, phase-to-ground=68/sqrt(3)=39 kV NESC Rule 235 E, 4b, open supply conductor up to 50 kv: H basic=11"=0.917' Voltage Adder: C adder=(68-50)*0.2"/12=0.3' Altitude adder : zero C total=H basic + C adder= 0.917' + 0.3'=**1.217' (bare)** **1.5' (rounded to nearest 0.5')** **2' (w/0.5' buffer)** **CHOSEN**

NESC- Clearance to Anchor Guys calculation:

for Cases: Medium Wind (6 psf) and No Wind:

	NESC- AC Equiv
V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230H V max=68 KV (5% over V nom)
V max=56 KV dc pole to ground < 139 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	Equivalent max ac system voltage=65*1.05=68 KV Equivalent max ac system voltage, phase-to-ground=68/sqrt(3)=39 kV NESC Rule 235 E, 4b, open supply conductor up to 50 kv: H basic=16"=1.333' Voltage Adder: C adder=(68-50)*0.25"/12=0.375' Altitude adder : zero C total=H basic + C adder= 1.333' + 0.375'=**1.708' (bare)** **1.7' (rounded to nearest 0.5')** **2.2 ' (w/0.5' buffer)** **CHOSEN**

NESC-Clearance to Right –of-Way (Blowout):

for Cases: Medium Wind (6 psf) and No Wind:

NESC- DC:	NESC- AC Equiv
V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230H V max=68 KV (5% over V nom)
V max=56 KV dc pole to ground < 139 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	Equivalent max ac system voltage=65*1.05=68 KV Equivalent max ac system voltage, phase-to-ground=68/sqrt(3)=39 kV NESC Rule 234B, clearance to buildings, open supply conductor up to 22 kv: H basic=4.5' (**with 6 psf wind)** H basic=7.5' (**with no wind**) Voltage Adder: C adder=(39-22)*0.4"/12=0.566' Altitude adder : zero **Medium Wind (6 psf):** C total=H basic + C adder= 4.5' + 0.566'=**5.066' (bare)** **5' (rounded)** **5.5' (w/0.5' buffer)** **CHOSEN** **No Wind (0 psf):** C total=H basic + C adder= 7.5' + 0.566'=**8.066' (bare)** **8' (rounded)** **8.5' (w/0.5' buffer)** **CHOSEN**

NESC- Clearance Conductor-to-Water calculation

NESC- DC: V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	**NESC- AC Equiv** V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230H V max=68 KV (5% over V nom)
V max=56 KV dc pole to ground < 139 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	Equivalent max ac system voltage=65*1.05=68 KV Equivalent max ac system voltage, phase-to-ground=68/sqrt(3)=39 kV NESC Rule 232, Table 232-1, open supply conductor up to 22 kV: 6. Water areas not suitable for sail boating or where sail boating is prohibited: H basic=17’ 7. Water areas suitable for sail boating, including rivers, lakes, ponds, canals with unobstructed surface area: (1) less than 0.08 km^2 (20 acres): H basic=20.5’ (2) over 0.08 to 0.8 km^2 (20 to 200 acres): H basic=28.5’ (3) over 0.8 to 8 km^2 (200 to 2000 acres): H ref=34.5’ (4) over 8 km^2 (2000 acres): Mississippi River Crossing: H ref=40.5’ Voltage Adder: C adder=(39-22)*0.4”/12=0.57’ Altitude at Mississippi River Crossing location: Alt=300’ from PLS-CADD Model 300’ < 1500’ results: Altitude Adder=0, results: C alt=0 e. Water areas not suitable for sail boating or where sail boating is prohibited: C total=H basic + C adder= 17’ + 0.57’=**17.57’ (bare)** **C total=17.50’ (rounded to nearest 0.5’)** **C total=18.5’ (w/1’ buffer)** **CHOSEN** f. Water areas suitable for sail boating, including rivers, lakes, ponds, canals with unobstructed surface area: (1) less than 0.08 km^2 (20 acres): C total=H basic + C adder= 20.5’ + 0.57’=**21.07’ (bare)** **C total=21’ (rounded to nearest 0.5’)** **C total=22’ (w/1’ buffer)** **CHOSEN** (2) over 0.08 to 0.8 km^2 (20 to 200 acres): C total=H basic + C adder= 28.5’ + 0.57’=**29.07’ (bare)** **C total=29’ (rounded to nearest 0.5’)** **C total=30’ (w/1’ buffer)** **CHOSEN** (3) over 0.8 to 8 km^2 (200 to 2000 acres): C total=H basic + C adder= 34.5’ + 0.57’=**35.07’ (bare)** **C total=35’ (rounded to nearest 0.5’)** **C total=36’ (w/1’ buffer)** 4) over 8 km^2 (2000 acres): Mississippi River Crossing: C total=H basic + C adder= 40.5’ + 0.57’=**41.07’ (bare)** **C total=41’ (rounded to nearest 0.5’)** **C total=42’ (w/1’ buffer)** **CHOSEN**

NESC-Clearance Metal Return Conductor (MRC) to Grain Bins calculation:

NESC- DC:	**NESC- AC Equiv**
V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230 H V max=68 KV (5% over V nom)
V max=56 KV dc pole to ground < 139 kV dc pole to ground **Therefore Alternative DC Calculations are N/A.** But, if is necessary to know what would be the values, here are the calculations: Rule 234H2, Table 234-5, item b: “other installation”” grain bins: V ref=9’; H ref=3’ Rule 234H3a : Electric Clearances: For Ref Altitude < 1500 ft: V=V max=1.05*V nom=1.05*53=56 kV: C ref=3.28*(V*PU*a/(500*k)^1.667*b*c C ref V =3.28*(56*1.8*1.15/(500*1.15)^1.667*1.03*1.2=0.28’ C ref H=3.28*(56*1.8*1.15/(500*1.15)^1.667*1.03*1.0=0.23’ Rule 234H3, b: For assumed maximum altitude for this line (worst case scenario): 3000 ft: Altitude Adder: (3000’-1500’)/1000’*3%=4.5% C alt V =C ref V *1.045=0.28’*1.045=0.29’ C alt H =C ref H *1.045=0.23’*1.045=0.24’ Grain Bins: **Vertical:** V total=V ref + C alt V = 9’ + 0.29’=**9.29’ (bare)** **10’ (rounded)** **13’ (w/3’ buffer)** **Horizontal:** H total=H ref + C alt H = 3’ + 0.24**’** =**3.24’ (bare)** **4’ (rounded)** **7’ (w/3’ buffer)**	Equivalent max ac system voltage=65*1.05=68 KV Equivalent max ac system voltage, phase-to-ground=68/sqrt(3)=40 kV **CASE 1: Rule 234 F1: PERMANENT ELEVATOR** **NESC Figure 234-4 (a):** **Vertical:** NESC Rule 234F1.a, open supply conductor up to 22 kV: Grain Bins: V basic=18’ Rule 234G1: Voltage Adder: C adder=(40-22)*0.4”/12=0.6’ Altitude adder : zero (Altitude, worst case assumed: 3000 ft , which is less than 3300 ft) V total=V basic+ C adder=18’+0.6’=**18.6’ (bare)** **18.6’ (rounded)** **21.6’ (w/3’ buffer)** **CHOSEN** **Horizontal (At Rest, No Wind):** NESC Rule 234F1.b, open supply conductor up to 22 kV: Grain Bins: H basic=15’ Rule 234G1: Voltage Adder: C adder=(40-22)*0.4”/12=0.6’ Altitude adder : zero (Altitude, worst case assumed: 3000 ft , which is less than 3300 ft) H total=H basic+ C adder=15’+0.6’=**15.6’ (bare)** **15.6’ (rounded)** **18.6’ (w/3’ buffer)** **CHOSEN** **Horizontal (Displaced, 6 psf Wind):** NESC Rule 234D1b, open supply conductor up to 22 kV: Grain Bins with permanent elevator under wind are considered as “Building” under wind: H basic=4.5’ Rule 234G1: Voltage Adder: C adder=(40-22)*0.4”/12=0.6’ Altitude adder : zero (Altitude, worst case assumed: 3000 ft , which is less than 3300 ft) H total=H basic+ C adder=4.5’+0.6’=**5.1’ (bare)** **5.1’ (rounded)** **8.1’ (w/3’ buffer)** **CHOSEN**

CASE 2: RULE 234 F 2: PORTABLE ELEVATOR
ARE CONSIDERED BY NESC ONLY AT REST, NO WIND DISPLACEMENT:

CASE 2.1: LOADED SIDE
NESC Figure 234-4 (b):

Vertical:

18.6' (rounded)
21.6' (w/3' buffer)
CHOSEN

Horizontal (At Rest, No Wind):

18.6' (rounded)
21.6' (w/3' buffer)
CHOSEN

CASE 2.2: UN-LOADED SIDE
NESC Figure 234-4 (b):

UNLOADED SIDE is considered by NESC as "Buildings" Rule 234C

Vertical:

Rule 234 C, Table 234-1, 1.Building, b.Vertical,(1)
"building not accessible to pedestrians" (the elevator):

V basic=12.5' (No Wind)

Rule 234G1:
Voltage Adder: C adder=(40-22)*0.4"/12=0.6'

Altitude adder : zero
(Altitude, worst case assumed: 3000 ft , which is less than 3300 ft)

V total=V basic+ C adder=12.5'+0.6'=**13.1' (bare)**
13.1' (rounded)
16.1' (w/3' buffer)
CHOSEN

Horizontal (At Rest, No Wind):
Rule 234 C, Table 234-1, 1Building, a. Horizontal :

H basic=7.5' (No wind)

Rule 234G1:
Voltage Adder: C adder=(40-22)*0.4"/12=0.6'

Altitude adder : zero
(Altitude, worst case assumed: 3000 ft , which is less than 3300 ft)

H total=H basic+ C adder=7.5'+0.6'=**8.1' (bare)**
8.1' (rounded)
11.1' (w/3' buffer)
CHOSEN

Calculations of Required Vertical and Horizontal Clearances +/- 53 kV DC Metal Return Conductor (MRC) to

Under-Crossing Lines or Parallel/Adjacent Lines

500 kV, 345 kV, 230 kV, 161 kV, 138 kV,115 kV, 69 kV, 35 kV, 25, 12.5 KV AC Conductors and 0 KV Groundwire

Different Structures, Different Utilities, Different Circuits

Upper Circuit:

$V_{dc, crest (peak), pole-to-ground}$=53 kV dc   Equivalent to: $V_{ac, rms, phase-to-phase} = 53\ kV * \frac{\sqrt{3}}{\sqrt{2}} = 65\ kV\ ac$

Lower Circuit (Crossing or Parallel):

Vertical Clearance: NESC Rule 233 C.2.a, Table 233-1:

$$V = \frac{\left[24 + \left(65 * \frac{1.05}{\sqrt{3}} + V_{lower} * \frac{1.05}{\sqrt{3}} - 22\right) * 0.4\right]}{12}$$

Horizontal Clearance: NESC Rule 233 B.1.a:

$$H = \frac{\left(65 * \frac{1.05}{\sqrt{3}} + V_{lower} * \frac{1.05}{\sqrt{3}} - 22\right) * 0.4}{12}$$

Altitude: Maximum 3000’ in the entire P&E line, less than 3300’, results: Altitude adder=0 (Rule 233C2.b for Vertical and Rule 233B.2 for Horizontal).

Circuit Type	Upper Circuit: 53 kV dc (equivalent 65 kV ac)				
	Crossing or Parallel: Lower Circuit: V lower [kV]	V [ft] (Bare)	**V [ft] (with 3’buffer)**	H [ft] (Bare)	**H [ft] (with 3’buffer)**
Transmission	500	12.7	**15.7**	10.7	**13.7**
	345	9.6	**12.6**	7.6	**10.6**
	230	7.2	**10.2**	5.2	**8.2**
	161	5.8	**8.8**	3.8	**6.8**
	138	5.4	**8.4**	3.4	**6.4**
	115	4.9	**7.9**	2.9	**5.9**
	69	4.0	**7.0**	2.0	**5.0**
Distribution	35	3.3	**6.3**	1.3	**4.3**
	25	3.1	**6.1**	1.1	**4.1**
	12.5	2.8	**5.8**	0.8	**3.8**
Groundwire	0	2.6	**5.6**	0.6	**3.6**

Required Vertical Clearances are used for Under-Crossing Lines, for following loading cases:

1. Upper 53 KV dc Metal Return Conductor (MRC) at MOT or at 32 F, with Ice (0.5” for Heavy NESC locations; or 0.25” for Medium NESC locations), which ever results in greater sag, and Under-Crossed Line conductor at 60 F Bare.

2. Upper 53 KV dc Metal Return Conductor (MRC) at 60 F, and Under-Crossed Line conductor at 60 F, 6 psf transverse wind (the transverse wind, from both directions, on the Under-Crossing Line is parallel to the 53 kV dc line, thus having no effect on the 53 kV dc line, but having an effect on the Under-Crossing Line, raising its conductor and getting it closer to the 53 kV dc Metal Return Conductor(MRC)).

Required Vertical and Horizontal Clearances are used for Parallel or Adjacent Lines, for following cases:

1. Upper 53 kV dc Metal Return Conductor (MRC) and Parallel Line conductor, both under 6 psf transverse wind, from both directions.

2. Upper 53 KV dc Metal Return Conductor (MRC) at MOT or at 32 F, with Ice (0.5” for Heavy NESC locations; or 0.25” for Medium NESC locations), which ever results in greater sag, and Parallel or Adjacent Line conductor at 60 F Bare.

Note: if the Upper Circuit and Lower Circuit are swapped: Upper Circuit is the 500 KV ac, or 345 KV ac, or 230 KV ac, etc., and the Lower Circuit is the 53 KV dc, loading cases are swapped also, but the required clearances remain the same.

Vertical Clearances +/- 600 kV DC Pole Conductor (PC) to +/- 53 KV DC Metal Return Conductor (MRC):

Different Circuits, Same Supports, Same Utility

NESC- DC:	**NESC- AC Equiv**
Pole Conductor (PC): V nom=600 KV peak, pole-ground V max=632 KV (5% over V nom) Metal Return Conductor (MRC): V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	Pole Conductor (PC): V nom=735 KV rms, phase-to-phase 735=600*sqrt(3)/sqrt(2) Rule 230 H V max=772 KV (5% over V nom) Metal Return Conductor (MRC): V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230 H V max=68 KV (5% over V nom)
V max= V H = 632 KV dc pole to ground > 139 kV dc pole to ground **Therefore Alternative DC Calculations are applicable.** **NESC Rule 235C3: "Alternate Clearances":** can be used, if switching surge factor is known, but it cannot be less than the values from Rule 233C3 (crossing): **Vertical: Rule 233 C3.b (1): Electrical Component:** D=3.28*[((V H*PU+V L)*a)/(500*k)]^1.667*b*c Where: V H = 600*1.05=632 KV, dc, max, pole-to-ground V L = 53*1.05=56 KV, dc, max, pole-to-ground a =1.15 b = 1.03 c = 1.2 k=1.4 PU = 1.8 (switching surge factor) Results: D=12.46' DC Line Altitude Adder ("threshold" value:1500'): Assumed Altitude=3000' (worst case)> 1500', results: (3000'-1500')/1000'*3%=4.5% D alt =D*1.045=12.46*1.045=13.02' LIMITS: Rule 233 C3c:, Table 233-1. Vertical: the "Alternate Clearance" shall not be less than the clearances required by Rule 233C1 & 233C2, with the lower voltage circuit at ground potential: D=2+0.4/12*[600*1.05/sqrt(2)+0KV-22]=16.12'**,** **rounded up: 17' (bare)** **D=17'+3' buffer=20' (with 3' buffer)**	**NESC Rule 235 C :** **Vertical Clearance of Different Circuits, Same Supports, Same Utility:** **Rule 235.C.2a, Table 235-5, 2d: SAME UTILITY, AT SUPPORTS:** V=[16/12+(50-8.7)*0.4/12]+[(735*1.05/sqrt(3)+65*1.05/sqrt(3)-50)*0.4/12]= =2.71' + 14.50'=17.2'**, rounded up: 17.5' (bare)** **V=17.5'+3' buffer=20.5' (with 3' buffer) CHOSEN** **Rule 235.C.2.b(1),(b): SAME UTILITY, IN SPAN:** V=[16/12+(50-8.7)*0.4/12]*0.75 +[(735*1.05/sqrt(3)+65*1.05/sqrt(3)-50)*0.4/12]= =2.03' + 14.50'=16.53'**, rounded up: 17' (bare)** **V=17'+3' buffer=20' (with 3' buffer) CHOSEN** AC Line Altitude Adder ("threshold" value 3300'): Assumed 3000' (worst case) < 3300', results: Altitude Adder=0.

Horizontal Clearances +/- 600 kV DC Pole Conductor (PC) to +/- 53 KV DC Metal Return Conductor (MRC):

Different Circuits, Same Supports, Same Utility

NESC- DC:	**NESC- AC Equiv**
Pole Conductor (PC): V nom=600 KV peak, pole-ground V max=632 KV (5% over V nom) Metal Return Conductor (MRC): V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	Pole Conductor (PC): V nom=735 KV rms, phase-to-phase 735=600*sqrt(3)/sqrt(2) Rule 230 H V max=772 KV (5% over V nom) Metal Return Conductor (MRC): V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230 H V max=68 KV (5% over V nom)
V max= V H = 632 KV dc pole to ground > 139 kV dc pole to ground **Therefore Alternative DC Calculations are applicable.** **NESC Rule 235B3: "Alternate Clearances":** can be used, if switching surge factor is known, but it cannot be less than the values from Rule 235B3.b: **Vertical: Rule 235 B3: Electrical Component:** D=3.28*[(V L-L*PU*a)/(500*k)]^1.667*b Where: V L-L = maximum dc operating voltage between poles of different Cricuits, same support structure: V L-L = V H+ V L = 632 + 56 =688 KV, dc, max, pole-to-pole V H = 600*1.05=632 KV, dc, max, pole-to-ground V L = 53*1.05=56 KV, dc, max, pole-to-ground PU = 1.8 (switching surge factor) a=1.15 b=1.03 k=1.4 **Results:** D=11' DC Line Altitude Adder ("threshold" value:1500'): Assumed Altitude=3000' (worst case)> 1500', results: (3000'-1500')/1000'*3%=4.5% **D alt**=D*1.045=11*1.045=**11.50' (bare)** **D alt=11.50't+3' buffer=14.50' (with 3' buffer)** **Limit: Rule 235B.3.b: the clearance derived from Rule 235B3a Should not be less than the basic clearance given in Table 235-1 computed for 169 kV ac:** **C limit=28.5/12+0.4/12*(169*1.05-500=6.62' (bare)** **D =11.50' (bare)> C limit=6.62' (bare), OK** **Results:** **H=14.5' (with 3' buffer)**	**NESC Rule 235 B :** **Horizontal Clearance of Different Circuits, Same Supports, Same Utility:** **Rule 235B.1.a, Table 235-1: Supply Conductors of different circuits:** H=28.5/12+0.4/12*(735*1.05/sqrt(3)+65*1.05/sqrt(3)-50)= =2.375'+14.50'=16.875'**, rounded up: 17' (bare)** **H=17'+3' buffer=20' (with 3' buffer) CHOSEN** **Rule 235B.1b, Clearance according to Sags:** C=0.3/12*(735*1.05/sqrt(3)+65*1.05/sqrt(3))+8/12*sqrt(56.195*12/12)= =12.125'+5'=**17.125', rounded: 17' (bare)** results**: C=17'+3' buffer=20' (with 3' buffer) CHOSEN** S=sag in ft, at 60 F, final, unloaded sag, no wind, no ice: 600 KV dc : ACSR Bluebird: S 60 F, final=56.81' in RS=1500' 53 kV dc: ACSR Chukar: S 60 F, final=55.58' in RS=1500' S avg = (56.81'+55.58')/2=56.195' AC Line Altitude Adder ("threshold" value 3300'): Assumed 3000' (worst case) < 3300', results: Altitude Adder=0.

Vertical Clearances +/- 53 kV DC Metal Return Conductor (MRC) to 0 KV Shieldwire (OPGW):

Different Circuits, Same Supports, Same Utility

NESC- DC:	**NESC- AC Equiv:**
Metal Return Conductor (MRC): V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	Metal Return Conductor (MRC): V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230 H V max=68 KV (5% over V nom)
V max= 56 KV dc pole to ground < 139 kV dc pole to ground **Therefore Alternative DC Calculations are N/A.** But, if is necessary to know what would be the values, here are the calculations: **NESC Rule 235C3: "Alternate Clearances":** can be used, if switching surge factor is known, but it cannot be less than the values from Rule 233C3 (crossing): **Vertical: Rule 233 C3.b (1): Electrical Component:** D=3.28*[((V H*PU+V L)*a)/(500*k)]^1.667*b*c Where: V H = 53*1.05=56 KV, dc, max, pole-to-ground V L = 0 KV (shieldwire) a =1.15 b = 1.03 c = 1.2 k=1.4 PU = 1.8 (switching surge factor) Results: D=0.2' DC Line Altitude Adder ("threshold" value:1500'): Assumed Altitude=3000' (worst case)> 1500', results: (3000'-1500')/1000'*3%=4.5% D alt =D*1.045=0.2*1.045=0.21' LIMITS: Rule 233 C3c:, Table 233-1. Vertical: the "Alternate Clearance" shall not be less than the clearances required by Rule 233C1 & 233C2, with the lower voltage circuit at ground potential: D=2+0.4/12*[53*1.05/sqrt(2)+0KV-22]=2.58'**, rounded up: 3' (bare)** **D=3'+1' buffer=4' (with 1' buffer)**	**NESC Rule 235 C :** **Vertical Clearance of Different Circuits, Same Supports, Same Utility:** **Rule 235.C.2a, Table 235-5, 2d: SAME UTILITY, AT SUPPORTS:** **Because : 68/sqrt(3)=39.4 KV, ac, max, phase-to-ground, which is less than 50 KV, there is no additional adder of 0.4 "/ per each KV over 50 KV:** V=[16/12+(50-8.7)*0.4/12]=2.71'**, rounded up: 3' (bare)** **V=3'+1' buffer=4' (with 1' buffer) CHOSEN** **Rule 235.C.2.b(1),(b): SAME UTILITY, IN SPAN:** V=[16/12+(50-8.7)*0.4/12]*0.75=2.03'**, rounded : 2' (bare)** **V=2'+1' buffer=3' (with 1' buffer) CHOSEN** AC Line Altitude Adder ("threshold" value 3300'): Assumed 3000' (worst case) < 3300', results: Altitude Adder=0.

Horizontal Clearances +/- 53 kV DC Metal Return Conductor (MRC) to 0 KV Shieldwire (OPGW):

Different Circuits, Same Supports, Same Utility

NESC- DC:	NESC- AC Equiv
Metal Return Conductor (MRC): V nom=53 KV peak, pole-ground V max=56 KV (5% over V nom)	Metal Return Conductor (MRC): V nom=65 KV rms, phase-to-phase 65=53*sqrt(3)/sqrt(2) Rule 230 H V max=68 KV (5% over V nom)
V max= 56 KV dc pole to ground < 139 kV dc pole to ground **Therefore Alternative DC Calculations are N/A.** But, if is necessary to know what would be the values, here are the calculations: **NESC Rule 235B3: "Alternate Clearances":** can be used, if switching surge factor is known, but it cannot be less than the values from Rule 235B3.b: **Vertical: Rule 235 B3: Electrical Component:** D=3.28*[(V L-L*PU*a)/(500*k)]^1.667*b Where: V L-L = maximum dc operating voltage between poles of different circuits, same support structure: V L-L = V H+ V L = 56 + 0 =56 KV, dc, max, pole-to-pole V H = 53*1.05=56 KV, dc, max, pole-to-ground V L = 0*1.05=0 KV (shieldwire) PU = 1.8 (switching surge factor) a=1.15 b=1.03 k=1.4 **Results:** D=0.17' DC Line Altitude Adder ("threshold" value:1500'): Assumed Altitude=3000' (worst case)> 1500', results: (3000'-1500')/1000'*3%=4.5% **D alt**=D*1.045=0.17*1.045=**0.18' , rounded up: 1'(bare)** **D alt=1 ' +1' buffer=2' (with 1' buffer)**	**NESC Rule 235 B :** **Horizontal Clearance of Different Circuits, Same Supports, Same Utility:** **Rule 235B.1.a, Table 235-1: Supply Conductors of different circuits:** **Because : 68/sqrt(3)=39.4 KV, ac, max, phase-to-ground, which is less than 50 KV, there is no additional adder of 0.4 "/ per each KV over 50 KV:** H=28.5/12=2.375', **rounded up: 2.5' (bare)** **H=2.5'+1' buffer=3.5' (with 1' buffer)** **Rule 235B.1b, Clearance according to Sags:** C=0.3/12*(65*1.05/sqrt(3)+0 kV) + 8/12*sqrt(47.73*12/12)= =0.985'+4.6'=**5.5' (bare);** results**: C=5.5' +1' buffer=6.5' (with 1' buffer) CHOSEN** S=sag in ft, at 60 F, final, unloaded sag, no wind, no ice: 53 kV dc: ACSR Chukar: S 60 F, final=55.58' in RS=1500' 0 KV dc: Shieldwire (OPGW): S 60 F, final=39.88' in RS=1500' S avg =(55.58'+39.88")/2=47.73' AC Line Altitude Adder ("threshold" value 3300'): Assumed 3000' (worst case) < 3300', results: Altitude Adder=0.

Calculations of Required Vertical and Horizontal Clearances +/- 53 kV DC Metal Return Conductor (MRC) to

Other Utility Structure , Signs, Billboards, Fences, Buildings (Roof Accessible and Not Accessible to Pedestrians),

Bridges Super Structure (No Personnel Access), Bridge Deck, Swimming Pools

Summary Table: "AC EQUIVALENT CALCULATIONS":

Case	Reference Clearance 234B, 234C, 234D, 234E		Voltage Adder: Rule 234G1		Total Clearance Without Buffer		**Total Clearance With 3' Buffer**	
	Vertical [ft]	Horizontal [ft]	D Vertical [ft]	D Horizontal [ft]	Vertical [ft]	Horizontal [ft]	**Vertical [ft]**	**Horizontal [ft]**
From Other Supporting Structures (Other Utility Structure)	5.5	5.0 (at rest) 4.5 (displaced)	0	0 (at rest) 0.6 (displaced)	5.5	5.0 (at rest) 5.1 (displaced)	**8.5**	**8.0 (at rest) 8.1 (displaced)**
From Signs, Billboards, Fences, except Bridges and Buildings, above or under catwalks (Accessible to Pedestrians)	13.5	7.5 (at rest) 4.5 (displaced)	0.6	0.6 (at rest) 0.6 (displaced)	14.1	8.1 (at rest) 5.1 (displaced)	**17.1**	**11.1 (at rest) 8.1 (displaced)**
From Signs, Billboards, Fences, except Bridges and Buildings, no catwalks (Not-Accessible to Pedestrians)	8.0	7.5 (at rest) 4.5 (displaced)	0.6	0.6 (at rest) 0.6 (displaced)	8.6	8.1 (at rest) 5.1 (displaced)	**11.6**	**11.1 (at rest) 8.1 (displaced)**
From Buildings (Roof Accessible to Pedestrians)	13.5	7.5 (at rest) 4.5 (displaced)	0.6	0.6 (at rest) 0.6 (displaced)	14.1	8.1 (at rest) 5.1 (displaced)	**17.1**	**11.1 (at rest) 8.1 (displaced)**
Buildings (Roof Not-Accessible to Pedestrians)	12.5	7.5 (at rest) 4.5 (displaced)	0.6	0.6 (at rest) 0.6 (displaced)	13.1	8.1 (at rest) 5.1 (displaced)	**16.1**	**11.1 (at rest) 8.1 (displaced)**
From Bridges Super Structure (No Personnel Access)	12.5	7.5 (at rest) 4.5 (displaced)	0.6	0.6 (at rest) 0.6 (displaced)	13.1	8.1 (at rest) 5.1 (displaced)	**16.1**	**11.1 (at rest) 8.1 (displaced)**
From Bridge Deck	18.5	7.5 (at rest) 4.5 (displaced)	0.6	0.6 (at rest) 0.6 (displaced)	19.1	8.1 (at rest) 5.1 (displaced)	**22.1**	**11.1 (at rest) 8.1 (displaced)**
From Swimming Pools (V=Dim. "A") (H=Dim. "B")	25	17 (at rest) (displaced not defined)	0.6	0.6 (at rest) (displaced not defined)	25.6	17.6 (at rest) (displaced not defined)	**28.6**	**20.6 (at rest) (displaced not defined)**

The Clearances specified in Rule 234B, 234C, 234D, 234E (Equivalent AC) cannot be reduced using Alternate Clearances per Rule 234H2 & 234H3, because:

V max= 56 KV dc pole to ground < 139 kV dc pole to ground, therefore Alternative DC Calculations are N/A for the Metal Return Conductor (MRC).

$V_{dc, crest (peak), pole-to-ground}$=53 kV dc   Equivalent to: $V_{ac, rms, phase-to-phase} = 53\ kV * \frac{\sqrt{3}}{\sqrt{2}} = 65\ kV\ ac$

Clearances of Wires from Other Supporting Structures (Other Utility Structure, Light or Traffic Light Stand):

Standard Clearances Calculations per Rule 234B:

Bare values:

Rule 234B1a: H=5.0' (at rest)

Rule 234B1b: H=4.5'+0.4/12*[65*1.05/sqrt(3)-22]=5.1' (displaced, 6 psf wind)

Rule 234B2. V=5.5'

Altitude adder: zero (Altitude, worst case for P&E Project: 3000 ft , which is less than 3300 ft, the altitude "threshold" for standard clearance calculations)

These values obtained per Rule 234B (AC Equivalent) cannot be replaced (reduced) by Alternate Clearance Calculation (Switching Factor Calculation) per Rule 234H: 234H2, Table 234-5, d+ 234H3a, because:

V max= 56 KV dc pole to ground < 139 kV dc pole to ground, therefore Alternative DC Calculations are N/A for the Metal Return Conductor (MRC).

Clearances of Wires from Signs, Billboards, Chimneys, Antennas, Tanks, Other Installations, except Bridges and Buildings, above or under catwalks and other surfaces upon which personnel walk (Accessible to Pedestrians):

Standard Clearances Calculations per **Rule 234C:**

Bare values:

Rule 234C1a, Table 234-1, item 2.a(1): H=7.5'+0.4/12*[65*1.05/sqrt(3)-22]=8.1' (at rest)

Rule 234C1b: H=4.5'+0.4/12*[65*1.05/sqrt(3)-22]=5.1' (displaced)

Rule 234C1a, Table 234-1, item 2.b (1): V=13.5'+0.4/12*[65*1.05/sqrt(3)-22]=14.1'

These values obtained per **Rule 234C (AC Equivalent**) **cannot be replaced (reduced)** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, Table 234-5, b+ 234H3a, because:**

V max= 56 KV dc pole to ground < 139 kV dc pole to ground, therefore Alternative DC Calculations are N/A for the Metal Return Conductor (MRC).

Clearances of Wires from Signs, Billboards, Chimneys, Antennas, Tanks, Other Installations, except Bridges and Buildings, no catwalks (or other portions that are Not-Accesible to Pedestrians):

Standard Clearances Calculations per **Rule 234C:**

Bare values:

Rule 234C1a, Table 234-1, item 2.a(2): H=7.5'+0.4/12*[65*1.05/sqrt(3)-22]=8.1' (at rest)

Rule 234C1b: H=4.5'+0.4/12*[65*1.05/sqrt(3)-22]=5.1' (displaced)

Rule 234C1a, Table 234-1, item 2.b (2): V=8.0'+0.4/12*[65*1.05/sqrt(3)-22]=8.6'

These values obtained per **Rule 234C (AC Equivalent**) **cannot be replaced (reduced)** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, Table 234-5, b+ 234H3a, because:**

V max= 56 KV dc pole to ground < 139 kV dc pole to ground, therefore Alternative DC Calculations are N/A for the Metal Return Conductor (MRC).

Clearances of Wires from Buildings (Roof Accessible to Pedestrians):

Standard Clearances Calculations per **Rule 234C:**

Bare values:

Rule 234C1a, Table 234-1, item 1.a: H=7.5’+0.4/12*[65*1.05/sqrt(3)-22]=8.1’ (at rest)

Rule 234C1b: H=4.5’+0.4/12*[65*1.05/sqrt(3)-22]=5.1’ (displaced)

Rule 234C1a, Table 234-1, item 1.b(2): V=13.5’+0.4/12*[65*1.05/sqrt(3)-22]=14.1’

These values obtained per **Rule 234C (AC Equivalent**) **cannot be replaced (reduced)** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, Table 234-5, a + 234H3a, because:**

V max= 56 KV dc pole to ground < 139 kV dc pole to ground, therefore Alternative DC Calculations are N/A for the Metal Return Conductor (MRC).

Clearances of Wires from Buildings (Roof Not Accessible to Pedestrians):

Standard Clearances Calculations per **Rule 234C:**

Bare values:

Rule 234C1a, Table 234-1, item 1.a: H=7.5’+0.4/12*[65*1.05/sqrt(3)-22]=8.1’ (at rest)

Rule 234C1b: H=4.5’+0.4/12*[65*1.05/sqrt(3)-22]=5.1’ (displaced)

Rule 234C1a, Table 234-1, item 1.b(1): V=12.5’+0.4/12*[65*1.05/sqrt(3)-22]=13.1’

These values obtained per **Rule 234C (AC Equivalent**) **cannot be replaced (reduced)** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, Table 234-5, a+ 234H3a, because:**

V max= 56 KV dc pole to ground < 139 kV dc pole to ground, therefore Alternative DC Calculations are N/A for the Metal Return Conductor (MRC).

Clearances of Wires from Bridges Super Structure (No Personnel Access):

Standard Clearances Calculations per **Rule 234D:**

Bare values:

Rule 234D1a, Table 234-2, item 2.a(2): H=7.5’+0.4/12*[65*1.05/sqrt(3)-22]=8.1’ (at rest)

Rule 234D1b: H=4.5’+0.4/12*[65*1.05/sqrt(3)-22]=5.1’ (displaced)

Rule 234D1a, Table 234-2, item 1.b: V=12.5’+0.4/12*[65*1.05/sqrt(3)-22]=13.1’

These values obtained per **Rule 234D (AC Equivalent**) **cannot be replaced (reduced)** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, Table 234-5, c+ 234H3a, because:**

V max= 56 KV dc pole to ground < 139 kV dc pole to ground, therefore Alternative DC Calculations are N/A for the Metal Return Conductor (MRC).

Clearances of Wires from Bridge Deck:

Standard Clearances Calculations per **Rule 234D:**

Bare values:

Rule 234D1a, Table 234-2, item 2.a(2): H=7.5’+0.4/12*[65*1.05/sqrt(3)-22]=8.1’ (at rest)

Rule 234D1b: H=4.5’+0.4/12*[65*1.05/sqrt(3)-22]=5.1’ (displaced)

Rule 234D1a, Table 234-2, item 1.b+Commentary: V=12.5’+6’+0.4/12*[65*1.05/sqrt(3)-22]=19.1’

These values obtained per **Rule 234D (AC Equivalent**) **cannot be replaced (reduced)** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, Table 234-5, c+ 234H3a, because:**

V max= 56 KV dc pole to ground < 139 kV dc pole to ground, therefore Alternative DC Calculations are N/A for the Metal Return Conductor (MRC).

<u>Clearances of Wires from Swimming Pools (Vertical=Dimension "A"; Horizontal=Dimension "B"):</u>

Standard Clearances Calculations per **Rule 234E:**

Bare values:

Rule 234E1, <u>Table 234-3, item B (Figure 234-3, Dim."B")</u>: H=17'+0.4/12*[65*1.05/sqrt(3)-22]=17.6' (at rest) (not defined displaced, under wind)

Rule 234E1, Table 234-3, item A (Figure 234-3, Dim."A"): V=25'+0.4/12*[65*1.05/sqrt(3)-22]=25.6' (at rest)

These values obtained per **Rule 234E (AC Equivalent**) **<u>cannot be replaced (reduced)</u>** by Alternate Clearance Calculation (Switching Factor Calculation) per **Rule 234H: 234H2, <u>Table 234-5, e,f</u>+ 234H3a, because:**

V max= 56 KV dc pole to ground < 139 kV dc pole to ground, therefore <u>Alternative DC Calculations are N/A for the Metal Return Conductor (MRC).</u>

APPENDIX P1 – MISSISSIPPI RIVER CROSSING-METAL RETURN CLEARANCES TABLES

Comparison of Clearances for Clean Line +/- 600 kV Project Plains & Eastern

Case	**NESC- DC** V nom=59 KV peak, pole-ground V max=62 KV (5% over V nom)	**NESC- AC Equivalent** V nom=72 KV rms, phase-to-phase 72=59*sqrt(3)/sqrt(2) Rule 230 H V max=76 KV (5% over V nom)	**EPRI** T/L Reference Book HVDC Lines	**MAD* for Tools** (IEEE 516-2009) **+ Working Space** (NESC Rule 236& 237)	**Conclusion**: Values used in design
Conductor to Ground:	V max=62 KV dc pole to ground < 138 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	Rule 232 B and 232 C:	Not addressed.	N/A	
a. Track rails of railroads		27.23’ (bare) 27.5’ (rounded to 0.5’) 28.5’ (w/1’ buffer)			**28.5’**
b. Streets, Alleys, roads, driveways, and parking lots		19.23’ (bare) 19.5’ (rounded to 0.5’) 20.5’ (w/1’ buffer)			**20.5’**
c. Spaces and ways subject to pedestrians or restricted traffic:		15.23’ (bare) 15.5’ (rounded to 0.5’) 16.5’ (w/1’ buffer)			**16.5’**
d. Vehicular areas		19.23’ (bare) 19.5’ (rounded) 20.5’ (w/1’ buffer)			**20.5’**
Conductor to Water:	V max=62 KV dc pole to ground < 138 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	Rule 232, Table 232-1:	Not addressed.	N/A	
e. Water areas not suitable for sail boating or where sail boating is prohibited		17.733’ (bare) 18’ (rounded to 0.5’) 19’ (w/1’ buffer)			**19’**
f. Water areas suitable for sail boating, including rivers, lakes, ponds, canals with unobstructed surface area:					
1) less than 0.08 km^2 (20 acres)		21.233’ (bare) 21.5’ (rounded to 0.5’) 22.5’ (w/1’ buffer)			**22.5’**
(2) over 0.08 to 0.8 km^2 (20 to 200 acres)		29.233’ (bare) 29.5’ (rounded to 0.5’) 30.5’ (w/1’ buffer)			**30.5’**
3) over 0.8 to 8 km^2 (200 to 2000 acres)		35.233’ (bare) 35.5’ (rounded to 0.5’) 36.5’ (w/1’ buffer)			**36.5’**
(4) over 8 km^2 (2000 acres) Mississippi River Crossing		41.233’ (bare) 41.5’ (rounded to 0.5’) 42.5’ (w/1’ buffer)			**42.5’**

Case	NESC- DC V nom=59 KV peak, pole-ground V max=62 KV (5% over V nom)	NESC- AC Equivalent V nom=72 KV rms, phase-to-phase 72=59*sqrt(3)/sqrt(2) Rule 230 H V max=76 KV (5% over V nom)	EPRI T/L Reference Book HVDC Lines	MAD* for Tools (IEEE 516-2009) + Working Space (NESC Rule 236& 237)	Conclusion: Values used in design
Conductor to Structure No Wind	V max=62 KV dc pole to ground < 138 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	1.347’ (bare) 1.5’ (rounded tp 0.5’) 2’ (w/0.5’ buffer) Rule 235E, Table 235-6, item 4b	1’ No Wind Case corresponds to Lightning Impulse, required clearance from Figure 10-13, page 150. Lightning Surge will be at least 30% higher than Switching Surge: 96*1.3=125 kV Surge Factor: Ti=1.8	N/A	**2’**
Conductor to Structure Medium Wind 6 psf	V max=62 KV dc pole to ground < 138 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	1.347’ (bare) 1.5’ (rounded to 0.5’) 2’ (w/0.5’ buffer) Rule 235E, Table 235-6, item 4b	0.82’ Medium Wind Case corresponds to Switching Impulse, required clearance from Figure 10-13, page 150 Switching Surge=1.8*53 =96 kV Surge Factor: Ti=1.8	N/A	**2’**
Conductor to Structure Extreme Wind 24.3 psf	Not addressed	Not addressed	0.5’ (no buffer) 0.75’ (w/0.25’ buffer) Extreme Wind corresponds to Steady State required clearance from Fig.10-3 , Page 145 and Fig.10-4, Page 146.	Not addressed	**0.75’**

*MAD=Minimum Approach Distance.

NESC-Clearance Conductor to Ground calculation:

NESC- DC: V nom=59 KV peak, pole-ground V max=62 KV (5% over V nom)	**NESC- AC Equiv** V nom=72 KV rms, phase-to-phase 72=59*sqrt(3)/sqrt(2) Rule 230 H V max=76 KV (5% over V nom)
V max=62 KV dc pole to ground < 138 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	Equivalent max ac system voltage=72*1.05=76 KV Equivalent max ac system voltage, phase-to-ground=76/sqrt(3)=44 kV NESC Rule 232, Table 232-1, open supply conductor up to 22 kv: a. Track rails of railroads: H basic=26.5’ b. Streets, Alleys, roads, driveways, and parking lots: H basic=18.5’ c. Spaces and ways subject to pedestrians or restricted traffic: H basic=14.5’ d. Vehicular areas: H basic=18.5’ Voltage Adder: C adder=(44-22)*0.4”/12=0.73’ Altitude adder : zero a. Track rails of railroads: C total=H basic + C adder= 26.5’ + 0.73’=**27.23’ (bare)** **27.5’ (rounded to nearest 0.5’)** **28.5’ (w/1’ buffer)** **CHOSEN** b. Streets, Alleys, roads, driveways, and parking lots: C total=H basic + C adder= 18.5’ + 0.73’=**19.23’ (bare)** **19.5’ (rounded to nearest 0.5’)** **20.5’ (w/1’ buffer)** **CHOSEN** c. Spaces and ways subject to pedestrians or restricted traffic : C total=H basic + C adder= 14.5’ + 0.73’=**15.23’ (bare)** **15.5’ (rounded to nearest 0.5’)** **16.5’ (w/1’ buffer)** **CHOSEN** d. Vehicular Areas: C total=H basic + C adder= 18.5’ + 0.73’=**19.23’ (bare)** **19.5’ (rounded)** **20.5’ (w/1’ buffer)** **CHOSEN**

NESC- Clearance Conductor-to-Structure calculation

for Cases: Medium Wind (6 psf) and No Wind:

NESC- DC:	**NESC- AC Equiv**
V nom=59 KV peak, pole-ground V max=62 KV (5% over V nom)	V nom=72 KV rms, phase-to-phase 72=59*sqrt(3)/sqrt(2) Rule 230H V max=76 KV (5% over V nom)
V max=62 KV dc pole to ground < 138 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	Equivalent max ac system voltage=72*1.05=76 KV Equivalent max ac system voltage, phase-to-ground=76/sqrt(3)=44 kV NESC Rule 235 E, 4b, open supply conductor up to 50 kv: H basic=11"=0.917' Voltage Adder: C adder=(76-50)*0.2"/12=0.43' Altitude adder : zero C total=H basic + C adder= 0.917' + 0.43'=**1.347' (bare)** **1.5' (rounded to nearest 0.5')** **2' (w/0.5' buffer)** **CHOSEN**

NESC- Clearance to Anchor Guys calculation:

for Cases: Medium Wind (6 psf) and No Wind:

NESC- AC Equiv
V nom=72 KV rms, phase-to-phase 72=59*sqrt(3)/sqrt(2) Rule 230H V max=76 KV (5% over V nom)
Equivalent max ac system voltage=72*1.05=76 KV Equivalent max ac system voltage, phase-to-ground=76/sqrt(3)=44 kV NESC Rule 235 E, 4b, open supply conductor up to 50 kv: H basic=16"=1.333' Voltage Adder: C adder=(76-50)*0.25"/12=0.542' Altitude adder : zero C total=H basic + C adder= 1.333' + 0.542'=**1.875' (bare)** **1.9' (rounded to nearest 0.5')** **2.4 ' (w/0.5' buffer)** **CHOSEN**

NESC-Clearance to Right –of-Way (Blowout):

for Cases: Medium Wind (6 psf) and No Wind:

NESC- AC Equiv V nom=72 KV rms, phase-to-phase 72=59*sqrt(3)/sqrt(2) Rule 230H V max=76 KV (5% over V nom)
Equivalent max ac system voltage=72*1.05=76 KV Equivalent max ac system voltage, phase-to-ground=76/sqrt(3)=44 kV NESC Rule 234B, clearance to buildings, open supply conductor up to 22 kv: H basic=4.5' (**with 6 psf wind)** H basic=7.5' (**with no wind**) Voltage Adder: C adder=(44-22)*0.4"/12=0.733' Altitude adder : zero **Medium Wind (6 psf):** C total=H basic + C adder= 4.5' + 0.733'=**5.233' (bare)** **5.5' (rounded to nearest 0.5)** **6' (w/0.5' buffer)** **CHOSEN** **No Wind (0 psf):** C total=H basic + C adder= 7.5' + 0.733'=**8.233' (bare)** **8.5' (rounded to nearest 0.5')** **9.0' (w/0.5' buffer)** **CHOSEN**

NESC- Clearance Conductor-to-Water calculation

NESC- DC: V nom=59 KV peak, pole-ground V max=62 KV (5% over V nom)	**NESC- AC Equiv** V nom=72 KV rms, phase-to-phase 72=59*sqrt(3)/sqrt(2) Rule 230H V max=76 KV (5% over V nom)
V max=62 KV dc pole to ground < 138 kV dc pole to ground Therefore Alternative DC Calculations are N/A.	Equivalent max ac system voltage=72*1.05=76 KV Equivalent max ac system voltage, phase-to-ground=76/sqrt(3)=44 kV NESC Rule 232, Table 232-1, open supply conductor up to 22 kV: 6. Water areas not suitable for sail boating or where sail boating is prohibited: H basic=17’ 7. Water areas suitable for sail boating, including rivers, lakes, ponds, canals with unobstructed surface area: (1) less than 0.08 km^2 (20 acres): H basic=20.5’ (2) over 0.08 to 0.8 km^2 (20 to 200 acres): H basic=28.5’ (3) over 0.8 to 8 km^2 (200 to 2000 acres): H ref=34.5’ (4) over 8 km^2 (2000 acres): Mississippi River Crossing: H ref=40.5’ Voltage Adder: C adder=(44-22)*0.4”/12=0.733’ Altitude at Mississippi River Crossing location: Alt=300’ from PLS-CADD Model 300’ < 1500’ results: Altitude Adder=0, results: C alt=C adder=0.733’ e. Water areas not suitable for sail boating or where sail boating is prohibited: C total=H basic + C adder= 17’ + 0.733’=**17.733’ (bare)** **C total=18’ (rounded to nearest 0.5’)** **C total=19’ (w/1’ buffer)** **CHOSEN** f. Water areas suitable for sail boating, including rivers, lakes, ponds, canals with unobstructed surface area: (1) less than 0.08 km^2 (20 acres): C total=H basic + C adder= 20.5’ + 0.733’=**21.233’ (bare)** **C total=21.5’ (rounded to nearest 0.5’)** **C total=22.5’ (w/1’ buffer)** **CHOSEN** (2) over 0.08 to 0.8 km^2 (20 to 200 acres): C total=H basic + C adder= 28.5’ + 0.733’=**29.233’ (bare)** **C total=29.5’ (rounded to nearest 0.5’)** **C total=30.5’ (w/1’ buffer)** **CHOSEN** (3) over 0.8 to 8 km^2 (200 to 2000 acres): C total=H basic + C adder= 34.5’ + 0.733’=**35.233’ (bare)** **C total=35.5’ (rounded to nearest 0.5’)** **C total=36.5’ (w/1’ buffer)** 4) over 8 km^2 (2000 acres): Mississippi River Crossing: C total=H basic + C adder= 40.5’ + 0.733’=**41.233’ (bare)** **C total=41.5’ (rounded to nearest 0.5’)** **C total=42.5’ (w/1’ buffer)** **CHOSEN**

POWER ENGINEERS

Note: Appendix Q is using Power & Ampacity from conceptual design Rev.D, however the conclusions are still valid for the updated performance requirements.

600 kV DC Bipolar -Clean Line: Plains & Eastern, Rock Island, and Grain Belt Express

APPENDIX Q- Metal Return Selection Analysis

Type	Calculated Neccesary MOT for current I metal return=1860 A (See Note 1)	Maximum Final Sag at calculated MOT in Ruling Span=1500 ft	Necessary DC Voltage, peak metal return-to-ground for dc current I metal return=1860 A	Total Leakage Distance (Se Notes 2,3)	Necessary Number of Bells (Se Notes 2,3)	Necessary Insulator Length (Se Notes 2,3)
ACSR Bluebird 2156 kCMIL Price:$4.35/ft	MOT=210 F= 99 C	Max. Final Sag=68.09 ft	±43 kV	1488 mm= 58.58" (34.6 mm/kV*43 kV=1488 mm)	3 (1488 mm/(550 mm/bell))	513 mm= 1.7 ft (bells only) 788 mm=2.58 ft (insulator+hardware) (171 mm*3 bells)+275 mm hardware
ACSR Chuckar 1780 kCMIL Price:$3.35/ft CHOSEN	MOT=238 F= 114 C	Max. Final Sag=68.58 ft	±53 kV	1834 mm= 72.20" (34.6 mm/kV*53 kV=1834 mm)	4 (1834 mm/(550 mm/bell))	684 mm= 2.24 ft 959 mm=3.14 ft (insulator+hardware) (171 mm*4 bells)+275 mm hardware
ACSR Lapwing 1590 kCMIL Price:$2.95/ft	MOT=261 F= 127 C	Max. Final Sag=71.12 ft	±60 kV	2076 mm= 81.73" (34.6 mm/kV*60 kV=2076 mm)	4 (2076 mm/(550 mm/bell))	684 mm= 2.24 ft 959 mm=3.14 ft (insulator+hardware) (171 mm*4 bells)+275 mm hardware

Prices: from General Cable

Notes:

1. Contingency N1 for the positive and negative poles: one of the 2 poles goes out, and that pole emergency regime current: I pole, emergency=3720 A (20% over nominal regime: 3100 A) must be taken and be split between the 2 metal return conductors: I metal return=3720 A/2=1860 A.

2. Contamination Level: Medium: Specific Leakage Distance=34.6 mm/KV

3. Insulator: Sediver Toughened Glass DC Fog Type: N180 P/C 171 DR:

M&E Strength=180 kN (40 kips)

Spacing=171 mm=6.75"

Diameter=330 mm=13"

Leakage Distance=550 mm/bell

Formulas:

Total Leakage Distance=Specific Leakage Distance*DC Voltage, peak, metal return-ground

Number of Bells=Total Leakage Distance/Leakage Distance

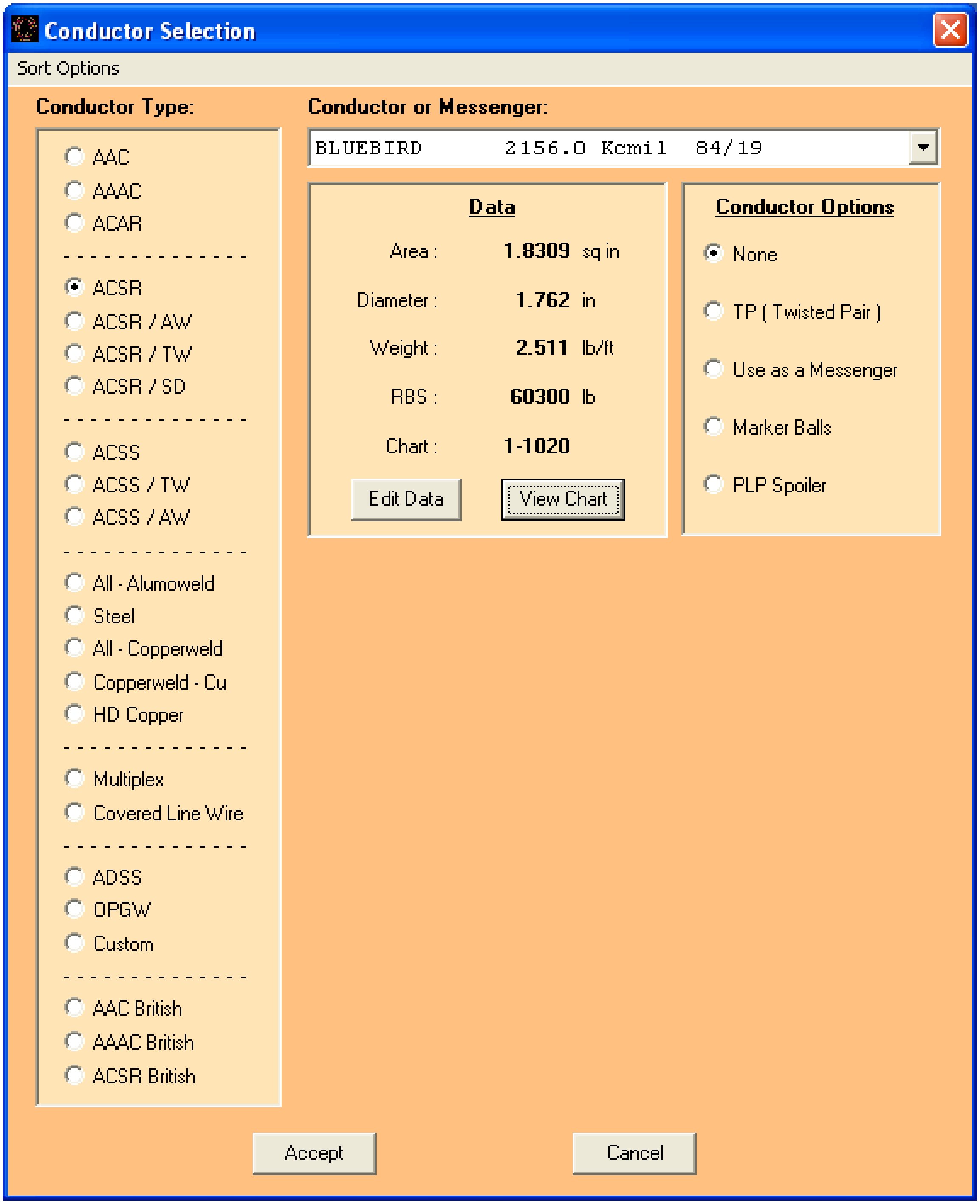
Insulator Length=Spacing*Number of Bells+Hardware Length

4. Other type of conductors were considered:

ACSS/TW Bunting: for I=1860 A, its corresponding MOT=360 F and sag @ MOT its too high, plus its corresponding dc voltage, for I=3720 A/2=1860 A, it is high: ± 98 kV,more expensive: $8.11/ft.

composite conductors: ACCR Falcon, ACCT/TW Cumberland, ACCC Cardinal: they sag less, but are cost prohibitive: example: ACCR Falcon: $ 29.04/ft ; ACCRCumberland: $ 34.50/ft vs. ACSR Chuckar $3.35/ft.

Conclusion: it was chosen ACSR Chuckar that sags only 0.49 ft more than ACSR Bluebird in ruling span=1500 ft, and it is smaller and ligther than ACSR Bluebird, resulting in lower forces on structures, so lower cost for structures. Plus is cheaper than ACSR Bluebird. Any other ACSR smaller than Chuckar has resulted in sags that control the tower height, and the purpose is that the pole conductor to control the structure height, and not the metal return conductor.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ACAR
ACSR
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ACSS / AW
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Steel
All - Copperweld
Copperweld - Cu
HD Copper
Multiplex
Covered Line Wire
ADSS
OPGW
Custom
AAC British
AAAC British
ACSR British
Conductor or Messenger:
BLUEBIRD 2156.0 Kcmil 84/19
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Diameter : 1.762 in
Weight : 2.511 lb/ft
RBS : 60300 lb
Chart : 1-1020
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View Chart
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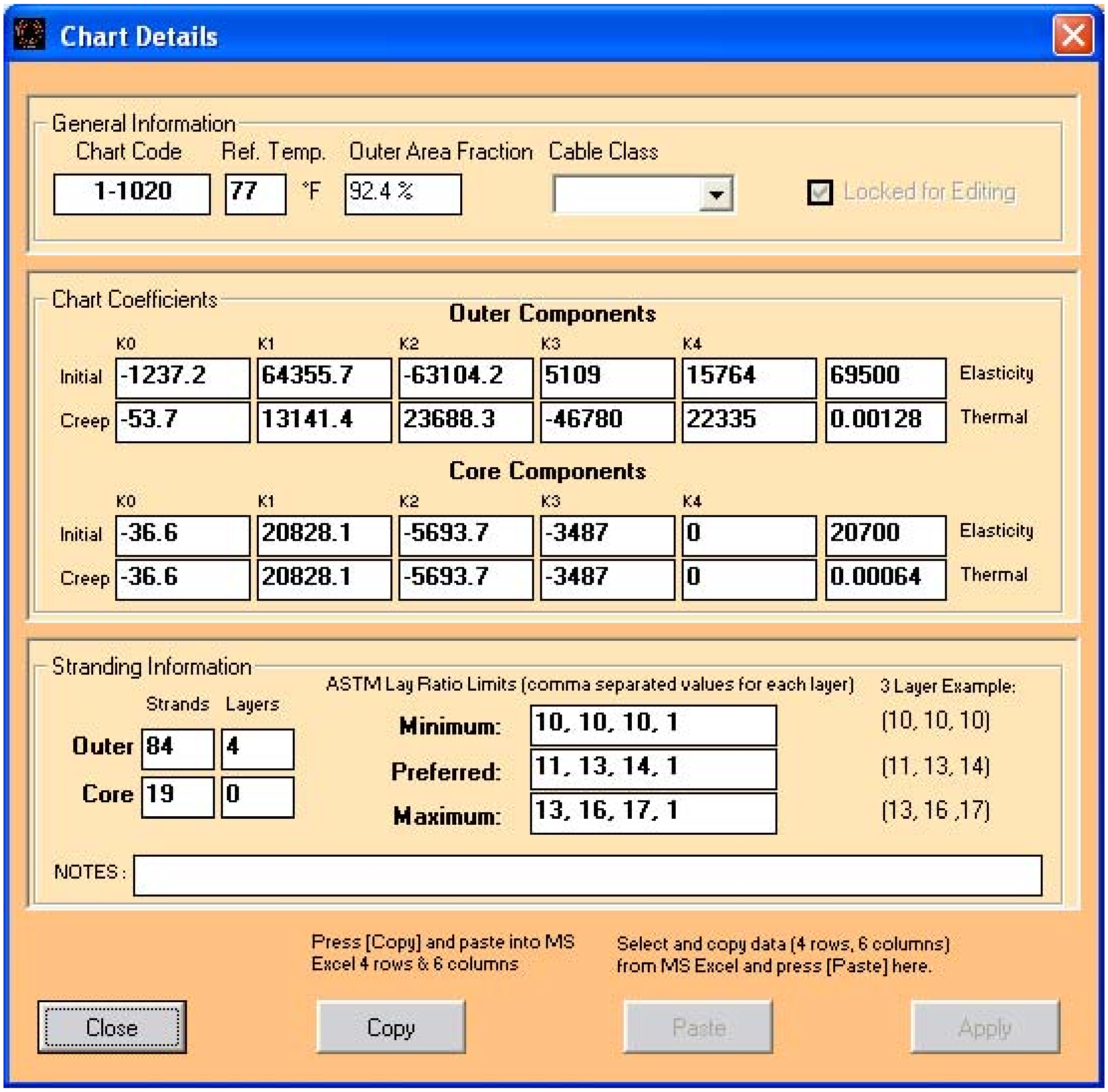
Use as a Messenger
Marker Balls
PLP Spoiler
Accept
Cancel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General Information
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Outer Components
K0
K1
K2
K3
K4
Initial
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64355.7
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69500
Elasticity
Creep
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13141.4
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Thermal
Core Components
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K1
K2
K3
K4
Initial
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-5693.7
-3487
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Thermal
Stranding Information
Strands
Layers
Outer
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4
Core
19
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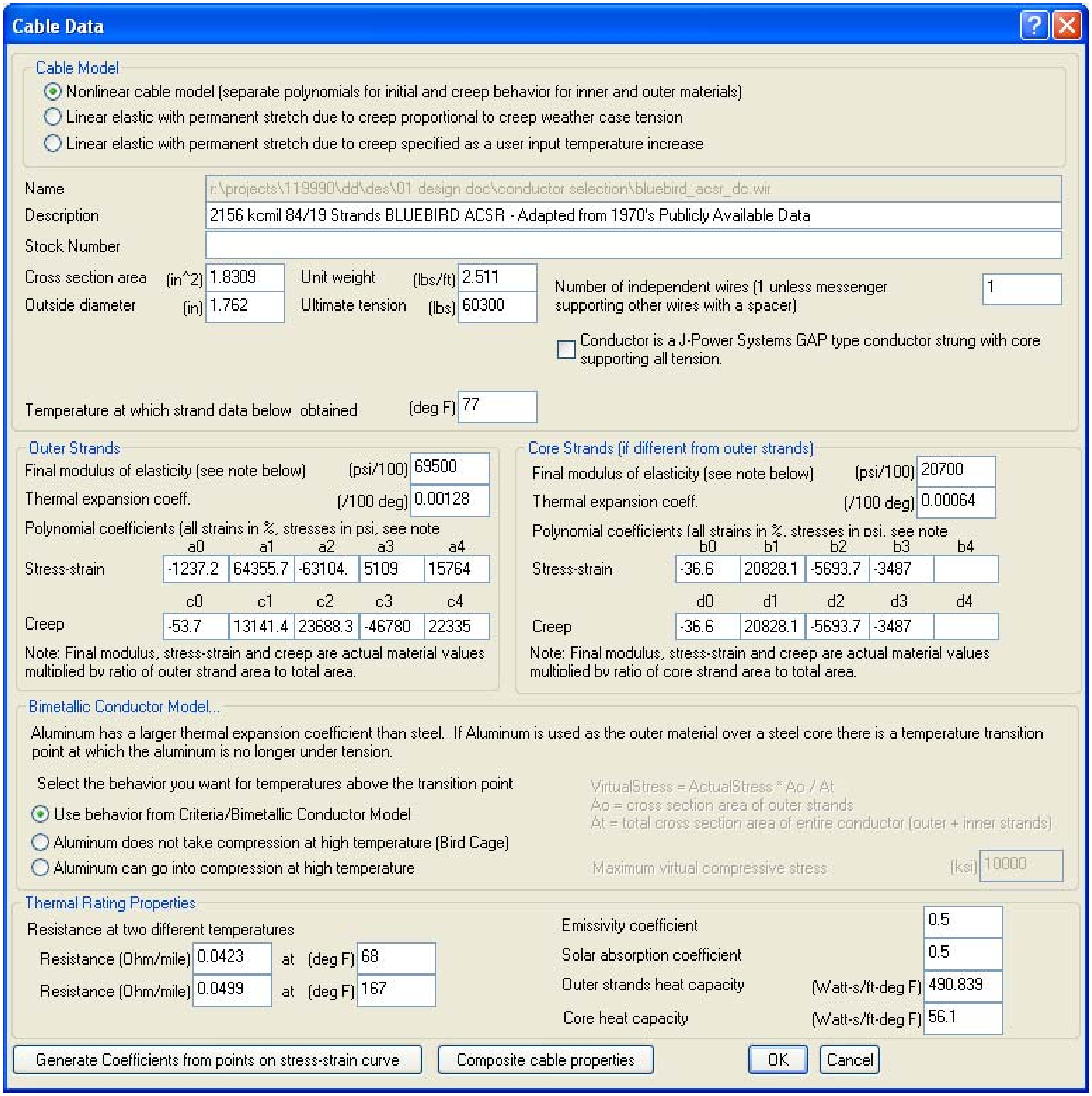
Minimum:
10, 10, 10, 1
Preferred:
11, 13, 14, 1
Maximum:
13, 16, 17, 1
3 Layer Example:
(10, 10, 10)
(11, 13, 14)
(13, 16 ,17)
NOTES :
Press [Copy] and paste into MS Excel 4 rows & 6 columns
Select and copy data (4 rows, 6 columns) from MS Excel and press [Paste] here.
Close
Copy
Paste
Apply

acsr_bluebird_dc.wir: the resistances values in this table are DC Resistances.



Cable Data

Cable Model

- (•) Nonlinear cable model (separate polynomials for initial and creep behavior for inner and outer materials)
- ( ) Linear elastic with permanent stretch due to creep proportional to creep weather case tension
- ( ) Linear elastic with permanent stretch due to creep specified as a user input temperature increase

Name: r:\projects\119990\dd\des\01 design doc\conductor selection\bluebird_acsr_dc.wir

Description: 2156 kcmil 84/19 Strands BLUEBIRD ACSR - Adapted from 1970's Publicly Available Data

Stock Number:

Cross section area (in^2) 1.8309 | Unit weight (lbs/ft) 2.511 | Number of independent wires (1 unless messenger supporting other wires with a spacer) 1

Outside diameter (in) 1.762 | Ultimate tension (lbs) 60300

[ ] Conductor is a J-Power Systems GAP type conductor strung with core supporting all tension.

Temperature at which strand data below obtained (deg F) 77

Outer Strands

Final modulus of elasticity (see note below) (psi/100) 69500

Thermal expansion coeff. (/100 deg) 0.00128

Polynomial coefficients (all strains in %, stresses in psi, see note

	a0	a1	a2	a3	a4
Stress-strain	-1237.2	64355.7	-63104.	5109	15764
	c0	c1	c2	c3	c4
Creep	-53.7	13141.4	23688.3	-46780	22335

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of outer strand area to total area.

Core Strands (if different from outer strands)

Final modulus of elasticity (see note below) (psi/100) 20700

Thermal expansion coeff. (/100 deg) 0.00064

Polynomial coefficients (all strains in %, stresses in psi, see note

	b0	b1	b2	b3	b4
Stress-strain	-36.6	20828.1	-5693.7	-3487	
	d0	d1	d2	d3	d4
Creep	-36.6	20828.1	-5693.7	-3487	

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of core strand area to total area.

Bimetallic Conductor Model...

Aluminum has a larger thermal expansion coefficient than steel. If Aluminum is used as the outer material over a steel core there is a temperature transition point at which the aluminum is no longer under tension.

Select the behavior you want for temperatures above the transition point

- (•) Use behavior from Criteria/Bimetallic Conductor Model
- ( ) Aluminum does not take compression at high temperature (Bird Cage)
- ( ) Aluminum can go into compression at high temperature

VirtualStress = ActualStress * Ao / At
Ao = cross section area of outer strands
At = total cross section area of entire conductor (outer + inner strands)

Maximum virtual compressive stress (ksi) 10000

Thermal Rating Properties

Resistance at two different temperatures

Resistance (Ohm/mile) 0.0423 at (deg F) 68

Resistance (Ohm/mile) 0.0499 at (deg F) 167

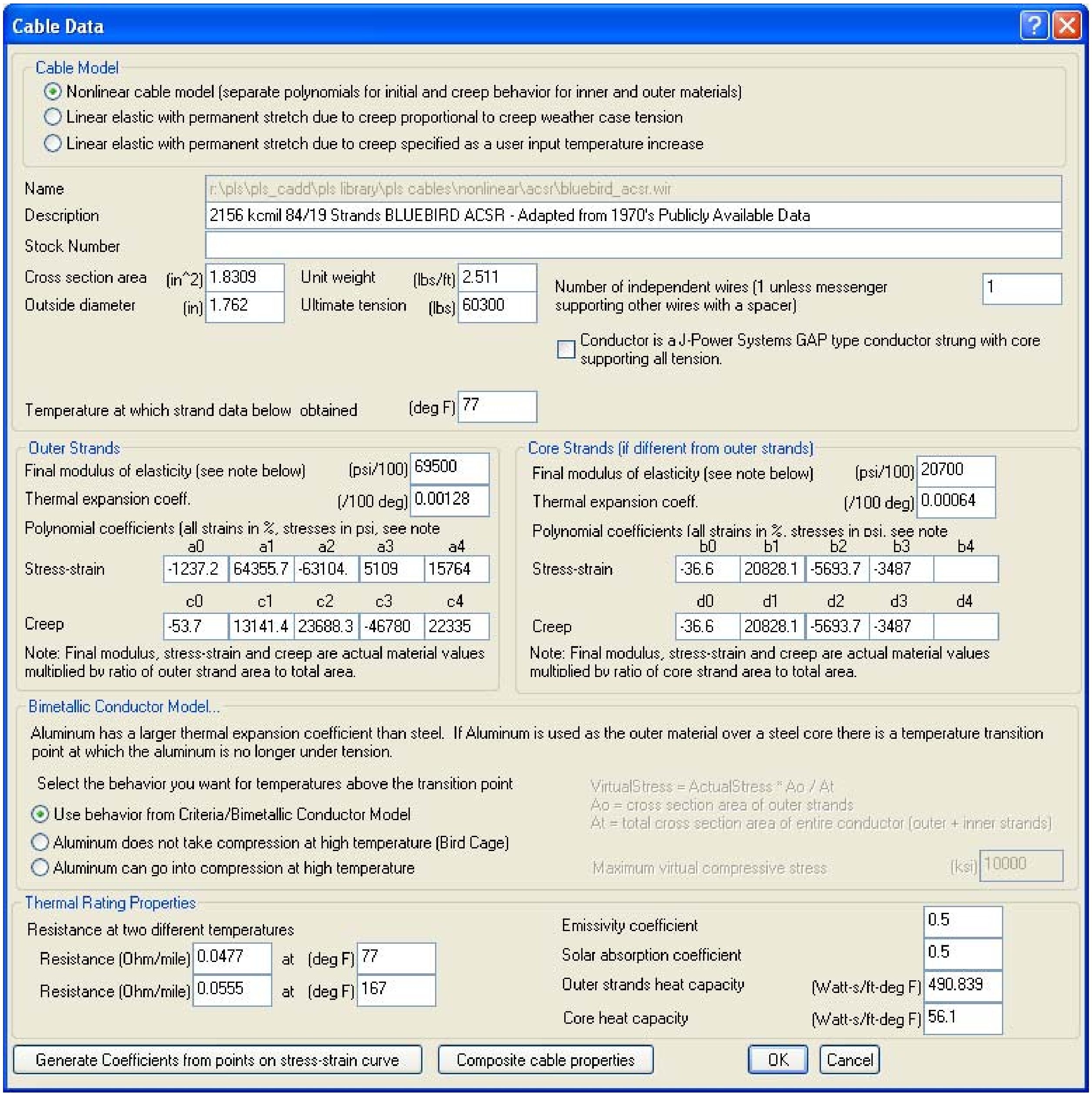
Emissivity coefficient 0.5

Solar absorption coefficient 0.5

Outer strands heat capacity (Watt-s/ft-deg F) 490.839

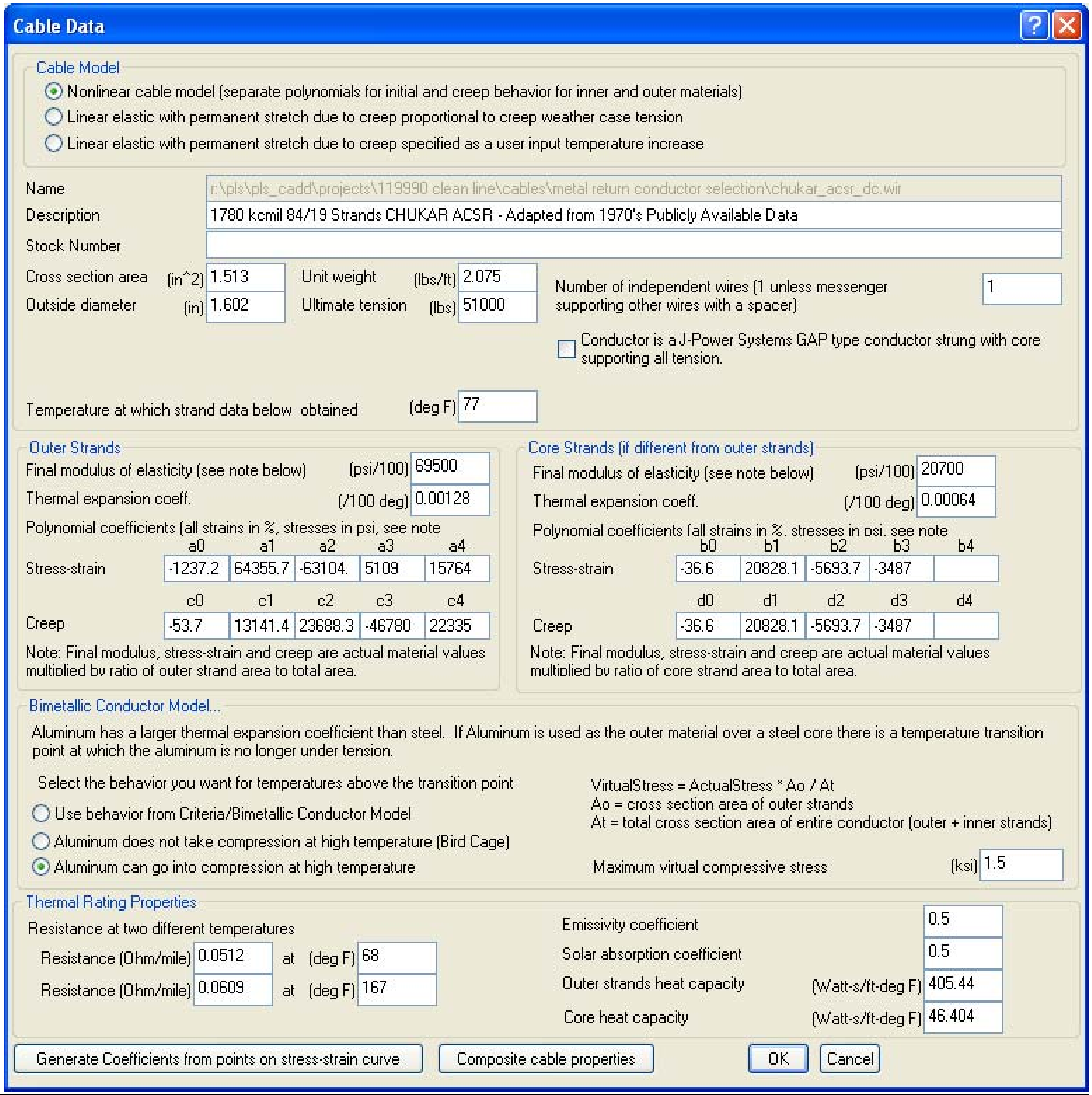
Core heat capacity (Watt-s/ft-deg F) 56.1

Generate Coefficients from points on stress-strain curve | Composite cable properties | OK | Cancel acsr_bluebird.wir: the resistances values in this table are AC Resistances.



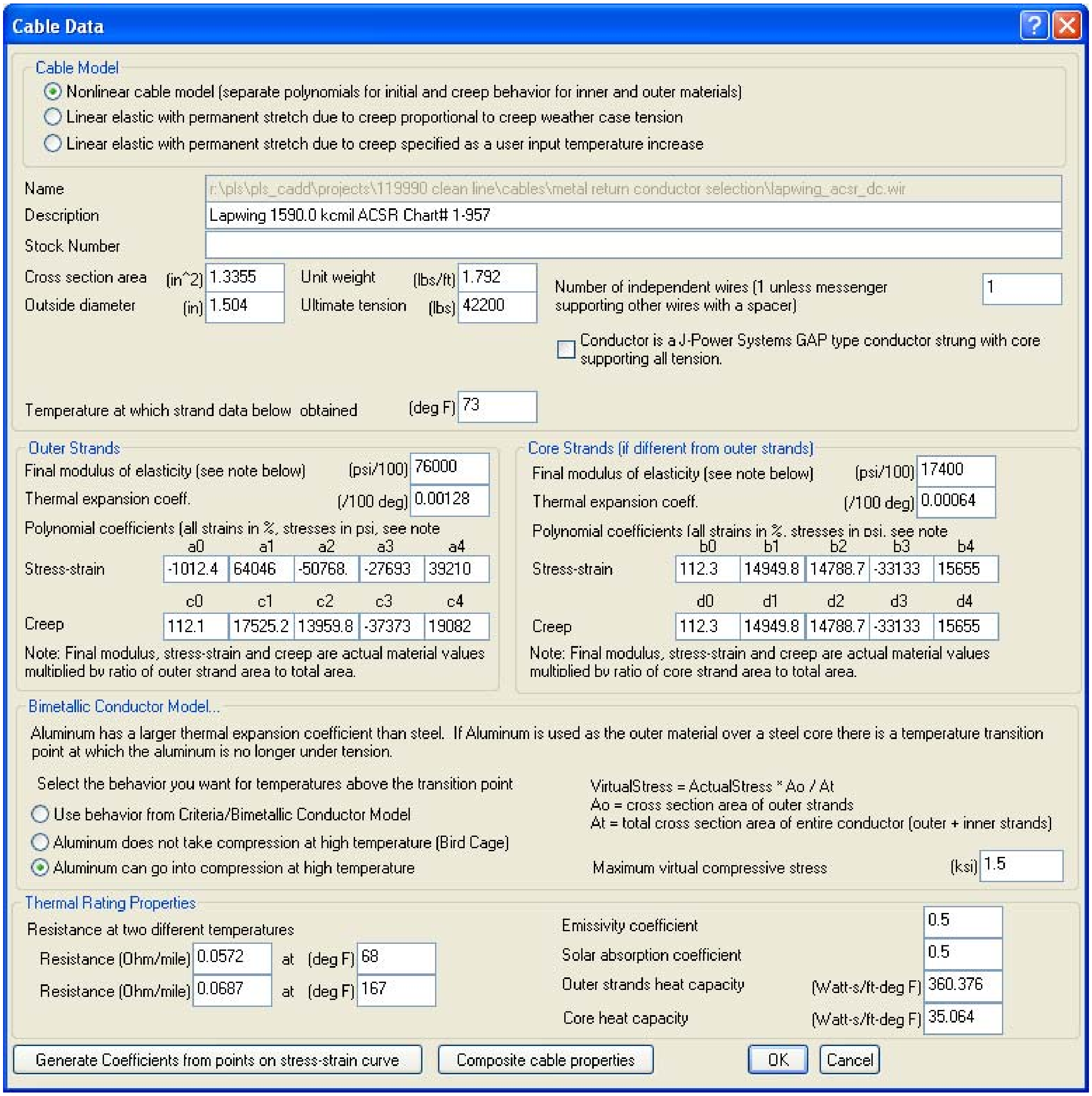
ACSR CHUCKAR wire File with DC Resistances

acsr_chuckar_dc.wir



ACSR LAPWING wir File with DC Resistances:

acsr_lapwing_dc.wir



METAL RETURN CONDUCTOR

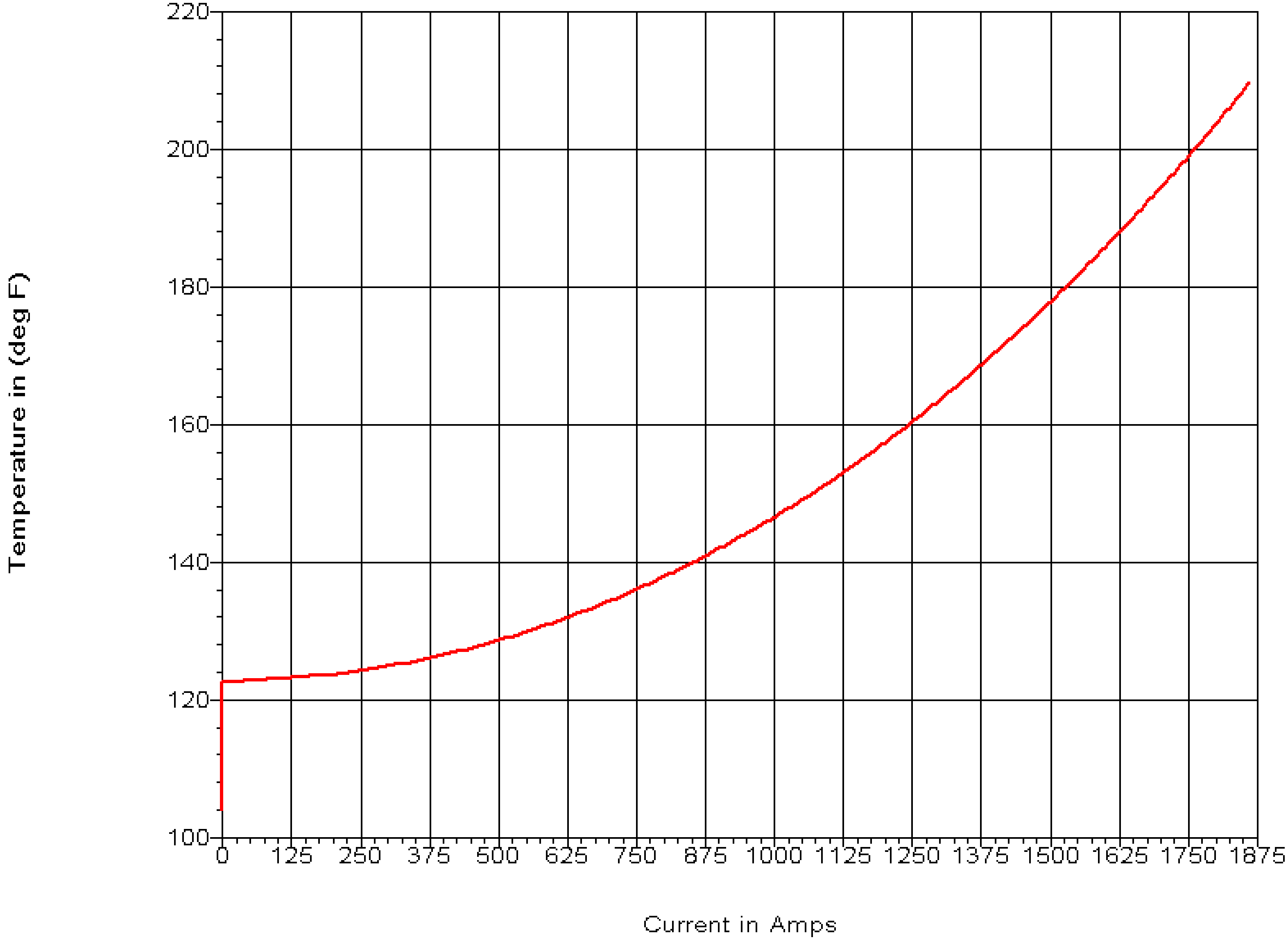
IEEE Std. 738-2006 method of calculation
EMERGENCY REGIME: I pole=3720 A; I metal return conductor=3720/2=1860 A
(20% over Normal Regime: I pole3100 A)

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 1000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2011) (day of the year with most solar heating)

Conductor description: 2156 kcmil 84/19 Strands BLUEBIRD ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.762 (in)
Conductor resistance is 0.0423 (Ohm/mile) at 68.0 (deg F)
and 0.0499 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 7.088 (Watt/ft) (corresponds to Global Solar Radiation of 96.549 (Watt/ft^2) - which was calculated)
Radiation cooling is 11.525 (Watt/ft)
Convective cooling is 30.403 (Watt/ft)

Given a constant dc current of 1860.0 amperes,
The conductor temperature is 209.6 (deg F)


220
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625
750
875
1000
1125
1250
1375
1500
1625
1750
1875
Temperature in (deg F)
Current in Amps

PLS-CADD Version 10.64x64   4:02:27 PM Wednesday, January 19, 2011
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\cables\metal return conductor selection\clean line_metal return_1500 ft_acsr bluebird.loa'

Criteria notes:
Metal Return Conductor
O F Final After Load @25% Controls (ACSR Bluebird)

Section #1 '1:Back'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\bluebird_acsr_dc.wir', Ruling span (ft) 1500
Sagging data: Catenary (ft) 5542.17, Horiz. Tension (lbs) 13916.4 Condition I Temperature (deg F) 60.0001
Weather case for final after creep 60, Equivalent to 78.9 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B, Equivalent to 24.1 (deg F) temperature increase

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-Rule 250B	0.92	3.92	4.32	23570	23344	39	5399	52.18	21874	21630	36	5002	56.33	23570	23344	39	5399	52.18
2	NESC Rule 250D	1.46	7.19	7.34	34003	33551	56	4572	61.66	33438	32977	55	4494	62.74	34003	33551	56	4572	61.66
3	32deg, .5", 0psf	0.00	3.92	3.92	21004	20796	35	5309	53.07	19300	19074	32	4869	57.88	20753	20542	34	5244	53.73
4	60deg, 0", 97mph	3.57	2.51	4.36	22119	21874	37	5013	56.20	20513	20248	34	4641	60.74	21911	21664	36	4965	56.75
5	60deg, 0", 12.2 psf	1.79	2.51	3.08	16692	16530	28	5359	52.57	15087	14907	25	4833	58.31	16232	16065	27	5208	54.09
6	0deg, 0", 4psf	0.59	2.51	2.58	15801	15681	26	6081	46.31	13960	13825	23	5361	52.55	15270	15147	25	5874	47.95
7	60deg, 0", 6psf	0.88	2.51	2.66	14753	14616	24	5493	51.28	13204	13051	22	4905	57.46	14248	14107	24	5301	53.14
8	0	0.00	2.51	2.51	15465	15349	26	6113	46.07	13635	13503	23	5378	52.39	14925	14806	25	5896	47.76
9	32	0.00	2.51	2.51	14666	14544	24	5792	48.63	13010	12872	22	5126	54.96	14139	14013	23	5580	50.47
10	60	0.00	2.51	2.51	14044	13916	23	5542	50.83	12525	12382	21	4931	57.15	13532	13399	22	5336	52.79
11	90	0.00	2.51	2.51	13442	13309	22	5300	53.15	12054	11905	20	4741	59.45	12957	12819	21	5105	55.19
12	120	0.00	2.51	2.51	12906	12767	21	5084	55.42	11629	11474	19	4570	61.69	12445	12300	21	4899	57.53
13	160	0.00	2.51	2.51	12267	12121	20	4827	58.38	11123	10960	18	4365	64.59	11840	11688	20	4655	60.55
14	210	0.00	2.51	2.51	11578	11423	19	4549	61.97	10571	10400	18	4142	68.09	11188	11027	19	4391	64.20
15	284	0.00	2.51	2.51	10726	10558	18	4205	67.07	9886	9703	16	3864	73.01	10388	10214	17	4068	69.34

Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\clean line_plains & eastern 600kv dc_segment 7.DON'

METAL RETURN CONDUCTOR

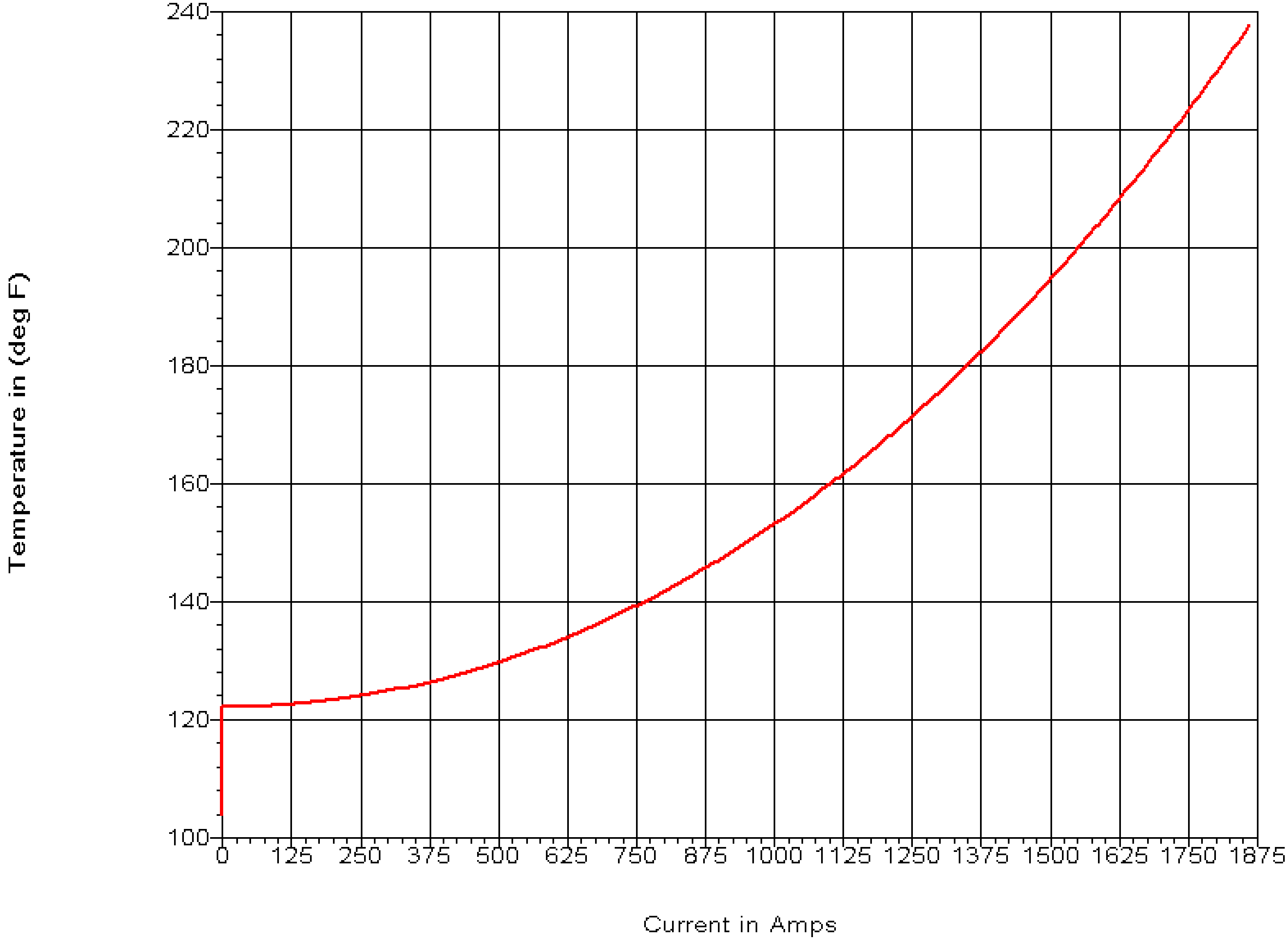
IEEE Std. 738-2006 method of calculation
EMERGENCY REGIME: I pole=3720 A; I metal return conductor=3720/2=1860 A
(20% over Normal regime: I pole=3100 A)

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 1000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2011) (day of the year with most solar heating)

Conductor description: 1780 kcmil 84/19 Strands CHUKAR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.602 (in)
Conductor resistance is   0.0512 (Ohm/mile) at 68.0 (deg F)
                    and   0.0609 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   6.445 (Watt/ft) (corresponds to Global Solar Radiation of   96.549 (Watt/ft^2) - which was calculated)
Radiation cooling is   14.245 (Watt/ft)
Convective cooling is   36.636 (Watt/ft)

Given a constant dc current of 1860.0 amperes,
The conductor temperature is 237.6 (deg F)


Temperature in (deg F)
240
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375
500
625
750
875
1000
1125
1250
1375
1500
1625
1750
1875
Current in Amps

METAL RETURN CONDUCTOR

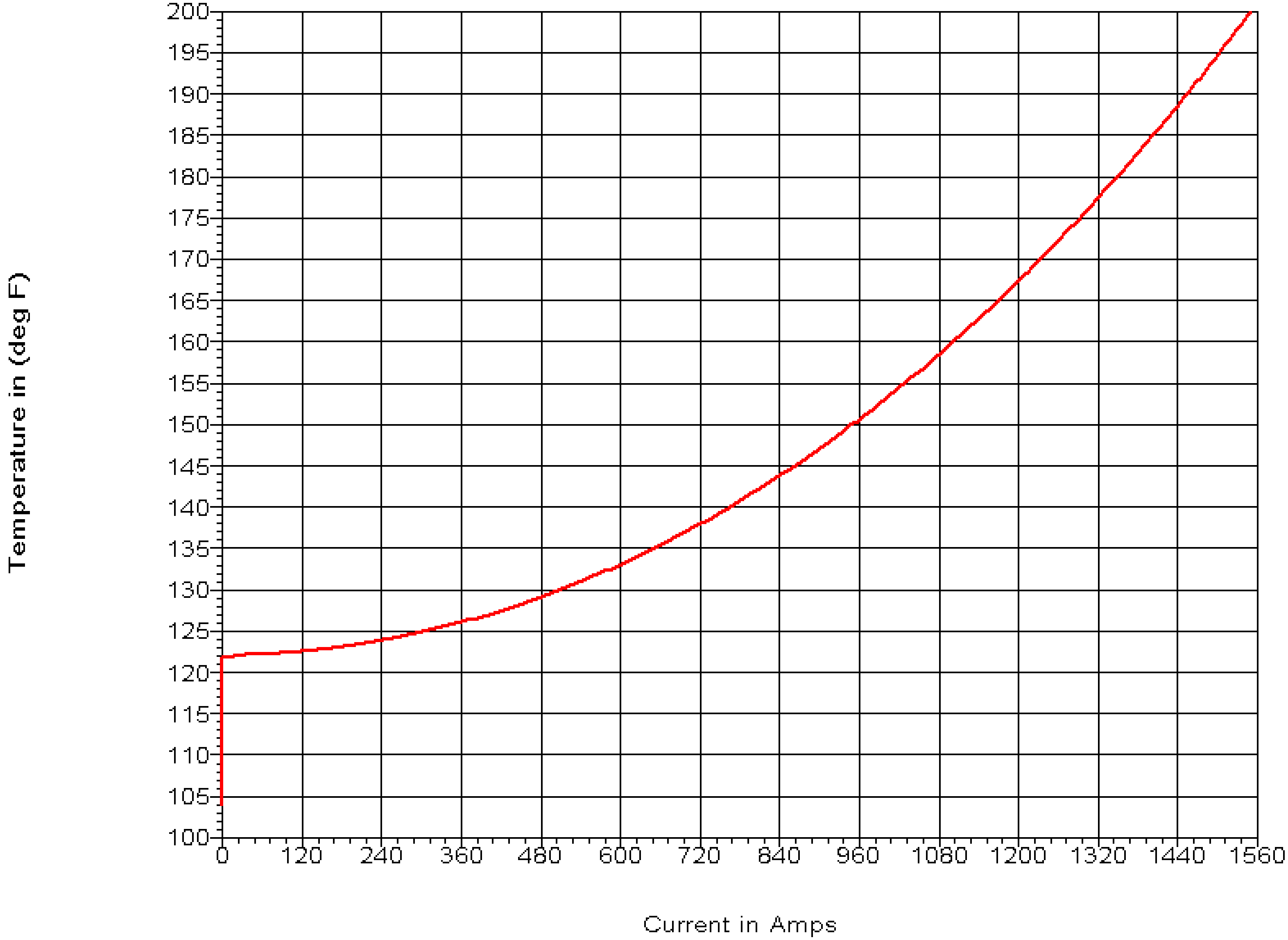
IEEE Std. 738-2006 method of calculation
NORMAL REGIME: I pole=3100 A; I metal return ondutor=3100/2=1550 A

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 1000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2011) (day of the year with most solar heating)

Conductor description: 1780 kcmil 84/19 Strands CHUKAR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.602 (in)
Conductor resistance is   0.0512 (Ohm/mile) at 68.0 (deg F)
                    and   0.0609 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   6.445 (Watt/ft) (corresponds to Global Solar Radiation of   96.549 (Watt/ft^2) - which was calculated)
Radiation cooling is   9.294 (Watt/ft)
Convective cooling is   26.333 (Watt/ft)

Given a constant ac current of 1550.0 amperes,
The conductor temperature is 200.0 (deg F)


200
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105
100
0
120
240
360
480
600
720
840
960
1080
1200
1320
1440
1560
Temperature in (deg F)
Current in Amps

Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\cables\metal return conductor selection\clean line_metal return_1500 ft_acsr chuckar.loa'

Criteria notes:
Metal Return Conductor
O F Final After Load @25% Controls (ACSR Chuckar)

Section #1 '1:Back'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\metal return conductor selection\chukar_acsr_dc.wir', Ruling span (ft) 1500
Sagging data: Catenary (ft) 5763.86, Horiz. Tension (lbs) 11960 Condition I Temperature (deg F) 60.0001
Weather case for final after creep 60, Equivalent to 80.7 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B, Equivalent to 28.7 (deg F) temperature increase

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-Rule 250B	0.87	3.38	3.79	20981	20786	41	5482	51.38	19521	19311	38	5093	55.32	20981	20786	41	5482	51.38
2	NESC Rule 250D	1.40	6.51	6.66	30518	30103	60	4522	62.34	30414	29998	60	4506	62.56	30518	30103	60	4522	62.34
3	32deg, .5", 0psf	0.00	3.38	3.38	18533	18357	36	5428	51.90	17004	16813	33	4971	56.68	18255	18077	36	5345	52.71
4	60deg, 0", 97mph	3.24	2.08	3.85	19795	19582	39	5085	55.41	18380	18150	36	4713	59.80	19590	19375	38	5031	56.00
5	60deg, 0", 12.2 psf	1.63	2.08	2.64	14688	14554	29	5517	51.06	13203	13053	26	4948	56.95	14192	14052	28	5327	52.88
6	0deg, 0", 4psf	0.53	2.08	2.14	13697	13602	27	6348	44.35	11983	11874	23	5542	50.83	13106	13006	26	6070	46.39
7	60deg, 0", 6psf	0.80	2.08	2.22	12775	12665	25	5694	49.46	11338	11214	22	5042	55.89	12229	12114	24	5446	51.72
8	0	0.00	2.08	2.08	13360	13269	26	6394	44.03	11649	11544	23	5564	50.63	12756	12660	25	6101	46.15
9	32	0.00	2.08	2.08	12628	12531	25	6039	46.63	11085	10975	22	5289	53.26	12048	11946	24	5757	48.92
10	60	0.00	2.08	2.08	12061	11960	24	5764	48.86	10650	10535	21	5077	55.50	11505	11399	23	5493	51.28
11	90	0.00	2.08	2.08	11518	11411	23	5499	51.22	10228	10108	20	4871	57.85	10991	10879	22	5243	53.73
12	120	0.00	2.08	2.08	11028	10917	22	5261	53.55	9852	9727	19	4688	60.13	10538	10421	21	5022	56.10
13	160	0.00	2.08	2.08	10453	10336	20	4981	56.57	9403	9272	18	4468	63.09	10005	9882	20	4762	59.18
14	238	0.00	2.08	2.08	9530	9401	19	4531	62.22	8676	8534	17	4113	68.58	9149	9015	18	4344	64.90
15	284	0.00	2.08	2.08	9080	8944	18	4310	65.42	8317	8168	16	3936	71.66	8735	8594	17	4142	68.10

Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\cables\metal return conductor selection\clean line_metal return_1500 ft_acsr lapwing.loa'

Criteria notes:
Metal Return Conductor
O F Final After Load @25% Controls (ACSR Lapwing)

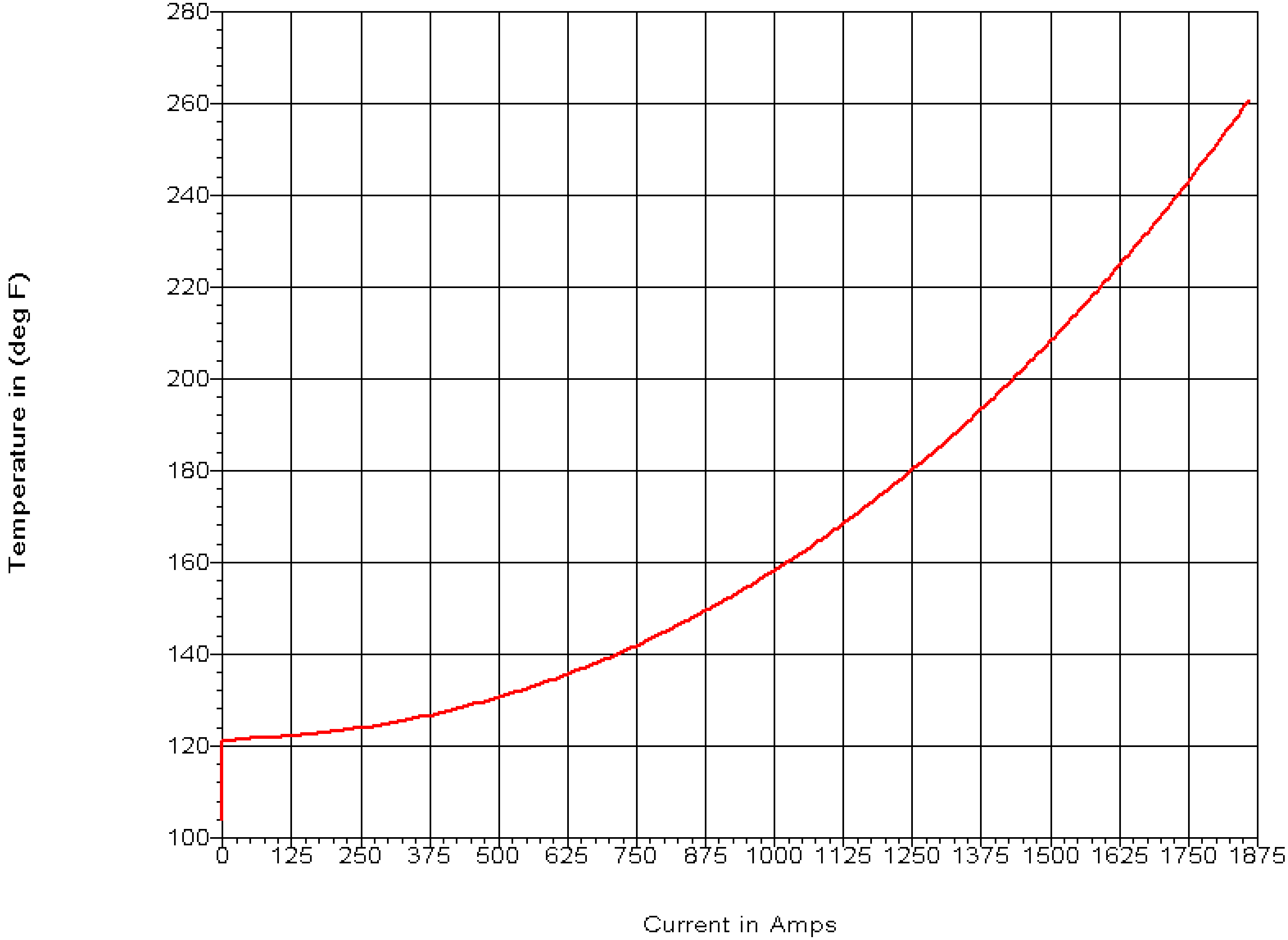
IEEE Std. 738-2006 method of calculation
EMERGENCY REGIME: I pole=3720 A; I metal return conductor=3720/2=1860 A

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 1000 (ft)
Conductor bearing is -16 (deg) (perpendicular to solar azimuth for maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2011) (day of the year with most solar heating)

Conductor description: Lapwing 1590.0 kcmil ACSR Chart# 1-957
Conductor diameter is 1.504 (in)
Conductor resistance is 0.0572 (Ohm/mile) at 68.0 (deg F)
and 0.0687 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is 6.050 (Watt/ft) (corresponds to Global Solar Radiation of 96.549 (Watt/ft^2) - which was calculated)
Radiation cooling is 16.617 (Watt/ft)
Convective cooling is 41.580 (Watt/ft)

Given a constant dc current of 1860.0 amperes,
The conductor temperature is 260.7 (deg F)


280
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625
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875
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1125
1250
1375
1500
1625
1750
1875
Current in Amps
Temperature in (deg F)

Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\cables\metal return conductor selection\clean line_metal return_1500 ft_acsr bluebird.LOA'

Criteria notes:
  Metal Return Conductor
  O F Final After Load @25% Controls (ACSR Bluebird)

IEEE Std. 738-2006 method of calculation

Air temperature is 104.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 1000 (ft)
Conductor bearing is 90 (deg) (user specified bearing, may not be value producing maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2011) (day of the year with most solar heating)

Conductor description: 1780 kcmil 84/19 Strands CHUKAR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.602 (in)
Conductor resistance is   0.0512 (Ohm/mile) at 68.0 (deg F)
                    and   0.0609 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   5.727 (Watt/ft) (corresponds to Global Solar Radiation of   85.794 (Watt/ft^2) - which was calculated)
Radiation cooling is   1.496 (Watt/ft)
Convective cooling is   5.195 (Watt/ft)

Given a constant ac current of 300.0 amperes,
The conductor temperature is 122.9 (deg F)

POWER ENGINEERS

SHEET NUMBER: 1 OF 1

PROJECT: CLEAN LINE: ± 600kVDC

PROJECT NUMBER: 119940

SUBJECT: ACSR CHUKAR - DC RESISTANCES CALCULATION

BY: CRISTIAN MILITARU

DATE: 01/19/2011

CHECKED BY:

DATE:

1780 kcmil ACSR CHUKAR; Per Southwire's Catalog:

$$\begin{cases} R_{dc@20°C=68°F} = 0.0512\ \Omega/mile \\ R_{ac@25°C=77°F} = 0.0561\ \Omega/mile \\ R_{ac@75°C=167°F} = 0.0658\ \Omega/mile \end{cases} \Rightarrow R_{ac@75°C} = R_{ac25°C} \cdot [1 + CTR \cdot (75° - 25°)] \Rightarrow$$

$$\Rightarrow CTR = \left(\frac{R_{ac@75°C}}{R_{ac@25°C}} - 1\right) \Big/ (75° - 25°) = \left(\frac{0.0658}{0.0561} - 1\right) \Big/ (75° - 25°) = 0.00346\ [1/deg\,C]$$

$$\Rightarrow R_{dc@75°C} = R_{dc@20°C} \cdot [1 + CTR \cdot (75° - 20°)] = 0.0512 \cdot [1 + 0.00346 \cdot (75 - 20)] = 0.0609\ \Omega/mile$$

I created acsr_chukar_dc.wir with:

$$\begin{cases} R_{dc@20°C=68°F} = 0.0512\ \Omega/mile \\ R_{dc@75°C=167°F} = 0.0609\ \Omega/mile \end{cases}$$

Using PLS-CAD - IEE 738 Method: I = 1860 A (emergency regime). MOT = 238 F = 114°C.

POWER ENGINEERS

SHEET NUMBER: 1 OF 1

PROJECT: CLEAN LINE : ±600kV DC

PROJECT NUMBER: 119990

SUBJECT: ACSR LAPWING - DC RESISTANCES CALCULATION

BY: CRISTIAN MILITARU DATE: 01/20/2011

CHECKED BY: DATE:

1590 kcmil ACSR LAPWING: per Southwire's Catalog:

$$\begin{cases} R_{dc@20^\circ C=68^\circ F} = 0.0572 \ \Omega/mile \\ R_{ac@25^\circ C=77^\circ F} = 0.0620 \ \Omega/mile \\ R_{ac@75^\circ C=167^\circ F} = 0.0733 \ \Omega/mile \end{cases} \Rightarrow R_{ac\,75^\circ C} = R_{ac\,25^\circ C} \cdot [1 + CTR \cdot (75-25)] \Rightarrow$$

$$\Rightarrow CTR = \left(\frac{R_{ac@75^\circ C}}{R_{ac@25^\circ C}} - 1\right) / (75^\circ - 25^\circ) = \left(\frac{0.0733}{0.0620} - 1\right) / (75^\circ - 25^\circ) = 0.00364 \ [1/deg\ C]$$

$$\Rightarrow R_{dc@75^\circ C} = R_{dc@20^\circ C} \cdot [1 + CTR \cdot (75^\circ - 20^\circ)] = 0.0572\,[1 + 0.00364 \cdot (75^\circ - 20^\circ)] = 0.0687 \ \Omega/mile$$

I created acsr_lapwing_dc.wir units:

$$\begin{cases} R_{dc@20^\circ C=68^\circ F} = 0.0572 \ \Omega/mile \\ R_{dc@75^\circ C=167^\circ F} = 0.0687 \ \Omega/mile \end{cases}$$

Using PLS-CAD IEEE 738 Method: $I = 1860A$ (emergency regime): $MOT = 281^\circ F = 127^\circ C$

$$\begin{cases} m_{AL} = 1.4981 \ lbs/Ft \\ m_{ST} = 0.2922 \ lbs/Ft \\ m_{total} = 1.7903 \ lbs/Ft \end{cases} \quad \begin{cases} A_{AL} = 1.2492 \ sq.in. \\ A_{ST} = 0.0863 \ sq.in. \\ A_{total} = 1.3355 \ sq.in. \end{cases} \quad \begin{cases} c_{P\,AL} = 433 \ w.sec/lbs\,^\circ C \\ c_{P\,ST} = 216 \ w.sec/lbs\,^\circ C \\ \boxed{1.8\,[1/^\circ C] = 1\,[1/^\circ F]} \end{cases}$$

OUTER STRANDS: $m_{AL} \cdot c_{P\,AL} = 1.4981 \ lbs/Ft \cdot 433 \ w.sec/lbs\,^\circ C = 648.6773 \ w.sec/Ft\,^\circ C =$
$= \underline{360.376} \ [w.sec/Ft\,^\circ F]$

CORE: $m_{ST} \cdot c_{P\,ST} = 0.2922 \ lbs/Ft \cdot 216 \ w.sec/lbs\,^\circ C = 63.1152 \ w.sec/Ft\,^\circ C = \underline{35.064} \ [w.sec/Ft\,^\circ F]$

POWER ENGINEERS

SHEET NUMBER: 1 OF

PROJECT: CLEAN LINE ± 600 kV DC: PLAINS & EASTERN

PROJECT NUMBER: 119990

SUBJECT: METAL RETURN INSULATION CALCULATION

BY: CRISTIAN MILITARU

DATE: 01/19/2011

CHECKED BY:

DATE:

For 2 ACSR Bluebird, that take total 3720A, each one taking 1860A, [2 ACSR Chukar]

the corresponding optimum voltage it is: [± 53 kV]

$V_{metal\ return} = \pm 43\ kV$ d.c.

Specific Leakage Distance = 34.6 mm/kV (medium contamination)

Total Leakage Distance = 34.6 mm/kV · 43 kV = 1488 mm = 58.58 inches (medium contamination) [53 kV 1834 mm = 72.20 inches]

To be Used: Sediver's Toughened Glass DC Fog Type — latest DC Insulator Catalog

N 180 P/C 171DR 180kN (40 kips)

M&E Strength = 180 kN = 40 kips
Spacing = 171 mm = 6.75"
Diameter = 330 mm = 13"
Leakage Distance = 550 mm / bell

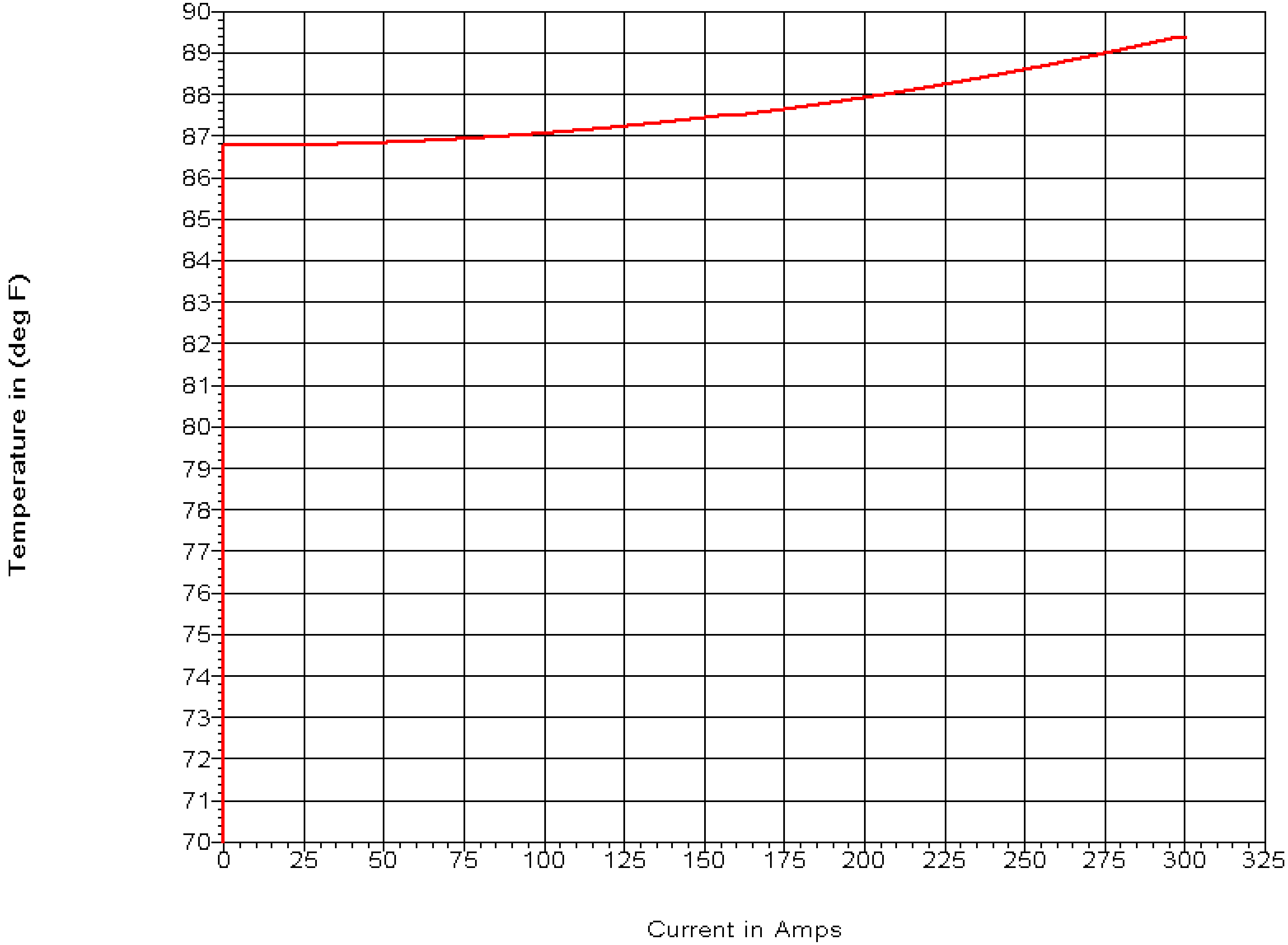
Necessary Number of Bells = Total Leakage Distance / Insulator Leakage Distance per Bell = 1488 mm / (550 mm/bell) = 2.7 ≈ 3 bells [1834 mm 3.33 ≈ 4 bells]

Necessary Insulator Length = Spacing · Number of Bells = 171 mm · 3 bells = 513 mm ≅ 1.7 ft [4 bells 684 mm ≈ 2.24 ft]

Insulator Hardware Length = 0.9 ft (both sides of the insulator string)

Total Necessary Insulator Length = 3 Bells + Hardware = 1.7 ft + 0.9 ft = 2.6 ft = 0.91 m [2.24 = 3.14 ft = 0.95 m]

```
PLS-CADD Version 10.76x64    12:11:34 PM Friday, April 29, 2011
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\cables\metal return conductor selection\clean line_metal return_1500 ft_acsr bluebird.LOA'

Criteria notes:
  Metal Return Conductor
  O F Final After Load @25% Controls (ACSR Bluebird)


IEEE Std. 738-2006 method of calculation

Air temperature is 70.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 1000 (ft)
Conductor bearing is 90 (deg) (user specified bearing, may not be value producing maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2011) (day of the year with most solar heating)

Conductor description: 1780 kcmil 84/19 Strands CHUKAR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.602 (in)
Conductor resistance is     0.0512 (Ohm/mile) at  68.0 (deg F)
                    and     0.0609 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is      5.727 (Watt/ft) (corresponds to Global Solar Radiation of   85.794 (Watt/ft^2) - which was calculated)
Radiation cooling is     1.281 (Watt/ft)
Convective cooling is    5.354 (Watt/ft)

Given a constant ac current of 300.0 amperes,
The conductor temperature is 89.4 (deg F)
```


Temperature in (deg F)
90
89
88
87
86
85
84
83
82
81
80
79
78
77
76
75
74
73
72
71
70
0
25
50
75
100
125
150
175
200
225
250
275
300
325
Current in Amps

PLS-CADD Version 10.76x64   12:14:02 PM Friday, April 29, 2011
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\cables\metal return conductor selection\clean line_metal return_1500 ft_acsr bluebird.LOA'

Criteria notes:
  Metal Return Conductor
  O F Final After Load @25% Controls (ACSR Bluebird)

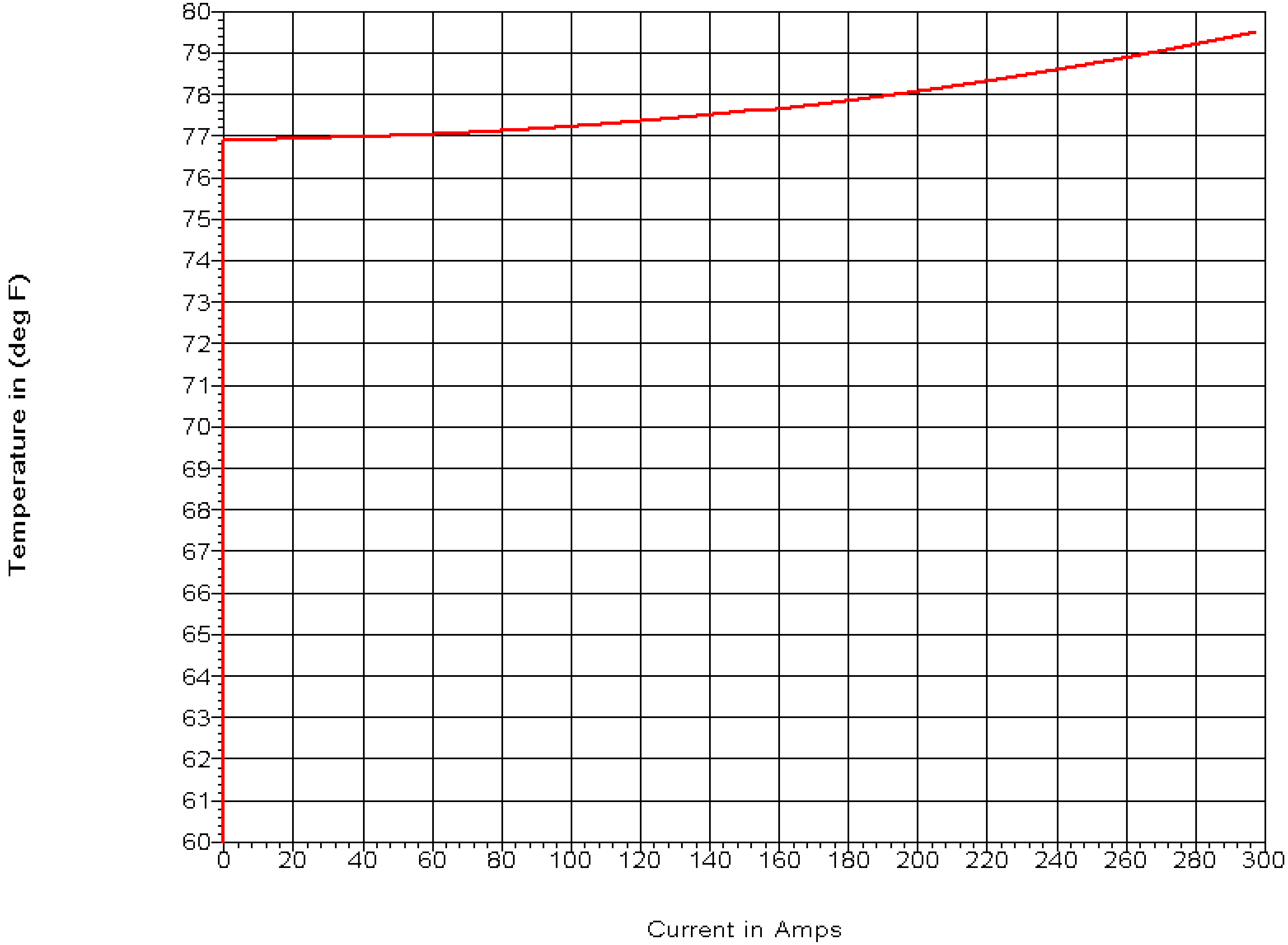
IEEE Std. 738-2006 method of calculation

Air temperature is 60.00 (deg F)
Wind speed is 2.00 (ft/s)
Angle between wind and conductor is 90 (deg)
Conductor elevation above sea level is 1000 (ft)
Conductor bearing is 90 (deg) (user specified bearing, may not be value producing maximum solar heating)
Sun time is 14 hours (solar altitude is 62 deg. and solar azimuth is -106 deg.)
Conductor latitude is 35.0 (deg)
Atmosphere is CLEAR
Day of year is 172 (corresponds to June 21 in year 2011) (day of the year with most solar heating)

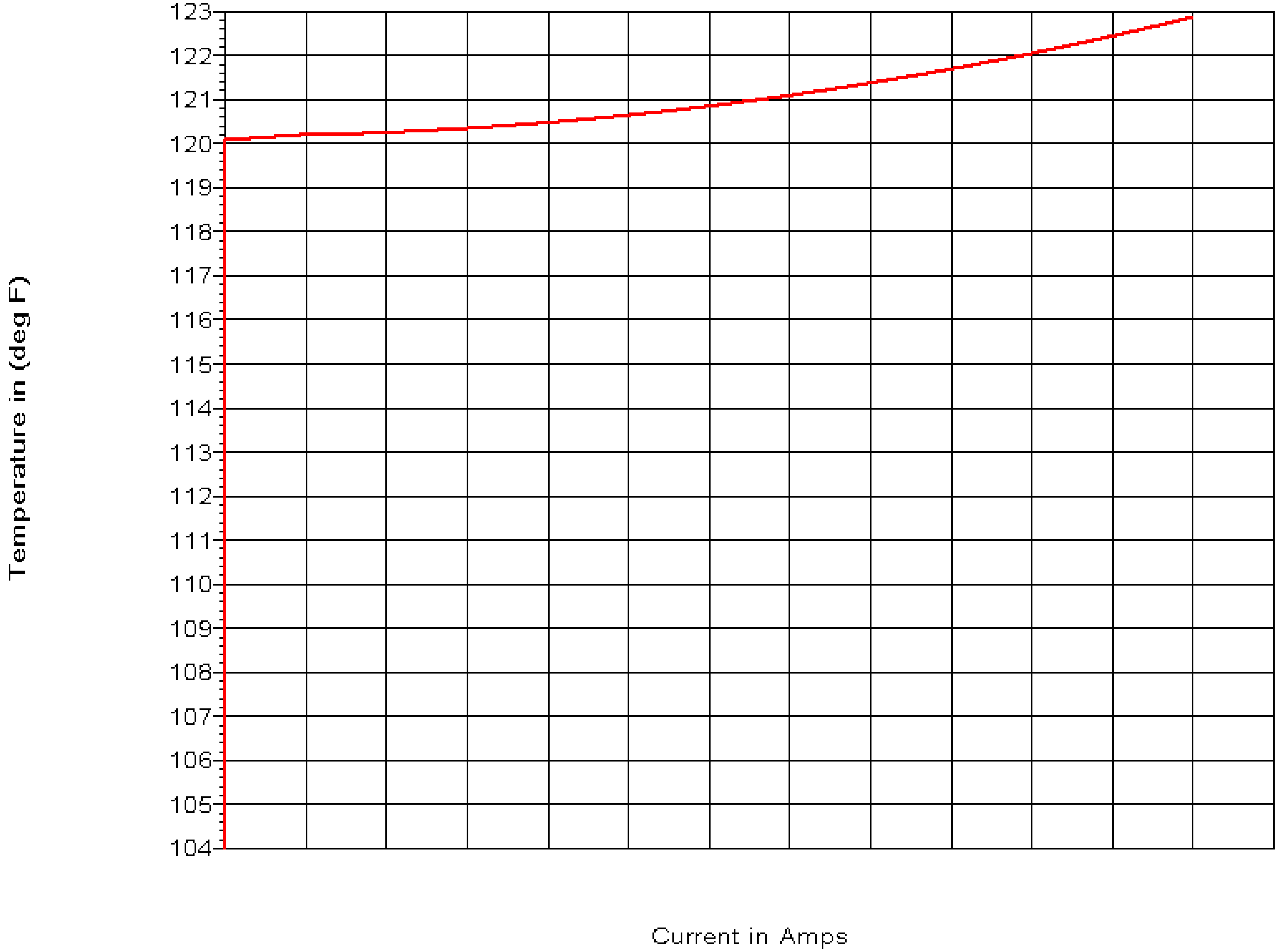
Conductor description: 1780 kcmil 84/19 Strands CHUKAR ACSR - Adapted from 1970's Publicly Available Data
Conductor diameter is 1.602 (in)
Conductor resistance is   0.0512 (Ohm/mile) at 68.0 (deg F)
                    and   0.0609 (Ohm/mile) at 167.0 (deg F)
Emissivity is 0.5 and solar absorptivity is 0.5

Solar heat input is   5.727 (Watt/ft) (corresponds to Global Solar Radiation of   85.794 (Watt/ft^2) - which was calculated)
Radiation cooling is   1.220 (Watt/ft)
Convective cooling is   5.397 (Watt/ft)

Given a constant ac current of 300.0 amperes,
The conductor temperature is 79.5 (deg F)



Temperature in (deg F)
80
79
78
77
76
75
74
73
72
71
70
69
68
67
66
65
64
63
62
61
60
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Current in Amps


123
122
121
120
119
118
117
116
115
114
113
112
111
110
109
108
107
106
105
104
Temperature in (deg F)
Current in Amps

PLS-CADD Version 10.74x64   9:53:51 AM Thursday, January 20, 2011
Power Engineers
Project Name: 'r:\pls\pls_cadd\projects\119990 clean line\cables\metal return conductor selection\clean line_metal return_1500 ft_acsr lapwing.loa'

Criteria notes:
  Metal Return Conductor
  O F Final After Load @25% Controls (ACSR Lapwing)

Section #1 '1:Back'
Cable 'r:\pls\pls_cadd\projects\119990 clean line\cables\metal return conductor selection\lapwing_acsr_dc.wir', Ruling span (ft) 1500
Sagging data: Catenary (ft) 5552.46, Horiz. Tension (lbs) 9950 Condition I Temperature (deg F) 60.0001
Weather case for final after creep 60, Equivalent to 69.1 (deg F) temperature increase
Weather case for final after load NESC Heavy-Rule 250B, Equivalent to 31.5 (deg F) temperature increase

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	Res.	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-Rule 250B	0.83	3.04	3.45	18377	18193	44	5272	53.43	17479	17285	41	5009	56.25	18377	18193	44	5272	53.43
2	NESC Rule 250D	1.37	6.07	6.23	27517	27114	65	4356	64.73	27517	27114	65	4356	64.73	27517	27114	65	4356	64.73
3	32deg, .5", 0psf	0.00	3.04	3.04	16059	15896	38	5232	53.85	15041	14866	36	4893	57.59	15801	15635	37	5146	54.75
4	60deg, 0", 97mph	3.05	1.79	3.53	17503	17300	41	4896	57.56	16592	16377	39	4635	60.82	17339	17133	41	4849	58.12
5	60deg, 0", 12.2 psf	1.53	1.79	2.36	12627	12502	30	5307	53.08	11591	11455	27	4863	57.95	12190	12061	29	5120	55.03
6	0deg, 0", 4psf	0.50	1.79	1.86	11428	11342	27	6095	46.20	10234	10138	24	5448	51.70	10902	10812	26	5810	48.47
7	60deg, 0", 6psf	0.75	1.79	1.94	10755	10655	25	5483	51.38	9742	9632	23	4956	56.86	10273	10169	24	5233	53.84
8	0	0.00	1.79	1.79	11089	11007	26	6142	45.85	9897	9805	23	5472	51.48	10553	10467	25	5841	48.22
9	32	0.00	1.79	1.79	10501	10414	25	5811	48.47	9418	9321	22	5201	54.17	9986	9895	24	5522	51.02
10	60	0.00	1.79	1.79	10040	9950	24	5552	50.73	9048	8947	21	4993	56.44	9553	9457	23	5277	53.38
11	90	0.00	1.79	1.79	9603	9508	23	5306	53.10	8693	8588	21	4792	58.81	9143	9042	22	5046	55.84
12	120	0.00	1.79	1.79	9212	9113	22	5085	55.41	8376	8266	20	4613	61.11	8779	8674	21	4841	58.22
13	160	0.00	1.79	1.79	8750	8645	21	4824	58.42	8000	7885	19	4400	64.07	8351	8241	20	4599	61.29
14	261	0.00	1.79	1.79	7817	7700	19	4297	65.62	7235	7108	17	3966	71.12	7493	7370	18	4113	68.57
15	284	0.00	1.79	1.79	7642	7521	18	4197	67.19	7088	6958	17	3883	72.66	7332	7206	17	4021	70.14

POWER ENGINEERS

Stuctures Comparison

Pole Type	Parameter	Pole w/o Metal Return	Pole with Metal Return Variant 1 Metal Return under Pole Conductor	Pole with Metal Return Variant 2 Metal Return above Pole Conductor	Comments /Conclusions
Basic Suspension Pole 0-2 deg All forces calculated based on: Ruling Span: 1000' Max Wind Span: 1000' Max Weight Span: 1500'	Height [ft]	106'-10"	117'-3"	106'-10"	Disadvantage Variant 1: Variant 1: with Metal Return under Pole Conductor has 10'-5" higher height vs Pole w/o Metal Return and vs. Variant 2. Advantage Variant 2 Variant 2: with Metal Return above Pole Conductor has the same height as Pole w/o Metal Return.
	Moment to Ground [kips*ft] under Extreme Wind Case 24.3 psf wind on conductor 26.33 psf wind on structure		Transverse: 4225.3	Transverse: 4120.9	Advantage Variant 2 Variant 2: with Metal Return above Pole Conductor has Moment to Ground 2.5% less than Variant 1: with Metal Return under Pole Conductor.
	Moment to Ground [kips*ft] under Broken Conductor Case 0 psf wind on conductor 6 psf wind on structure		Transverse: 5525.9 Longitudinal: 3241.1	Transverse: 4718.3 Longitudinal: 2909.8	Advantage Variant 2 Variant 2: with Metal Return above Pole Conductor has Moment to Ground 14.6% (T) and 10.2% (L) less than Variant1: with Metal Return under Pole Conductor.
	Live Line Maintenance Work (NESC Rule 236E & 237B and IEEE-516-2009)		Allows live line maintenance work for both Pole Conductor & Metal Return	Allows live line maintenance work for for Pole Conductor only	Advantage Variant 1 for live line work <u>but</u> see Note below.

<u>Note:</u> Advantage Variant 1 for live line maintenance work, but NESC Code does not require for live line maintenance work minimum clearances for dc voltages under +/-96 kV, and the metal return is energized at +/-53 kV. So remains custumer decision if they want to allow life line maintenance work on the metal return or not.
Both Variant 1 and 2 allow live line maintenance work on the pole conductor.

Pole Type	Parameter	Pole w/o Metal Return	Pole with Metal Return Variant 1 Metal Return under Pole Conductor	Pole with Metal Return Variant 2 Metal Return above Pole Conductor	Comments /Conclusions
Heavy Suspension Pole 0-2 deg All forces calculated based on: Ruling Span: 1500' Max Wind Span: 1500' Max Weight Span: 2250'	Height [ft]	136'-10"	147'-5"	136'-10"	Disadvantage Variant 1: Variant 1: with Metal Return under Pole Conductor has 10'-7" higher height vs Pole w/o Metal Return and vs. Variant 2. Advantage Variant 2 Variant 2: with Metal Return above Pole Conductor has the same height as Pole w/o Metal Return.
	Moment to Ground [kips*ft] under Extreme Wind Case 24.3 psf wind on conductor 26.33 psf wind on structure		Transverse: 7687.3	Transverse: 7542	Advantage Variant 2 Variant 2: with Metal Return above Pole Conductor has Moment to Ground 1.9% less than Variant 1: with Metal Return under Pole Conductor.
	Moment to Ground [kips*ft] under Broken Conductor Case 0 psf wind on conductor 6 psf wind on structure		Transverse: 10053.5 Longitudinal: 5896.7	Transverse: 8635.4 Longitudinal: 5325.5	Advantage Variant 2 Variant 2: with Metal Return above Pole Conductor has Moment to Ground 14.1% (T) and 9.7% (L) less than Variant1: with Metal Return under Pole Conductor.
	Live Line Maintenance Work (NESC Rule 236E & 237B IEEE-516-2009		Allows live line maintenance work for both Pole Conductor & Metal Return	Allows live line maintenance work for for Pole Conductor only	Advantage Variant 1 for live line work <u>but</u> see Note below.

<u>Note:</u> Advantage Variant 1 for live line maintenance work, but NESC Code does not require for live line maintenance work minimum clearances for dc voltages under +/-96 kV, and the metal return is energized at +/-53 kV. So remains custumer decision if they want to allow life line maintenance work on the metal return or not.
Both Variant 1 and 2 allow live line maintenance work on the pole conductor.

POWER ENGINEERS

Note: Appendix Q1 is using Power & Ampacity from conceptual design Rev.D, however the conclusions are still valid for the updated performance requirements.

600 kV DC Bipolar -Clean Line: Plains & Eastern, Rock Island, and Grain Belt Express

APPENDIX Q1- Metal Return Selection Analysis

Type	Calculated Neccesary MOT for current I metal return=1860 A (See Note 1)	Maximum Final Sag at calculated MOT in Ruling Span=4000 ft	Necessary DC Voltage, peak metal return-to-ground for dc current I metal return=1860 A	Total Leakage Distance (Se Notes 2,3)	Necessary Number of Bells (Se Notes 2,3)	Necessary Insulator Length (Se Notes 2,3)
ACSR Chuckar 1780 kCMIL Price:$3.35/ft	MOT=238 F= 114 C	Max. Final Sag=376.03 ft	±53 kV	1834 mm= 72.20" (34.6 mm/kV*53 kV=1834 mm)	4 (1834 mm/(550 mm/bell))	684 mm= 2.24 ft 959 mm=3.14 ft (insulator+hardware) (171 mm*4 bells)+275 mm hardware
ACCR/TW Pecos 1622 kCMIL Price:$24.16/ft	MOT=263 F= 128 C	Max. Final Sag=304.83 ft	±59 kV	2041 mm= 80.25" (34.6 mm/kV*59 kV=2041 mm)	4 (2076 mm/(550 mm/bell))	684 mm= 2.24 ft 959 mm=3.14 ft (insulator+hardware) (171 mm*4 bells)+275 mm hardware

Prices: from General Cable

Notes:

1. Contingency N1 for the positive and negative poles: one of the 2 poles goes out, and that pole emergency regime current: I pole, emergency=3720 A (20% over nominal regime: 3100 A) must be taken and be split between the 2 metal return conductors: I metal return=3720 A/2=1860 A.

2. Contamination Level: Medium: Specific Leakage Distance=34.6 mm/KV

3. Insulator: Sediver Toughened Glass DC Fog Type: N180 P/C 171 DR:

M&E Strength=180 kN (40 kips)

Spacing=171 mm=6.75"

Diameter=330 mm=13"

Leakage Distance=550 mm/bell

Formulas:

Total Leakage Distance=Specific Leakage Distance*DC Voltage, peak, metal return-ground

Number of Bells=Total Leakage Distance/Leakage Distance

Insulator Length=Spacing*Number of Bells+Hardware Length

4. Other type of conductors were considered:

ACSS/TW Bunting: for I=1860 A, its corresponding MOT=360 F and sag @ MOT its too high, plus its corresponding dc voltage, for I=3720 A/2=1860 A, it is high: ± 98 kV,more expensive: $8.11/ft.

Conclusion: It was chosen as Mettalic Return Conductor for Mississippi River Crossing the ACCR/TW Pecos because even if this will mean an additional cost of about $262K for the 3 spans of the Mississippi Rver Crossing Section (being $20.81/ft more expensive), the fact that the tower height will be reduced by about 71.2' (due to the difference in final sags @ MOT), will provide savings (tower, foundation, erection, etc.) higher than the additional $262K put in the MRC.

Clean Line +/- 600 kV DC Project Plain & Eastern

Appendix AA-Design Assumptions:

Sag and Tension:

NESC Heavy Common Point

0 deg Final After Load @ 25% Controls (Pole Conductor-ACSR Bluebird; MRC=Metal return Conductor-ACSR Chukar)

0 deg Final After Creep @25% Controls (OPGW-49ay85acs).

Mississippi River Crossing:

0 deg Final After Load @ 25% Controls (Conductor- ACCR/TW Pecos; MRC- ACCR/TW Pecos)

NESC Rule 250D-Extreme Ice with Concurrent Wind Initial @75% Controls (OPGW-161acs).

Structure Load Trees:

For all structures: Maximum Vertical Span (Maximum Weight Span): VS max=1.5*HS

For Conductor, MRC & OPGW only: Minimum Vertical Span (Minimum Weight Span): VS min=0.7*HS

Only for steel towers:

Minimum Vertical Span (Minimum Weight Span): VS min=100`

(For Basic, Medium, Heavy Suspension 0-2 deg, Small Angle Suspension 2-10 deg; Medium Angle Suspension 10-30 deg, and River Crossing Heavy Suspension 0-2 deg).

Minimum Vertical Span (Minimum Weight Span): VS min=-1000`

(For Dead-End 0-45 deg; Dead-End 45-90 deg).

For steel towers:

Ruling Span: RS=1500` used for tower load trees and to determine pole conductor, MRC and OPGW tensions

Horizontal Span (Wind Span): HS=RS=1500`

(For Basic Suspension 0-2 deg)

Horizontal Span (Wind Span): HS=1.2*RS=1800`

(For Medium Suspension 0-2deg;Small Angle Suspension 2-10 deg; Medium Angle Suspension 10-30 deg).

Horizontal Span (Wind Span): HS=1.67*RS=2500`

(For Heavy Suspension 0-2deg; Dead-End 0-45 deg; Dead-End 45-90 deg).

Mississippi River Crossing: is a separate case by itself, with actual 3 spans: 1000'; 4000' (actual river crossing); 1000':

Ruling Span: RS=3315'

Horizontal Span (Wind Span): HS=1.1*RS=3645' (For River Crossing Heavy Suspension 0-2 deg)

<u>For steel poles, “tower poles” (narrow base towers), guyed-poles</u>:

Ruling Span: RS=1200` used for pole load trees and to determine pole conductor, MRC and OPGW tensions

Horizontal Span (Wind Span): HS=0.833*RS=1000`

(For Basic Suspension 0-2 deg)

Horizontal Span (Wind Span): HS=1.0*RS=1200`

(For Medium Suspension 0-2deg; Small Angle Suspension 2-10 deg; Medium Angle Suspension 10-30 deg).

Horizontal Span (Wind Span): HS=1.25*RS=1500`

(For Heavy Suspension 0-2deg; Dead-End 0-45 deg; Dead-End 45-90 deg).

<u>Insulators Assemblies for Steel Lattice Towers</u>: all DC Glass Insulators

<u>Single "I" String Suspension: 1x25 kips=25 kips:</u>

Bell: Spacing=6.75”; Diameter=13”; Creepage Distance=21.65”; Number of Bells=43 (“Medium” Pollution: ESSD=0.03 mg/cm^2)

only for 600 kV dc jumper strings of Dead-ends (2 for DE90 and 1 for DE45) ; Length=23’-6” (including hardware);

Weight=1180 lbs (including hardware)

<u>Single “I” String Suspension: 1 x 50 kips=50 kips:</u>

Bell: Spacing=6.75”; Diameter=13”; Creepage Distance=21.65”; Number of Bells=4 (“Medium” Pollution: ESSD=0.03 mg/cm^2)

only for the 53 KV dc MRC Suspensions: Basic, Medium, Heavy Suspensions 0-2 deg, Small Angle Suspension 2-10 deg,

Medium Angle Suspension 10-30 deg; Length=4’-0”(including hardware); Weight=180 lbs (including hardware)

<u>Double "V" String Suspension: 2x50 kips=100 kips:</u>

Bell: Spacing=6.75”; Diameter=13”; Creepage Distance=21.65”; Number of Bells=43 (“Medium” Pollution: ESSD=0.03 mg/cm^2)

for Basic, Medium Suspension 0-2 deg; "V" string Angles: 45 deg & 45 deg.: One Side Length=29’-2” (including hardware);

Weight=4832 lbs (including hardware)

<u>Double "V" String Suspension: 2x66 kips=132 kips:</u>

Bell: Spacing=7-5/8”; Diameter=15”; Creepage Distance=27.95”; Number of Bells=44 (“Medium” Pollution: ESSD=0.03 mg/cm^2)

for Heavy Suspension 0-2 deg; "V" string Angles: 45 deg & 45 deg.: One Side Length=33’-6” (including hardware);

Weight=6706 lbs (including hardware)

<u>Triple "V" String Suspension: 3x50 kips=150 kips:</u>

Bell: Spacing=6.75”; Diameter=13”; Creepage Distance=21.65”; Number of Bells=43 (“Medium” Pollution: ESSD=0.03 mg/cm^2)

For Small Angle Suspension 2-10 deg; "V" String Angles: 20 deg & 35 deg; one side length=31’-6” (including hardware); weight=7389 lbs (including hardware)

For Medium Angle Suspension 10-30 deg; "V" String Angles: 12 deg & 65 deg. one side length=31'-6" (including hardware); weight=7389 lbs (including hardware)

Triple "V" String Suspension: 3x66 kips=198 kips:

Bell: Spacing=7-5/8"; Diameter=15"; Creepage Distance=27.95"; Number of Bells=44 ("Medium" Pollution: ESSD=0.03 mg/cm^2)

For River Crossing Heavy Suspension 0-2 deg; "V" string Angles: 45 deg & 45 deg: One Side Length=35'-6" (including hardware);

Weight=9884 lbs (including hardware)

Single String Dead-End: 1x 66 kips=66 kips:

Bell: Spacing=7-5/8"; Diameter=15"; Creepage Distance=27.95"; Number of Bells=4 ("Medium" Pollution: ESSD=0.03 mg/cm^2)

Only for the 53 KV dc MRC Dead-Ends 0-45 deg and 45-90 deg ; Length=4'-10"(including hardware); Weight=190 lbs (including hardware).

Quadruple String Dead-End: 4 x50 kips=200 kips:

Bell: Spacing=6.75"; Diameter=13"; Creepage Distance=21.65"; Number of Bells=43 ("Medium" Pollution: ESSD=0.03 mg/cm^2)

For Dead-End 0-45 deg and Dead-End 45-90 deg: Length=33'-7" (including hardware); Weight=4455 lbs (including hardware)

Insulators Assemblies for Steel Poles, "Tower Poles" (narrow base Towers) and Guyed Poles: all DC Glass Insulators

Single "I" String Suspension: 1x25 kips=25 kips:

Bell: Spacing=6.75"; Diameter=13"; Creepage Distance=21.65"; Number of Bells=43 ("Medium" Pollution: ESSD=0.03 mg/cm^2)

Only for 600 kV dc jumper strings of Dead-ends (2 for DE90 and 1 for DE45) ; Length=28' (including hardware);

Weight=2107 lbs (including hardware)

Single "I" String Suspension: 1 x 50 kips=50 kips:

Bell: Spacing=6.75"; Diameter=13"; Creepage Distance=21.65"; Number of Bells=4 ("Medium" Pollution: ESSD=0.03 mg/cm^2)

Only for the53 KV dc MRC Suspensions: Basic, Medium, Heavy Suspensions 0-2 deg, Small Angle Suspension 2-10 deg,

Medium Angle Suspension 10-30 deg; Length=4'-0"(including hardware); Weight=333 lbs (including hardware)

Single "V" String Suspension: 1x50 kips=50 kips:

Bell: Spacing=6.75"; Diameter=13"; Creepage Distance=21.65"; Number of Bells=43 ("Medium" Pollution: ESSD=0.03 mg/cm^2)

For Basic, and Medium Suspension 0-2 deg; "V" string Angles: 45 deg & 45 deg.: One Side Length=28' (including hardware);

Weight=2537 lbs (including hardware)

Double "V" String Suspension: 2x50 kips=100 kips

Bell: Spacing=6.75"; Diameter=13"; Creepage Distance=21.65"; Number of Bells=43 ("Medium" Pollution: ESSD=0.03 mg/cm^2)

For Heavy Suspension 0-2 deg; "V" string Angles: 45 deg & 45 deg.: One Side Length=29'-2" (including hardware);

Weight=4832 lbs (including hardware)

Small Angle Suspension 2-10 deg; Medium Angle Suspension 10-30 deg. One Side Length=29'-2" (including hardware);

Weight=4832 lbs (including hardware)

Single String Dead-End: 1x 66 kips=66 kips:

Bell: Spacing=5-7/8"; Diameter=15"; Creepage Distance=27.95"; Number of Bells=4 ("Medium" Pollution: ESSD=0.03 mg/cm^2)

Only for the 53 KV dc MRC Dead-Ends 0-45 deg and 45-90 deg; Length=4'-7" (including hardware); Weight=370 lbs (including hardware)

Quadruple String Dead-End: 4x50 kips=200 kips

Bell: Spacing=6.75"; Diameter=13"; Creepage Distance=21.65"; Number of Bells=43 ("Medium" Pollution: ESSD=0.03 mg/cm^2)

For Dead-End 0-45 deg and Dead-End 45-90 deg; Length=33'-7" (including hardware); Weight=4455 lbs (including hardware)

Shieldwire (OPGW):

Suspension Clamp:

Preformed type, AGS Unit, with 2 layers of armor rods: Length=10" (including hardware); weight=22 lbs (including hardware)

For all Suspension Towers and Poles: Basic, Medium, Heavy Suspension 0-2 deg; Small Angle Suspension 2-10 deg; Medium Angle Suspension 10-30 deg.

Dead-End Clamp:

Preformed type, with 2 layers of armor rods: Length=3'-2 $^{5/32}$" (including hardware); weight=44 lbs (including hardware)

For all Dead-End Towers and Poles: Dead-End 0-45 deg and Dead-End 45-90 deg.

Appendix AB
SNUB-OFF CASE
EXAMPLE OF CALCULATION

By: CIM 12/23/13
Checked by: ANR 12/23/13

Annex D

(informative)

Travelers or snub structure load calculation

The following is a method for calculating the actual load on travelers and snub structures when tension stringing. If structures are at the same elevation and there are no angles in the line, only the first and last travelers need to be considered. However, in rough terrain and situations in which angles are encountered, the load at these points should also be calculated. For snub structure loading, the weight of insulator assemblies and travelers must also be considered.

A = distance of tensioner or puller from structure
B = height of structure arm from elevation of tensioner or puller
D = sag during stringing operation (60°F, initial, sagging)
E = difference in elevation between points of attachment
$F°$ = angle of conductor from tensioner or puller to horizontal
$G°$ = angle tangent to conductor and horizontal
$K°$ = azimuth angle of departure in line
L = length of span
R_H = horizontal load on traveler
R_V = vertical load on traveler
R_{max} = total load on traveler
T = line tension (60°F, initial, sagging tension)

Example: Stringing tension is 5000 lb (T) and the tensioner is located 300 ft (A) from the first structure. Height from the point of attachment of the traveler to the elevation of the tensioner is 100 ft (B). The first span is 1000 ft (L), and sag during stringing is to be 50 ft (D). The angle of departure from the lead-in from the tensioner is 16° (K). The difference in elevation from the first to the second structure is 98 ft (E). The resultant load on the traveler is calculated as follows:

A = 300 ft
B = 100 ft
D = 50 ft
E = 98 ft
L = 1000 ft

$$\tan^{-1} F = \frac{B}{A} = \frac{100}{300} = 18.4°$$ (constant, as long as ratio $\frac{B}{A} = \frac{1}{3}$, is constant)

$$\tan^{-1} G = \frac{E + 4D}{L} = \frac{98 + 4 \cdot 50}{1000} = \frac{298}{1000} = 16.6°$$

The lead-in angle is 18.4° from horizontal, and the lead-out angle is 16.6°. The traveler will bisect the total angle of 35°, actually giving a 17.5° angle on either side.

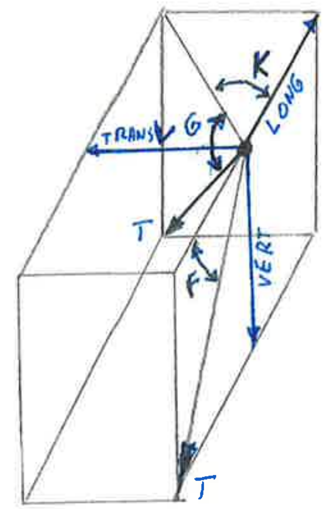
T = 5000 lb
K = 16°

To solve for R_V,

$$R_V = 2T\sin\frac{F° + G°}{2}$$

$$R_V = 2 \cdot 5000 \cdot \sin 17.5°$$

$R_V = 3007$ lb → VERIFICATION: R_V = VERT = T. [sin G + sin F] = 3007 lbs



To solve for R_H,

$$R_H = T \cdot \cos G \cdot \sin\frac{K}{2} + T \cdot \cos F \cdot \sin\frac{K}{2} = T \cdot (\cos G + \cos F) \cdot \sin\frac{K}{2}$$

$$R_H = 5000 \cdot (\cos 16.6° + \cos 18.4°) \cdot \sin\frac{16°}{2}$$

$R_H = 1327$ lb → VERIFICATION: $R_H = \sqrt{TRANSV^2 + LONG^2} = \sqrt{1321^2 + 138^2} = 1327$ lbs

To solve for R_{max},

TRANSV = T · cos G · sin K = 5000 · cos 16.6° · sin 16° = 1321 lbs

LONG = T · [cos G · cos K − cos F] = 5000 · [cos 16.6° · cos 16° − cos 18.4°] = −138 lbs

VERT = T · [sin G + sin F] = 5000 · [sin 16.6° + sin 18.4°] = 3007 lbs

$$R_{max} = \sqrt{3007^2 + 1327^2}$$

$R_{max} = 3287$ lb → VERIFICATION: $R_{MAX} = \sqrt{TRANSV^2 + LONG^2 + VERT^2} = \sqrt{1321^2 + 138^2 + 3007^2} = 3287$ lbs

Therefore, the total load on the traveler is 3280 lb. This value is approximate because the above formulas are based on parabolic rather than catenary equations, and sag is disregarded between the tensioner and first traveler. However, this method gives slightly less than actual load.

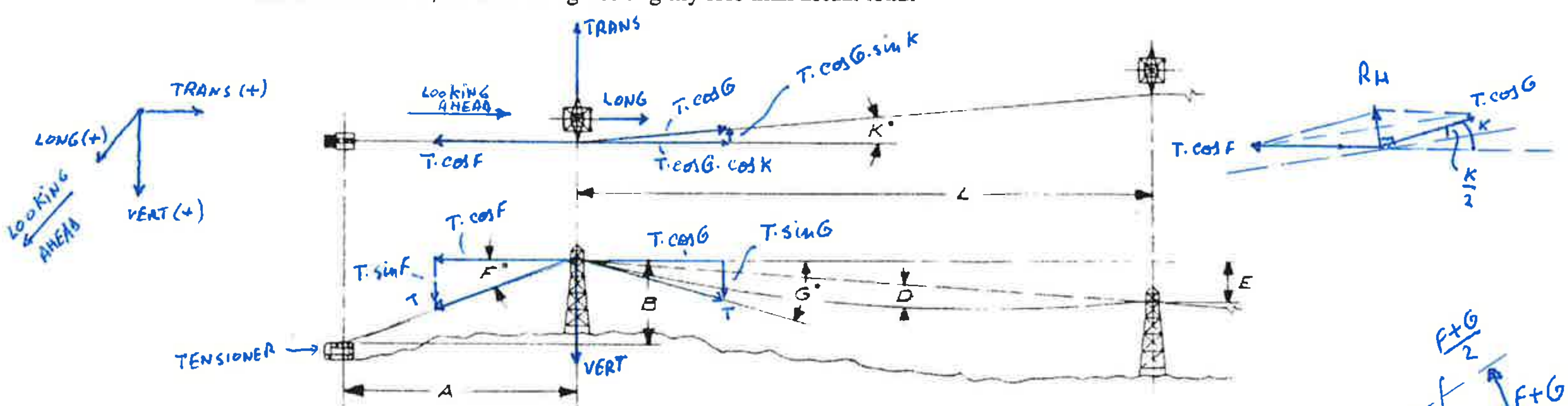
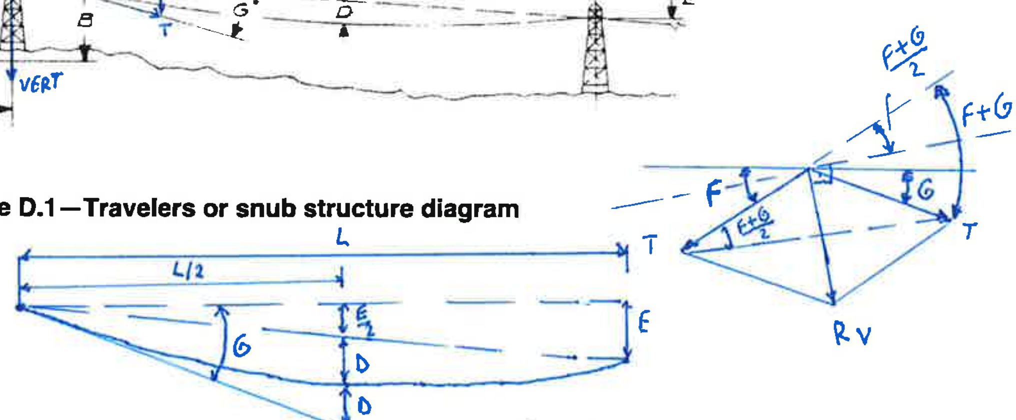


Figure D.1—Travelers or snub structure diagram



$$\tan G = \frac{\frac{E}{2} + D + D}{\frac{L}{2}} = \frac{\frac{E+4D}{2}}{\frac{L}{2}} = \frac{E+4D}{L}$$

1500' span OPGW

BY : AWR 05/30/14

CHECKED : CM 05/30/14

Suspension 0-2 Degree Snub off Loads IEEE 524-2002 ANNEX D

A = distance to tensioner or puller from structure

B = height of structure arm from elevation of tensioner or puller

D = sag during stringing operation

E = difference in elevation between points of attachments

F° = angle of conductor from tensioner or puller to horizontal

G° = angle tangent to conductor and horizontal

K° = azimuth angle of departure in line

L = length of span

R_H = horizontallaod on travelers

R_v= vertical load on travelers

R_{max} = total load on traveler

T = line tension

A=	615 ft
B =	205 ft
D =	32.73 ft
E =	80 ft
L =	1500 ft
F° = $\tan^{-1}$(B/A) =	18.4 Degrees
G° = $\tan^{-1}$((E+4D)/L) =	8.0 Degrees
T =	4088 Lbs
K° =	2 Degrees
Rv = 2Tsin((F°+ G°)/2)	1870 Lbs
Rh = 2Tsin(K°/2)	143 Lbs
Rmax = sqrt(R_v^2 + R_H^2)	1875 Lbs
Transverse Load = Tcos(G°)*sin(K°)	141 Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	167 Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	1862 Lbs

Verification: R_{max} = sqrt($Trans^2$+$Long^2$+$Vert^2$)

Total Load (No OLF)		
Transverse Load = Tcos(G°)*sin(K°)	141	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	167	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	1862	Lbs

Total Load (With OLF)		
Transverse Load = Tcos(G°)*sin(K°)	212	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	251	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	2793	Lbs

1500' span ACSR Chukar (HRC)

BY: ANR 05/30/14
CHECKED: CM 05/30/14

Suspension 0-2 Degree Snub off Loads IEEE 524-2002 ANNEX D

A = distance to tensioner or puller from structure
B = height of structure arm from elevation of tensioner or puller
D = sag during stringing operation
E = difference in elevation between points of attachments
F° = angle of conductor from tensioner or puller to horizontal
G° = angle tangent to conductor and horizontal
K° = azimuth angle of departure in line
L = length of span
R_H = horizontallaod on travelers
R_v= vertical load on travelers
R_{max} = total load on traveler
T = line tension

A=	585 ft
B =	195 ft
D =	44.14 ft
E =	80 ft
L =	1500 ft
F° = $\tan^{-1}$(B/A) =	18.4 Degrees
G° = $\tan^{-1}$((E+4D)/L) =	9.7 Degrees
T =	13349 Lbs
K° =	2 Degrees
Rv = 2Tsin((F°+ G°)/2)	6491 Lbs
Rh = 2Tsin(K°/2)	466 Lbs
Rmax = sqrt(R_v^2 + R_H^2)	6507 Lbs
Transverse Load = Tcos(G°)*sin(K°)	459 Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	486 Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	6472 Lbs

Verification: R_{max} = sqrt($Trans^2$+$Long^2$+$Vert^2$)

Total Load (No OLF)		
Transverse Load = Tcos(G°)*sin(K°)	459	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	486	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	6472	Lbs

Total Load (With OLF)		
Transverse Load = Tcos(G°)*sin(K°)	688	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	729	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	9708	Lbs

ACSR
1500' span bluebird

Suspension 0-2 Degree Snub off Loads IEEE 524-2002 ANNEX D

A = distance to tensioner or puller from structure
B = height of structure arm from elevation of tensioner or puller
D = sag during stringing operation
E = difference in elevation between points of attachments
F° = angle of conductor from tensioner or puller to horizontal
G° = angle tangent to conductor and horizontal
K° = azimuth angle of departure in line
L = length of span
R_H = horizontallaod on travelers
R_v= vertical load on travelers
R_{max} = total load on traveler
T = line tension

BY: ANR 05/30/14
CHECKED: CM 05/30/14

A=	480 ft
B =	160 ft
D =	45.65 ft
E =	80 ft
L =	1500 ft
$F° = \tan^{-1}(B/A)$ =	18.4 Degrees
$G° = \tan^{-1}((E+4D)/L)$ =	9.9 Degrees
T =	15627 Lbs
K° =	2 Degrees
Rv = 2Tsin((F°+ G°)/2)	7658 Lbs
Rh = 2Tsin(K°/2)	545 Lbs
$Rmax = sqrt(R_V^2 + R_H^2)$	7677 Lbs
Transverse Load = Tcos(G°)*sin(K°)	537 Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	558 Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	7636 Lbs

Verification: $R_{max} = sqrt(Trans^2+Long^2+Vert^2)$

Total Load with 3 Bundle (No OLF)		
Transverse Load = Tcos(G°)*sin(K°)	1611	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	1675	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	22909	Lbs

Total Load with 3 Bundle (With OLF)		
Transverse Load = Tcos(G°)*sin(K°)	2416	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	2513	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	34364	Lbs

1200' span OPGW

Suspension 0-2 Degree Snub off Loads IEEE 524-2002 ANNEX D

A = distance to tensioner or puller from structure

B = height of structure arm from elevation of tensioner or puller

D = sag during stringing operation

E = difference in elevation between points of attachments

F° = angle of conductor from tensioner or puller to horizontal

G° = angle tangent to conductor and horizontal

K° = azimuth angle of departure in line

L = length of span

R_H = horizontallaod on travelers

R_v= vertical load on travelers

R_{max} = total load on traveler

T = line tension

BY: ANR 05/30/14

CHECKED: [illegible] 05/30/14

A=	525 ft
B =	175 ft
D =	18.69 ft
E =	70 ft
L =	1200 ft
$F° = \tan^{-1}(B/A) =$	18.4 Degrees
$G° = \tan^{-1}((E+4D)/L) =$	6.9 Degrees
T =	4592 Lbs
K° =	2 Degrees
$Rv = 2T\sin((F°+ G°)/2)$	2012 Lbs
$Rh = 2T\sin(K°/2)$	160 Lbs
$Rmax = \mathrm{sqrt}(R_v^2 + R_H^2)$	2019 Lbs
Transverse Load = Tcos(G°)*sin(K°)	159 Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	200 Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	2002 Lbs

Verification: $R_{max} = \mathrm{sqrt}(Trans^2+Long^2+Vert^2)$

Total Load (No OLF)		
Transverse Load = Tcos(G°)*sin(K°)	159	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	200	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	2002	Lbs

Total Load (With OLF)		
Transverse Load = Tcos(G°)*sin(K°)	239	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	300	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	3003	Lbs

ACSR

1200' span Chukar

Suspension 0-2 Degree Snub off Loads IEEE 524-2002 ANNEX D

A = distance to tensioner or puller from structure
B = height of structure arm from elevation of tensioner or puller
D = sag during stringing operation
E = difference in elevation between points of attachments
F° = angle of conductor from tensioner or puller to horizontal
G° = angle tangent to conductor and horizontal
K° = azimuth angle of departure in line
L = length of span
R_H = horizontallaod on travelers
R_v= vertical load on travelers
R_{max} = total load on traveler
T = line tension

BY: AND 05/30/14
CHECKED: CIA
05/30/14

A=	495 ft
B =	165 ft
D =	27.95 ft
E =	70 ft
L =	1200 ft

F° = $\tan^{-1}$(B/A) =	18.4 Degrees
G° = $\tan^{-1}$((E+4D)/L) =	8.6 Degrees
T =	13494 Lbs
K° =	2 Degrees

Rv = 2Tsin((F°+ G°)/2)	6312 Lbs
Rh = 2Tsin(K°/2)	471 Lbs
Rmax = sqrt(R_v^2 + R_H^2)	6329 Lbs

Transverse Load = Tcos(G°)*sin(K°)	465 Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	532 Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	6288 Lbs

Verification: R_{max} = sqrt($Trans^2$+$Long^2$+$Vert^2$)

Total Load (No OLF)		
Transverse Load = Tcos(G°)*sin(K°)	465	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	532	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	6288	Lbs

Total Load (With OLF)		
Transverse Load = Tcos(G°)*sin(K°)	698	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	798	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	9433	Lbs

AESR

1200' span Blue Bird

Suspension 0-2 Degree Snub off Loads IEEE 524-2002 ANNEX D

A = distance to tensioner or puller from structure
B = height of structure arm from elevation of tensioner or puller
D = sag during stringing operation
E = difference in elevation between points of attachments
F° = angle of conductor from tensioner or puller to horizontal
G° = angle tangent to conductor and horizontal
K° = azimuth angle of departure in line
L = length of span
R_H = horizontallaod on travelers
R_v= vertical load on travelers
R_{max} = total load on traveler
T = line tension

BY: ANR 05/30/14
CHECKED: CMA 05/30/14

A=	390	ft
B =	130	ft
D =	29.01	ft
E =	70	ft
L =	1200	ft
$F° = \tan^{-1}(B/A)$ =	18.4	Degrees
$G° = \tan^{-1}((E+4D)/L)$ =	8.8	Degrees
T =	15770	Lbs
K° =	2	Degrees
Rv = 2Tsin((F°+ G°)/2)	7429	Lbs
Rh = 2Tsin(K°/2)	550	Lbs
$Rmax = sqrt(R_v^2 + R_H^2)$	7449	Lbs
Transverse Load = Tcos(G°)*sin(K°)	544	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	614	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	7403	Lbs

Verification: $R_{max} = sqrt(Trans^2+Long^2+Vert^2)$

Total Load with 3 Bundle (No OLF)		
Transverse Load = Tcos(G°)*sin(K°)	1631	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	1841	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	22209	Lbs

Total Load with 3 Bundle (With OLF)		
Transverse Load = Tcos(G°)*sin(K°)	2446	Lbs
Longitudinal Load = Tcos(G°)*cos(K°)-Tcos(F°)	2761	Lbs
Vertical Load = Tsin(G°)+Tsin(F°)	33313	Lbs

Appendix AC

Clamp and Insulator Parameters

TOWERS

By:	CIM	6/9/2014
Checked:	ANR	6/9/2014

Suspension 0-2 deg

TABLE 1

CLAMP / INSULATOR PARAMETERS												
TOWER TYPE			BASIC, MEDIUM					HEAVY				
WIRE	WIRE TYPE	CLAMP / INSULATOR TYPE	LENGTH	DIAMETER	AREA EXPOSED TO WIND	TOTAL WEIGHT (INCLUDING HARDWARE)	UTS	LENGTH	DIAMETER	AREA EXPOSED TO WIND	TOTAL WEIGHT (INCLUDING HARDWARE)	UTS
			[FT]	[IN]	[FT^2]	[LBS]	[KIPS]	[FT]	[IN]	[FT^2]	[LBS]	[KIPS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	Suspension Clamp	0.83	2	0.14	22	15.75	0.83	2	0.14	22	15.75
B	(3) - 2156 KCM ACSR "Bluebird"	Double "V" String Suspension 2x50=100 kips (Basic, Medium) **Double** "V" String Suspension 2x66=132 kips (Heavy)	29.17 (ONE SIDE)	13 (ONE SIDE)	31.6 (ONE SIDE)	4832 (BOTH SIDES)	100 (ONE SIDE)	33.5 (ONE SIDE)	15 (ONE SIDE)	41.8 (ONE SIDE)	6765 (BOTH SIDES)	132 (ONE SIDE)
C	(1) - 1780 KCM ACSR "Chukar"	**Single** "I" String Suspension 1x25 =25 kips (Basic, Medium) **Single** "I" String Suspension 1x40 =40 kips (Heavy)	4	11	1.83	150	25	4	13	2.2	180	40

Small Angle Suspension 2-10 deg

TABLE 1

CLAMP / INSULATOR PARAMETERS							
WIRE	WIRE TYPE	CLAMP / INSULATOR TYPE	LENGTH	DIAMETER	AREA EXPOSED TO WIND	TOTAL WEIGHT (INCLUDING HARDWARE)	UTS
			[FT]	[IN]	[FT^2]	[LBS]	[KIPS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	Suspension Clamp	0.83	2	0.14	22	15.75
B	(3) - 2156 KCM ACSR "Bluebird"	**Triple** "V" String Suspension 3x50=150 kips	31.5 (ONE SIDE)	13 (ONE SIDE)	51.2 (ONE SIDE)	7389 (BOTH SIDES)	150 (ONE SIDE)
C	(1) - 1780 KCM ACSR "Chukar"	**Single** "I" String Suspension 1x40 =40 kips	4	13	2.2	180	40

Appendix AC   Clamp and Insulator Parameters

Medium Angle Suspension 10-30 deg

TABLE 1

CLAMP / INSULATOR PARAMETERS							
WIRE	WIRE TYPE	CLAMP / INSULATOR TYPE	LENGTH	DIAMETER	AREA EXPOSED TO WIND	TOTAL WEIGHT (INCLUDING HARDWARE)	UTS
			[FT]	[IN]	[FT^2]	[LBS]	[KIPS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	Suspension Clamp	0.83	2	0.14	22	15.75
B	(3) - 2156 KCM ACSR "Bluebird"	**Triple** "V" String Suspension 3x50=150 kips	31.5 (ONE SIDE)	13 (ONE SIDE)	51.2 (ONE SIDE)	7389 (BOTH SIDES)	150 (ONE SIDE)
C	(1) - 1780 KCM ACSR "Chukar"	**Single** "I" String Suspension 1x40 =40 kips	4	13	2.2	180	40

Dead-End 0-45 deg:

TABLE 1

CLAMP / INSULATOR PARAMETERS							
WIRE	WIRE TYPE	CLAMP / INSULATOR TYPE	LENGTH	DIAMETER	AREA EXPOSED TO WIND	TOTAL WEIGHT (INCLUDING HARDWARE)	UTS
			[FT]	[IN]	[FT^2]	[LBS]	[KIPS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	Dead-End Clamp	3.18	2.15	0.57	44	25
B	(3) - 2156 KCM ACSR "Bluebird"	**Quadruple** String Dead-End 4x66=264 kips	36.83	15	46.04	6718	264
		Single "I" **Jumper String** Suspension 1x25=25 kips	23.5	11	10.77	1180	25
C	(1) - 1780 KCM ACSR "Chukar"	**Single** String Dead-End 1x66 =66 kips	4.83	15	3.02	190	66

Note: Total Weight of Insulators (including hardware) **applied at end of crossarm:**

WIRE	WIRE TYPE	TOTAL WEIGHT (INCLUDING HARDWARE)
		[LBS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	2 * 44 =88
B	(3) - 2156 KCM ACSR "Bluebird"	2 * 6718 + 1180 = 14616
C	(1) - 1780 KCM ACSR "Chukar"	2 * 190= 380

Appendix AC

Clamp and Insulator Parameters

Dead-End 45-90 deg:

TABLE 1

CLAMP / INSULATOR PARAMETERS								
WIRE	WIRE TYPE	CLAMP / INSULATOR TYPE	LENGTH	DIAMETER	AREA EXPOSED TO WIND	TOTAL WEIGHT (INCLUDING HARDWARE)	UTS
			[FT]	[IN]	[FT^2]	[LBS]	[KIPS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	Dead-End Clamp	3.18	2.15	0.57	44	25
B	(3) - 2156 KCM ACSR "Bluebird"	**Quadruple** String Dead-End 4x66=264 kips	36.83	15	46.04	6718	264
		Single "I" **Jumper String** Suspension 1x25=25 kips	23.5	11	10.77	1180	25
C	(1) - 1780 KCM ACSR "Chukar"	**Double** String Dead-End 2x66 =132 kips	5.5	15	6.88	380	132

Note: Total Weight of Insulators (including hardware) **applied at end of crossarm:**

WIRE	WIRE TYPE	TOTAL WEIGHT (INCLUDING HARDWARE)
		[LBS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	2 * 44 =88
B	(3) - 2156 KCM ACSR "Bluebird"	2 * 6718 +2* 1180 = 15790
C	(1) - 1780 KCM ACSR "Chukar"	2 * 380= 760

Appendix AC

Clamp and Insulator Parameters

POLES

By:	CIM	6/3/2014
Checked:	ANR	6/3/2014

Suspension 0-2 deg

TABLE 1

CLAMP / INSULATOR PARAMETERS												
TOWER TYPE			BASIC, MEDIUM					HEAVY				
WIRE	WIRE TYPE	CLAMP / INSULATOR TYPE	LENGTH	DIAMETER	AREA EXPOSED TO WIND	TOTAL WEIGHT (INCLUDING HARDWARE)	UTS	LENGTH	DIAMETER	AREA EXPOSED TO WIND	TOTAL WEIGHT (INCLUDING HARDWARE)	UTS
			[FT]	[IN]	[FT^2]	[LBS]	[KIPS]	[FT]	[IN]	[FT^2]	[LBS]	[KIPS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	Suspension Clamp	0.83	2	0.14	22	15.75	0.83	2	0.14	22	15.75
B	(3) - 2156 KCM ACSR "Bluebird"	**Single** "V" String Suspension 1x50=100 kips (Basic, Medium) **Double "**V" String Suspension 2x50=100 kips (Heavy)	28.0 (ONE SIDE)	13 (ONE SIDE)	15.2 (ONE SIDE)	2537 (BOTH SIDES)	50 (ONE SIDE)	29.17 (ONE SIDE)	13 (ONE SIDE)	31.6 (ONE SIDE)	4832 (BOTH SIDES)	100 (ONE SIDE)
C	(1) - 1780 KCM ACSR "Chukar"	**Single** "I" String Suspension 1x25 =25 kips (Basic, Medium, Heavy)	4	11	1.83	150	25	4	11	1.83	150	25

Small Angle Suspension 2-10 deg

TABLE 1

CLAMP / INSULATOR PARAMETERS							
WIRE	WIRE TYPE	CLAMP / INSULATOR TYPE	LENGTH	DIAMETER	AREA EXPOSED TO WIND	TOTAL WEIGHT (INCLUDING HARDWARE)	UTS
			[FT]	[IN]	[FT^2]	[LBS]	[KIPS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	Suspension Clamp	0.83	2	0.14	22	15.75
B	(3) - 2156 KCM ACSR "Bluebird"	**Double "**V" String Suspension 2x50=100 kips	29.17 (ONE SIDE)	13 (ONE SIDE)	31.6 (ONE SIDE)	4832 (BOTH SIDES)	100 (ONE SIDE)
C	(1) - 1780 KCM ACSR "Chukar"	**Single** "I" String Suspension 1x25 =25 kips	4	11	1.83	150	25

Appendix AC

Clamp and Insulator Parameters

Medium Angle Suspension 10-30 deg

TABLE 1

CLAMP / INSULATOR PARAMETERS							
WIRE	WIRE TYPE	CLAMP / INSULATOR TYPE	LENGTH	DIAMETER	AREA EXPOSED TO WIND	TOTAL WEIGHT (INCLUDING HARDWARE)	UTS
			[FT]	[IN]	[FT^2]	[LBS]	[KIPS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	Suspension Clamp	0.83	2	0.14	22	15.75
B	(3) - 2156 KCM ACSR "Bluebird"	**Double "**V" String Suspension 2x50=100 kips	29.17 (ONE SIDE)	13 (ONE SIDE)	31.6 (ONE SIDE)	4832 (BOTH SIDES)	100 (ONE SIDE)
C	(1) - 1780 KCM ACSR "Chukar"	**Single** "I" String Suspension 1x25 =25 kips	4	11	1.83	150	25

Dead-End 0-45 deg:

TABLE 1

CLAMP / INSULATOR PARAMETERS							
WIRE	WIRE TYPE	CLAMP / INSULATOR TYPE	LENGTH	DIAMETER	AREA EXPOSED TO WIND	TOTAL WEIGHT (INCLUDING HARDWARE)	UTS
			[FT]	[IN]	[FT^2]	[LBS]	[KIPS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	Dead-End Clamp	3.18	2.15	0.57	44	25
B	(3) - 2156 KCM ACSR "Bluebird"	**Quadruple** String Dead-End 4x50=200 kips	32.67	13	35.39	5150	200
		Single "I" **Jumper String** Suspension 1x25=25 kips	23.5	11	10.77	1180	25
C	(1) - 1780 KCM ACSR "Chukar"	**Single** String Dead-End 1x50 =50 kips	4	13	2.17	185	50

Note: Total Weight of Insulators (including hardware) **applied at end of crossarm:**

WIRE	WIRE TYPE	TOTAL WEIGHT (INCLUDING HARDWARE)
		[LBS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	2 * 44 =88
B	(3) - 2156 KCM ACSR "Bluebird"	2 * 5150 + 1180 = 11480
C	(1) - 1780 KCM ACSR "Chukar"	2 * 185= 370

Appendix AC   Clamp and Insulator Parameters

Dead-End 45-90 deg:

TABLE 1

CLAMP / INSULATOR PARAMETERS							
WIRE	WIRE TYPE	CLAMP / INSULATOR TYPE	LENGTH	DIAMETER	AREA EXPOSED TO WIND	TOTAL WEIGHT (INCLUDING HARDWARE)	UTS
			[FT]	[IN]	[FT^2]	[LBS]	[KIPS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	Dead-End Clamp	3.18	2.15	0.57	44	25
B	(3) - 2156 KCM ACSR "Bluebird"	**Quadruple** String Dead-End 4x50=200 kips	32.67	13	35.39	5150	200
		Single "I" **Jumper String** Suspension 1x25=25 kips	23.5	11	10.77	1180	25
C	(1) - 1780 KCM ACSR "Chukar"	**Single** String Dead-End 1x66 =66 kips	4.83	15	3.02	190	66

Note: Total Weight of Insulators (including hardware) **applied at end of crossarm:**

WIRE	WIRE TYPE	TOTAL WEIGHT (INCLUDING HARDWARE)
		[LBS]
A	(1) - OPGW (49ay 85acs-2c 1-1427)	2 * 44 =88
B	(3) - 2156 KCM ACSR "Bluebird"	2 * 5150 +2* 1180 = 12660
C	(1) - 1780 KCM ACSR "Chukar"	2 * 190= 380

Appendix AD- DC Glass Insulator Assemblies for Clean Line +/- 600 KV DC Line-Plain and Eastern Project By: CIM 06/09/2014; Checked: ANR 6/9/2014

Insulator Assembly Type		SML [kips]	DC Glass Bell Parameters				Insulator String Parameters			
			Spacing (Height) [in]	Diameter [in]	Creepage Distance [in]	Number of Bells	Insulator String Length w/o hardware [ft]	Insulator String Length with hardware [ft] (approximate)	Insulator String Total Weight with hardware [lbs] (approximate)	Pollution Range: ESDD [mg/cm^2]
Single "I" String Suspension	Only for **600 kV dc Jumper Strings of all Dead-End Towers and Poles (2 for DE90 and 1 for DE 45)**	1x25=25	5.75	11	17.5	43	20.6	23.5	1180	
Single "I" String Suspension	Only for **53 kV DC MRC, for Suspension Towers: Basic, Medium Suspension 0-2 deg, and Suspension Poles: Basic, Medium, Heavy Suspension 0-2 deg**, **Small Angle Suspension 2-10 deg; Medium Angle Suspension10-30 deg**	1x25=25	5.75	11	17.5	4	1.92	4	150	
Single "I" String Suspension	Only for **53 kV DC MRC, for Suspension Towers Heavy Suspension 0-2 deg; Small Angle Suspension 2-10 deg; Medium Angle Suspension10-30 deg**	1x40=40	6.75	13	21.65	4	2.25	4	180	
Single "V" String Suspension	For **Basic, Medium Suspension** **Poles** 0-2 deg V string Angles: 45 & 45 deg	1x50 =50	6.75	13	21.65	43	24.2	28 (one side)	2537	
Double "V" String Suspension	For **Basic, Medium Suspension** **Towers** 0-2 deg V String Angles: 45 & 45 deg **Heavy Suspension Poles 0-2 deg** V string Angles: 45 & 45 deg **Small Angle Suspension Poles 2-10 deg** V string Angles: 20 & 35 deg **Medium Angle Suspension Poles 10-30 deg;** V string Angles: 12 & 65 deg	2x50 =100	6.75	13	21.65	43	24.2	29.17 (one side)	4832	0.025-0.040, with some zones at 0.08 (In general Light to Medium, with local Heavy Contamination) NSDD=5*ESDD
Double "V" String Suspension	For **Heavy Suspension** **Towers** 0-2 deg V string Angles: 45 & 45 deg	2x66 =132	7.625	15	27.95	44	28	33.5 (one side)	6765	
Triple "V" String Suspension	**For Small Angle Suspension Towers 2-10 deg; V String Angles: 20 & 35 deg, and for Medium Angle Suspension Towers 10-30 deg; V string Angles 12 & 65 deg**	3x50 =150	6.75	13	21.65	43	24.2	31.5 (one side)	7389	
Triple "V" String Suspension	**For River Crossing Heavy Suspension Towers 0-2 deg; V string Angles: 45 & 45 deg**	3x66 =198	7.625	15	27.95	44	28	35.5 (one side)	9884	
Single String Dead-End	Only for **53 kV DC MRC, for Dead-End Poles 0-45**	1x50=50	6.75	13	21.65	4	2.25	4	185	
Single String Dead-End	Only for **53 kV DC MRC, for Dead-End Poles 45-90 and Towers 0-45**	1x66=66	7.625	15	27.95	4	2.5	4.83	190	
Double String Dead-End	Only for **53 kV DC MRC, for Dead-End Towers 45-90**	2x66=66	7.625	15	27.95	4	2.5	5.5	380	
Quadruple String Dead-End	Only for **600 kV DC Pole Conductor, for all Dead-End Poles : 0-45 deg and 45-90 deg**	4x50=200	6.75	13	21.65	43	24.19	32.67	5150	
Quadruple String Dead-End	Only for **600 kV DC Pole Conductor, for all Dead-End Towers : 0-45 deg and 45-90 deg**	4x66=264	7.625	15	27.95	44	27.95	36.83	6718	

Appendix AE
Stringing/Broken Case
Example of Calculation

POWER ENGINEERS

SHEET NUMBER: 1 OF 1

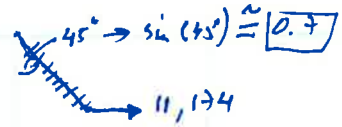
PROJECT: Clean Line

PROJECT NUMBER: 132836

SUBJECT: Stringing/Broken Subconductor for Bluebird 3 bundle: 60°F, 0" ice, 4psf wind.

BY: ANR DATE: 5-28-14

CHECKED BY: CIM DATE: 5-28-14



$$\frac{15963(2)+11{,}174}{15963(3)} = .9$$

$15963(.9) = 14{,}367$ lbs

$$\frac{15963(2)}{15963(3)} = .666$$

$.666(15963) = 10{,}631$ lbs

$15{,}963(.7) = 11{,}174$ lbs

To accurately calculate loading tree forces the following will be done:

Back span broken with 70% tension in ahead span. Ahead & Back span tensions will be adjusted to model 1 broken subconductor:

Back Span tension: 10,631 lbs ✓

Ahead Span tension: 14,367 lbs ✓

APPENDIX AF- INSULATOR LOADINGS CHECK
METAL CONDUCTOR DE INSULATOR ASSEMBLY

By: CIM 6/4/2014
Checked: ANR 6/4/2014

Dead-End 0-45 deg **At 45 deg**

Load Case		WITHOUT OLF Vertical Loads Fy lbs	WITHOUT OLF Transverse Loads Fx lbs	WITHOUT OLF Longitudinal Loads Fz lbs	Resultant Loads Fr lbs	Type of DE Insulator
1DE	NESC Heavy-DE	**6733**	**9114**	**19394**	**22462**	**Single**
2aDE	NESC Extreme Wind-DE	**4300**	**10500**	**16900**	**20356**	**Single**
3DE	NESC Extreme Ice with Concurrent Wind-DE	**10400**	**11800**	**24700**	**29283**	**Single**
4DE	NESC Medium- DE	**5400**	**7252**	**15394**	**17853**	**Single**

Formulas:

Fr=SQRT(Fy^2+Fx^2+Fz^2)

Assumptions for Insulator Design:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy & NESC Heavy DE); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**66000**	[lbs]
NESC Heavy Strength Reduction Factor:	**0.4**	[-]
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]
NESC Heavy Insulator Strength	26400	[lbs]
Rest of the Cases Insulator Strength :	42900	[lbs]

Insulator type: **glass**

Wind Direction: both directions

Note: **NESC Heavy DE Transverse w/o OLF=** TR wind +TR tension=2710/2.5+13249/1.65=9114 **lbs**

NESC Medium DE Transverse w/o OLF= TR wind +TR tension=2190/2.5+10521/1.65=7252 **lbs**

Transverse with OLF=TR wind+TR tension=2710+13249=15959 lbs=16.0 kips

Transverse with OLF=TR wind+TR tension=2190+10521 =12711 lbs=12.8 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
METAL CONDUCTOR DE INSULATOR ASSEMBLY

By: CIM 6/4/2014
Checked: ANR 6/4/2014

Dead_End 45-90 deg **At 90 deg**

Load Case		WITHOUT OLF Vertical Loads Fy lbs	WITHOUT OLF Transverse Loads Fx lbs	WITHOUT OLF Longitudinal Loads Fz lbs	Resultant Loads Fr lbs	Type of DE Insulator
1DE	NESC Heavy-DE	**6733**	**15920**	**14849**	**22788**	**Double**
2aDE	NESC Extreme Wind-DE	**4300**	**16400**	**12900**	**21304**	**Double**
3DE	NESC Extreme Ice with Concurrent Wind-DE	**10400**	**20500**	**18900**	**29759**	**Double**
4DE	NESC Medium-DE	**5400**	**12658**	**11818**	**18140**	**Double**

Formulas:

Fr=SQRT(Fy^2+Fx^2+Fz^2)

Assumptions for Insulator Design:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy & NESC Heavy DE); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**66000**	[lbs]
NESC Heavy Strength Reduction Factor:	**0.4**	[-]
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]
NESC Heavy Insulator Strength	26400	[lbs]
Rest of the Cases Insulator Strength :	42900	[lbs]

Insulator type: **glass**

Wind Direction: both directions

Note: **NESC Heavy DE Transverse w/o OLF=** TR wind +TR tension=2710/2.5+24480/1.65=15920 **lbs**

NESC Medium DE Transverse w/o OLF= TR wind +TR tension=2190/2.5+19440/1.65=12658 **lbs**

Transverse with OLF=TR wind+TR tension=2710+24480=27190 lbs=27.2 kips

Transverse with OLF=TR wind+TR tension=2190+19440 =21630 lbs=21.7 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
POLE CONDUCTOR DE INSULATOR ASSEMBLY

By: CIM 6/4/2014
Checked: ANR 6/4/2014

Dead-End 0-45 deg **At 0 deg**

Load Case		WITHOUT OLF Vertical Loads Fy lbs	WITHOUT OLF Transverse Loads Fx lbs	WITHOUT OLF Longitudinal Loads Fz lbs	Resultant Loads Fr lbs	Type of DE Insulator
1DE	NESC Heavy-DE	**36267**	**3453**	**71333**	**80098**	**Quadruple**
2aDE	NESC Extreme Wind-DE	**28300**	**11500**	**61700**	**68848**	**Double**
3DE	NESC Extreme Ice with Concurrent Wind-DE	**47700**	**4900**	**90000**	**101977**	**Triple**
4DE	NESC Medium- DE	**31867**	**2828**	**53091**	**61985**	**Triple**

Formulas:

Fr=SQRT(Fy^2+Fx^2+Fz^2)

Assumptions for Insulator Design:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy & NESC Heavy DE); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**66000**	[lbs]
NESC Heavy Strength Reduction Factor:	**0.4**	[-]
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]
NESC Heavy Insulator Strength	26400	[lbs]
Rest of the Cases Insulator Strength :	42900	[lbs]

Insulator type: **glass**

Wind Direction: both directions

Note: **NESC Heavy DE Transverse w/o OLF=** TR wind +TR tension=8632/2.5+0/1.65=**3453 lbs**

NESC Medium DE Transverse w/o OLF= TR wind +TR tension=7069/2.5+0/1.65=2828 **lbs**

Transverse with OLF=TR wind+TR tension=8632+0=8632 lbs=8.7 kips

Transverse with OLF=TR wind+TR tension=7069+0=7069 lbs=7.1 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
POLE CONDUCTOR DE INSULATOR ASSEMBLY

By: CIM 6/4/2014
Checked: ANR 6/4/2014

		Dead-End 0-45 deg			At 45 deg	
		WITHOUT OLF				
Load Case		Vertical Loads Fy lbs	Transverse Loads Fx lbs	Longitudinal Loads Fz lbs	Resultant Loads Fr lbs	Type of DE Insulator
1DE	NESC Heavy-DE	**36267**	**30732**	**65879**	**81239**	**Quadruple**
2aDE	NESC Extreme Wind-DE	**28300**	**35100**	**57000**	**72677**	**Double**
3DE	NESC Extreme Ice with Concurrent Wind-DE	**47700**	**39300**	**83200**	**103644**	**Triple**
4DE	NESC Medium- DE	**31867**	**24809**	**53091**	**66706**	**Triple**

Formulas:

Fr=SQRT(Fy^2+Fx^2+Fz^2)

Assumptions for Insulator Design:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy & NESC Heavy DE); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**66000**	[lbs]
NESC Heavy Strength Reduction Factor:	**0.4**	[-]
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]
NESC Heavy Insulator Strength	26400	[lbs]
Rest of the Cases Insulator Strength :	42900	[lbs]

Insulator type: **glass**

Wind Direction: both directions

Note: **NESC Heavy DE Transverse w/o OLF=** TR wind +TR tension=8632/2.5+45010/1.65=**30732 lbs**

NESC Medium DE Transverse w/o OLF= TR wind +TR tension=7069/2.5+36270/1.65=24809 **lbs**

Transverse with OLF=TR wind+TR tension=8632+45010=53700 lbs=53.7 kips

Transverse with OLF=TR wind+TR tension=7069+36270 =43339 lbs=43.4 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
POLE CONDUCTOR DE INSULATOR ASSEMBLY

By: CIM 6/4/2014
Checked: ANR 6/4/2014

Dead_End 45-90 deg **At 45 deg**

Load Case		WITHOUT OLF				
		Vertical Loads Fy lbs	Transverse Loads Fx lbs	Longitudinal Loads Fz lbs	Resultant Loads Fr lbs	Type of DE Insulator
1DE	NESC Heavy-DE	**40800**	**30732**	**65879**	**83361**	**Quadruple**
2aDE	NESC Extreme Wind-DE	**32900**	**35100**	**57000**	**74588**	**Double**
3DE	NESC Extreme Ice with Concurrent Wind-DE	**52200**	**39300**	**83200**	**105790**	**Triple**
4DE	NESC Medium-DE	**36400**	**24809**	**53091**	**68986**	**Triple**

Formulas:

Fr=SQRT(Fy^2+Fx^2+Fz^2)

Assumptions for Insulator Design:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy & NESC Heavy DE); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**66000**	[lbs]
NESC Heavy Strength Reduction Factor:	**0.4**	[-]
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]
NESC Heavy Insulator Strength	26400	[lbs]
Rest of the Cases Insulator Strength :	42900	[lbs]

Insulator type: **glass**

Wind Direction: both directions

Note: **NESC Heavy DE Transverse w/o OLF=** TR wind +TR tension=8632/2.5+45010/1.65=**30732 lbs**

NESC Medium DE Transverse w/o OLF= TR wind +TR tension=7069/2.5+36270/1.65=24809 **lbs**

Transverse with OLF=TR wind+TR tension=8632+45010=53700 lbs=53.7 kips

Transverse with OLF=TR wind+TR tension=7069+36270 =43339 lbs=43.4 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
POLE CONDUCTOR DE INSULATOR ASSEMBLY

By: CIM 6/4/2014
Checked: ANR 6/4/2014

Dead_End 45-90 deg **At 90 deg**

Load Case		WITHOUT OLF Vertical Loads Fy lbs	Transverse Loads Fx lbs	Longitudinal Loads Fz lbs	Resultant Loads Fr lbs	Type of DE Insulator
1DE	NESC Heavy-DE	40800	53857	50424	84308	Quadruple
2aDE	NESC Extreme Wind-DE	32900	55100	43700	77641	Double
3DE	NESC Extreme Ice with Concurrent Wind-DE	52200	68500	63700	107120	Triple
4DE	NESC Medium-DE	36400	43445	40667	69758	Triple

Formulas:
Fr=SQRT(Fy^2+Fx^2+Fz^2)

Assumptions for Insulator Design:
Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy & NESC Heavy DE); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	66000	[lbs]
NESC Heavy Strength Reduction Factor:	0.4	[-]
Rest of the Cases Strength Reduction Factor:	0.65	[-]
NESC Heavy Insulator Strength	26400	[lbs]
Rest of the Cases Insulator Strength :	42900	[lbs]

Insulator type: glass
Wind Direction: both directions

Note: **NESC Heavy DE Transverse w/o OLF=** TR wind +TR tension=8632/2.5+83168/1.65=53857 **lbs**
NESC Medium DE Transverse w/o OLF= TR wind +TR tension=7069/2.5+67018/1.65=43445 **lbs**

Transverse with OLF=TR wind+TR tension=8632+83168=91800 lbs=91.8 kips
Transverse with OLF=TR wind+TR tension=7069+67018 =74087 lbs=74.10 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
METAL RETURN CONDUCTOR INSULATOR ASSEMBLY

Basic Tower & Heavy Pole-Suspension 0-2 deg_MRC

I-Insulator

	Load Case	Unfactored Vertical Loads lbs	Unfactored Transverse Loads lbs	Unfactored Longitudinal Loads lbs	Unfactored Resultant Force R lbs	Factored Vertical Loads lbs	Factored Transverse Loads lbs	Factored Longitudinal Loads lbs	Wind OLF	Vertical OLF	Tension OLF	
1	NESC Heavy	7800	2033	0	**8061**	**11700**	**4500**	**0**	2.50	1.50	1.65	**Single**
2a	NESC Extreme Wind	4900	4800	0	**6859**	**4900**	**4800**	**0**	1.00	1.00	1.00	**Single**
2b	NESC Extreme Wind - Yaw 45°	4900	2600	100	**5548**	**4900**	**2600**	**100**	1.00	1.00	1.00	**Single**
2c	NESC Extreme Wind -Longitudinal 90°	400	500	100	**648**	**400**	**500**	**100**	1.00	1.00	1.00	**Single**
3	NESC Extreme Ice with Concurrent Wind	12200	2800	0	**12517**	**12200**	**2800**	**0**	1.00	1.00	1.00	**Single**
4	NESC Medium	6200	1626	0	**6410**	**9300**	**3600**	**0**	2.50	1.50	1.65	**Single**

By:	CIM	6/6/2014
Checked:	ANR	6/6/2014

Assumptions for Insulator Design:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**25000**	[lbs]
NESC Heavy Strength Reduction Factor:	**0.4**	[-]
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]
NESC Heavy Insulator Strength	**10000**	[lbs]
Rest of the Cases Insulator Strength :	**16250**	[lbs]

Insulator type: **glass**

Note: **NESC Heavy Transverse w/o OLF=** TR wind +TR tension=3252/2.5+1208/1.65=2033 **lbs**
NESC Medium Transverse w/o OLF= TR wind +TR tension=2628/2.5+948/1.65=1626 **lbs**

Transverse with OLF=TR wind+TR tension=3252+1208=4460 lbs=4.5 kips
Transverse with OLF=TR wind+TR tension=2628+948=3576 lbs=3.6 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
METAL RETURN CONDUCTOR INSULATOR ASSEMBLY

Medium Tower -Suspension 0-2 deg_MRC

		Unfactored	Unfactored	Unfactored	Unfactored	Factored	Factored	Factored				I-Insulator
Load Case		Vertical Loads lbs	Transverse Loads lbs	Longitudinal Loads lbs	Resultant Force R lbs	Vertical Loads lbs	Transverse Loads lbs	Longitudinal Loads lbs	Wind OLF	Vertical OLF	Tension OLF	
1	NESC Heavy	9333	2294	0	**9611**	**14000**	**5200**	**0**	2.50	1.50	1.65	**Single**
2a	NESC Extreme Wind	5800	5700	0	**8132**	**5800**	**5700**	**0**	1.00	1.00	1.00	**Single**
2b	NESC Extreme Wind - Yaw 45°	5800	3000	100	**6531**	**5800**	**3000**	**100**	1.00	1.00	1.00	**Single**
2c	NESC Extreme Wind -Longitudinal 90°	5800	500	100	**5822**	**5800**	**500**	**100**	1.00	1.00	1.00	**Single**
3	NESC Extreme Ice with Concurrent Wind	14600	3200	0	**14947**	**14600**	**3200**	**0**	1.00	1.00	1.00	**Single**
4	NESC Medium	7400	1843	0	**7626**	**11100**	**4200**	**0**	2.50	1.50	1.65	**Single**

By:	CIM	6/6/2014
Checked:	ANR	6/6/2014

Assumptions for Insulator Design:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**25000**	[lbs]	Insulator type:	**glass**
NESC Heavy Strength Reduction Factor:	**0.4**	[-]		
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]		
NESC Heavy Insulator Strength	**10000**	[lbs]		
Rest of the Cases Insulator Strength :	**16250**	[lbs]		

Note: **NESC Heavy Transverse w/o OLF=** TR wind +TR tension=3904/2.5+1208/1.65=2294 **lbs**
NESC Medium Transverse w/o OLF= TR wind +TR tension=3154/2.5+960/1.65=1843 **lbs**

Transverse with OLF=TR wind+TR tension=3904+1208=5112 lbs=5.2 kips
Transverse with OLF=TR wind+TR tension=3154+960=4114 lbs=4.2 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
METAL RETURN CONDUCTOR INSULATOR ASSEMBLY

Heavy Tower -Suspension 0-2 deg_MRC

		Unfactored	Unfactored	Unfactored	Unfactored	Factored	Factored	Factored				I-Insulator
Load Case		Vertical Loads lbs	Transverse Loads lbs	Longitudinal Loads lbs	Resultant Force R lbs	Vertical Loads lbs	Transverse Loads lbs	Longitudinal Loads lbs	Wind OLF	Vertical OLF	Tension OLF	
1	NESC Heavy	12867	2900	0	**13189**	**19300**	**6700**	**0**	2.50	1.50	1.65	**Single**
2a	NESC Extreme Wind	8000	7600	0	**11034**	**8000**	**7600**	**0**	1.00	1.00	1.00	**Single**
2b	NESC Extreme Wind - Yaw 45°	8000	4000	100	**8945**	**8000**	**4000**	**100**	1.00	1.00	1.00	**Single**
2c	NESC Extreme Wind -Longitudinal 90°	8000	500	100	**8016**	**8000**	**500**	**100**	1.00	1.00	1.00	**Single**
3	NESC Extreme Ice with Concurrent Wind	20100	4100	0	**20514**	**20100**	**4100**	**0**	1.00	1.00	1.00	**Single**
4	NESC Medium	10133	2334	0	**10399**	**15200**	**5400**	**0**	2.50	1.50	1.65	**Single**

By:	CIM	6/6/2014
Checked:	ANR	6/6/2014

Assumptions for Insulator Design:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**40000**	[lbs]	Insulator type:	**glass**
NESC Heavy Strength Reduction Factor:	**0.4**	[-]		
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]		
NESC Heavy Insulator Strength	**16000**	[lbs]		
Rest of the Cases Insulator Strength :	**26000**	[lbs]		

Note: **NESC Heavy Transverse w/o OLF=** TR wind +TR tension=5420/2.5+1208/1.65=2900 **lbs**

NESC Medium Transverse w/o OLF= TR wind +TR tension=4380/2.5+960/1.65=2334 **lbs**

Transverse with OLF=TR wind+TR tension=5420+1208=6628 lbs=6.7 kips

Transverse with OLF=TR wind+TR tension=4380+960=5340 lbs=5.4 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
METAL RETURN CONDUCTOR INSULATOR ASSEMBLY

Small Angle Tower-Suspension 2-10 deg_MRC

		Unfactored	Unfactored	Unfactored	Unfactored	Factored	Factored	Factored				I-Insulator
Load Case		Vertical Loads lbs	Transverse Loads lbs	Longitudinal Loads lbs	Resultant Force R lbs	Vertical Loads lbs	Transverse Loads lbs	Longitudinal Loads lbs	Wind OLF	Vertical OLF	Tension OLF	
1	NESC Heavy	9333	5219	0	**10693**	**14000**	**10000**	**0**	2.50	1.50	1.65	**Single**
2a	NESC Extreme Wind	5800	8200	0	**10044**	**5800**	**8200**	**0**	1.00	1.00	1.00	**Single**
2b	NESC Extreme Wind - Yaw 45°	5800	5000	100	**7658**	**5800**	**5000**	**100**	1.00	1.00	1.00	**Single**
2c	NESC Extreme Wind -Longitudinal 90°	5800	2200	100	**6204**	**5800**	**2200**	**100**	1.00	1.00	1.00	**Single**
3	NESC Extreme Ice with Concurrent Wind	14600	6900	0	**16148**	**14600**	**6900**	**0**	1.00	1.00	1.00	**Single**
4	NESC Medium	7400	4166	0	8492	**11100**	**8000**	**0**	2.50	1.50	1.65	**Single**

By: CIM 6/6/2014
Checked: ANR 6/6/2014

Assumptions for Insulator Design:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**40000**	[lbs]	Insulator type:	**glass**
NESC Heavy Strength Reduction Factor:	**0.4**	[-]		
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]		
NESC Heavy Insulator Strength	**16000**	[lbs]		
Rest of the Cases Insulator Strength :	**26000**	[lbs]		

Note: **NESC Heavy Transverse w/o OLF=** TR wind +TR tension=3904/2.5+6034/1.65=5219 **lbs** Transverse with OLF=TR wind+TR tension=3904+6034=9938 lbs=10.0 kips

NESC Medium Transverse w/o OLF= TR wind +TR tension=3154/2.5+4792/1.65=4166 **lbs** Transverse with OLF=TR wind+TR tension=3154+4792=7946 lbs=8.0 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
METAL RETURN CONDUCTOR INSULATOR ASSEMBLY

Medium Angle Tower-Suspension 10-30 deg_MRC

		Unfactored	Unfactored	Unfactored	Unfactored	Factored	Factored	Factored				I-Insulator
Load Case		Vertical Loads lbs	Transverse Loads lbs	Longitudinal Loads lbs	Resultant Force R lbs	Vertical Loads lbs	Transverse Loads lbs	Longitudinal Loads lbs	Wind OLF	Vertical OLF	Tension OLF	
1	NESC Heavy	9333	12422	0	**15538**	**14000**	**21900**	**0**	2.50	1.50	1.65	**Single**
2a	NESC Extreme Wind	5800	14500	0	**15617**	**5800**	**14500**	**0**	1.00	1.00	1.00	**Single**
2b	NESC Extreme Wind - Yaw 45°	5800	9700	400	**11309**	**5800**	**9700**	**400**	1.00	1.00	1.00	**Single**
2c	NESC Extreme Wind -Longitudinal 90°	5800	6300	100	**8564**	**5800**	**6300**	**100**	1.00	1.00	1.00	**Single**
3	NESC Extreme Ice with Concurrent Wind	14600	16100	0	**21734**	**14600**	**16100**	**0**	1.00	1.00	1.00	**Single**
4	NESC Medium	7400	9887	0	**12350**	**11100**	**17400**	**0**	2.50	1.50	1.65	**Single**

By:	CIM	6/6/2014
Checked:	ANR	6/6/2014

Assumptions for Insulator Design:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**40000**	[lbs]	Insulator type:	**glass**
NESC Heavy Strength Reduction Factor:	**0.4**	[-]		
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]		
NESC Heavy Insulator Strength	**16000**	[lbs]		
Rest of the Cases Insulator Strength :	**26000**	[lbs]		

Note: **NESC Heavy Transverse w/o OLF=** TR wind +TR tension=3904/2.5+17920/1.65=12422 **lbs** — Transverse with OLF=TR wind+TR tension=3904+17920=21824 lbs=21.9 kips

NESC Medium Transverse w/o OLF= TR wind +TR tension=3154/2.5+14232/1.65=9887 **lbs** — Transverse with OLF=TR wind+TR tension=3154+14232=17386 lbs=17.4 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
POLE CONDUCTOR "V" STRING INSULATOR ASSEMBLY

Basic Tower & Heavy Pole-Suspension 0-2 deg

		WITHOUT OLF		Right Side	Left Side							Type of V-Insulator	
Load Case		Vertical Loads Fy lbs	Transverse Loads Fx lbs	Compression side string Fc lbs	Tension side string Ft lbs	Load Pt. A Trans. T_A	Load Pt. A Vert. V_A	Load Pt. B Trans. T_B	Load Pt. B Vert. V_B	Trans. Applied Load	Vert. Applied Load	Right Side	Left Side
1	NESC Heavy	**31333**	**6632**	17466	26845	18983	18983	12351	12351	6632	31333	**Double**	**Double**
2a	NESC Extreme Wind	**21800**	**15900**	4172	26658	18850	18850	2950	2950	15900	21800	Single	Single
2b	NESC Extreme Wind - Yaw 45°	**21800**	**8600**	9334	21496	15200	15200	6600	6600	8600	21800	Single	Single
2c	NESC Extreme Wind -Longitudinal 90°	**21800**	**1500**	14354	16476	11650	11650	10150	10150	1500	21800	Single	Single
3	NESC Extreme Ice with Concurrent Wind	**45000**	**9000**	25456	38184	27000	27000	18000	18000	9000	45000	**Double**	**Double**
4	NESC Medium	**26067**	**5400**	14614	22251	15734	15734	10334	10334	5400	26067	**Double**	**Double**

Formulas:

Ft=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2) **(+)** String Angle-Left: **alpha1=** **45** Wind Direction: both directions

Fc=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2) **(-)** String Angle-Right: **alpha2=** **45**

T_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*cos(alpha1)

V_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*sin(alpha1)

T_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*cos(alpha2)

V_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*sin(alpha2)

By: CIM 6/3/2014
Checked: ANR 6/3/2014

Assumptions for Insulator Design: Per RUS1724E-200, Paragraph 8.9.1:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**50000**	[lbs]	Insulator type:	**glass**
NESC Heavy Strength Reduction Factor:	**0.4**	[-]		
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]		
NESC Heavy Insulator Strength	20000	[lbs]		
Rest of the Cases Insulator Strength :	32500	[lbs]		

Note: **NESC Heavy Transverse w/o OLF=** TR wind +TR tension=10358/2.5+4106/1.65=**6632 lbs** Transverse with OLF=TR wind+TR tension=10358+4106=14464 lbs=14.5 kips

NESC Medium Transverse w/o OLF= TR wind +TR tension=8484/2.5+3310/1.65=**5400 lbs** Transverse with OLF=TR wind+TR tension=8484+3310=11794 lbs=11.8 kips

Basic Pole Suspension 0-2 deg

		WITHOUT OLF		Right Side	Left Side							Type of V-Insulator	
Load Case		Vertical Loads Fy lbs	Transverse Loads Fx lbs	Compression side string Fc lbs	Tension side string Ft lbs	Load Pt. A Trans. T_A	Load Pt. A Vert. V_A	Load Pt. B Trans. T_B	Load Pt. B Vert. V_B	Trans. Applied Load	Vert. Applied Load	Right Side	Left Side
1	NESC Heavy	**22227**	**4448**	12572	18862	13338	13338	8890	8890	4448	22227	**Single**	**Single**
2a	NESC Extreme Wind	**15900**	**13710**	1549	20937	14805	14805	1095	1095	13710	15900	Single	Single
2b	NESC Extreme Wind - Yaw 45°	**15900**	**7460**	5968	16518	11680	11680	4220	4220	7460	15900	Single	Single
2c	NESC Extreme Wind -Longitudinal 90°	**15900**	**1390**	10260	12226	8645	8645	7255	7255	1390	15900	Single	Single
3	NESC Extreme Ice with Concurrent Wind	**36970**	**7670**	20718	31565	22320	22320	14650	14650	7670	36970	**Single**	**Single**
4	NESC Medium												

Formulas:

Ft=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2) **(+)** String Angle-Left: **alpha1=** **45** Wind Direction: both directions

Fc=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2) **(-)** String Angle-Right: **alpha2=** **45**

T_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*cos(alpha1)

V_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*sin(alpha1)

T_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*cos(alpha2)

V_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*sin(alpha2)

Assumptions for Insulator Design: Per RUS1724E-200, Paragraph 8.9.1:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**50000**	[lbs]	Insulator type:	**glass**
NESC Heavy Strength Reduction Factor:	**0.4**	[-]		
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]		
NESC Heavy Insulator Strength	20000	[lbs]		
Rest of the Cases Insulator Strength :	32500	[lbs]		

APPENDIX AF- INSULATOR LOADINGS CHECK
POLE CONDUCTOR "V" STRING INSULATOR ASSEMBLY

Medium Tower Suspension 0-2 deg

Load Case		Without OLF: Vertical Loads Fy lbs	Without OLF: Transverse Loads Fx lbs	Right Side: Compression side string Fc lbs	Left Side: Tension side string Ft lbs	Load Pt. A Trans. T_A	Load Pt. A Vert. V_A	Load Pt. B Trans. T_B	Load Pt. B Vert. V_B	Trans. Applied Load	Vert. Applied Load	Type of V-Insulator: Right Side	Type of V-Insulator: Left Side
1	NESC Heavy	**36600**	**7460**	20605	31155	22030	22030	14570	14570	7460	36600	**Double**	**Double**
2a	NESC Extreme Wind	**25200**	**18600**	4667	30971	21900	21900	3300	3300	18600	25200	**Single**	**Single**
2b	NESC Extreme Wind - Yaw 45°	**25200**	**10000**	10748	24890	17600	17600	7600	7600	10000	25200	Single	Single
2c	NESC Extreme Wind -Longitudinal 90°	**25200**	**1500**	16758	18880	13350	13350	11850	11850	1500	25200	Single	Single
3	NESC Extreme Ice with Concurrent Wind	**53000**	**10100**	30335	44618	31550	31550	21450	21450	10100	53000	**Double**	**Double**
4	NESC Medium	**30267**	**6078**	17104	25700	18173	18173	12095	12095	6078	30267	**Double**	**Double**

Formulas:

Ft=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2) **(+)**

Fc=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2) **(-)**

T_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*cos(alpha1)

V_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*sin(alpha1)

T_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*cos(alpha2)

V_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*sin(alpha2)

String Angle-Left: **alpha1=** **45**

String Angle-Right: **alpha2=** **45**

Wind Direction: both directions

By: CIM 6/3/2014

Checked: ANR 6/3/2014

Assumptions for Insulator Design: Per RUS1724E-200, Paragraph 8.9.1:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**50000**	[lbs]	Insulator type: **glass**
NESC Heavy Strength Reduction Factor:	**0.4**	[-]	
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]	
NESC Heavy Insulator Strength	20000	[lbs]	
Rest of the Cases Insulator Strength :	32500	[lbs]	

Note: **NESC Heavy Transverse w/o OLF=** TR wind +TR tension=12430/2.5+4106/1.65=**7460 lbs** Transverse with OLF=TR wind+TR tension=12430+4106=16536 lbs=16.6 kips

NESC Medium Transverse w/o OLF= TR wind +TR tension=10180/2.5+3310/1.65=**6078 lbs** Transverse with OLF=TR wind+TR tension=10180+3310=13490 lbs=13.5 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
POLE CONDUCTOR "V" STRING INSULATOR ASSEMBLY

Heavy Tower Suspension 0-2 deg

	Load Case	Vertical Loads Fy lbs (WITHOUT OLF)	Transverse Loads Fx lbs (WITHOUT OLF)	Compression side string Fc lbs (Right Side)	Tension side string Ft lbs (Left Side)	Load Pt. A Trans. T_A	Load Pt. A Vert. V_A	Load Pt. B Trans. T_B	Load Pt. B Vert. V_B	Trans. Applied Load	Vert. Applied Load	Type of V-Insulator Right Side	Type of V-Insulator Left Side
1	NESC Heavy	**50867**	**9394**	29326	42611	30131	30131	20737	20737	9394	50867	**Double**	**Double**
2a	NESC Extreme Wind	**35100**	**25000**	7142	42497	30050	30050	5050	5050	25000	35100	Single	Single
2b	NESC Extreme Wind - Yaw 45°	**35100**	**13200**	15486	34153	24150	24150	10950	10950	13200	35100	Single	Single
2c	NESC Extreme Wind -Longitudinal 90°	**35100**	**1500**	23759	25880	18300	18300	16800	16800	1500	35100	Single	Single
3	NESC Extreme Ice with Concurrent Wind	**73700**	**12800**	43063	61165	43250	43250	30450	30450	12800	73700	**Double**	**Double**
4	NESC Medium	**10133**	**7661**	1748	12582	8897	8897	1236	1236	7661	10133	**Single**	**Single**

Formulas:

Ft=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2) **(+)**

Fc=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2) **(-)**

T_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*cos(alpha1)

V_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*sin(alpha1)

T_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*cos(alpha2)

V_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*sin(alpha2)

String Angle-Left: **alpha1=** **45**

String Angle-Right: **alpha2=** **45**

Wind Direction: both directions

By: CIM 6/3/2014

Checked: ANR 6/3/2014

Assumptions for Insulator Design: Per RUS1724E-200, Paragraph 8.9.1:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**66000**	[lbs]	Insulator type:	**glass**
NESC Heavy Strength Reduction Factor:	**0.4**	[-]		
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]		
NESC Heavy Insulator Strength	26400	[lbs]		
Rest of the Cases Insulator Strength :	42900	[lbs]		

Note: **NESC Heavy Transverse w/o OLF=** TR wind +TR tension=17264/2.5+4106/1.65=**9394 lbs** Transverse with OLF=TR wind+TR tension=17264+4106=21370 lbs=21.4 kips

NESC Medium Transverse w/o OLF= TR wind +TR tension=14138/2.5+3310/1.65=**7661 lbs** Transverse with OLF=TR wind+TR tension=14138+3310=17448 lbs=17.5 kips

River Crossing Heavy Suspension 0-2 deg

Load Case		Vertical Loads Fy lbs	Transverse Loads Fx lbs	Right Side: Compression side string Fc lbs	Left Side: Tension side string Ft lbs	Load Pt. A Trans. T_A	Load Pt. A Vert. V_A	Load Pt. B Trans. T_B	Load Pt. B Vert. V_B	Trans. Applied Load	Vert. Applied Load	Type of V-Insulator: Right Side	Type of V-Insulator: Left Side
1	NESC Heavy	**50170**	**11560**	27301	43650	30865	30865	19305	19305	11560	50170	**Double**	**Double**
2a	NESC Extreme Wind	**33020**	**34870**	-1308	48005	33945	33945	-925	-925	33020	34870	Double	Double
2b	NESC Extreme Wind - Yaw 45°	**33020**	**18130**	10529	36169	25575	25575	7445	7445	18130	33020	Single	Single
2c	NESC Extreme Wind -Longitudinal 90°	**33020**	**1700**	22147	24551	17360	17360	15660	15660	1700	33020	Single	Single
3	NESC Extreme Ice with Concurrent Wind	**91630**	**18790**	51506	78079	55210	55210	36420	36420	18790	91630	**Double**	**Double**

Formulas:

Ft=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2) **(+)** String Angle-Left: **alpha1=** **45** Wind Direction: both directions

Fc=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2) **(-)** String Angle-Right: **alpha2=** **45**

T_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*cos(alpha1)

V_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*sin(alpha1)

T_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*cos(alpha2)

V_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*sin(alpha2)

Assumptions for Insulator Design: Per RUS1724E-200, Paragraph 8.9.1:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**66000**	[lbs]	Insulator type:	**glass**
NESC Heavy Strength Reduction Factor:	**0.4**	[-]		
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]		
NESC Heavy Insulator Strength	26400	[lbs]		
Rest of the Cases Insulator Strength :	42900	[lbs]		

APPENDIX AF- INSULATOR LOADINGS CHECK
POLE CONDUCTOR "V" STRING INSULATOR ASSEMBLY

Small Angle Tower Suspension 2-10 deg

Load Case		WITHOUT OLF Vertical Loads Fy lbs	WITHOUT OLF Transverse Loads Fx lbs	Right Side Compression side string Fc lbs	Left Side Tension side string Ft lbs	Load Pt. A Trans. T_A	Load Pt. A Vert. V_A	Load Pt. B Trans. T_B	Load Pt. B Vert. V_B	Trans. Applied Load	Vert. Applied Load	Type of V-Insulator Right Side	Type of V-Insulator Left Side
1	NESC Heavy	39133	17398	37627	51315	48221	17551	30823	21582	17398	39133	Triple	Triple
2a	NESC Extreme Wind	27800	27200	20534	43248	44021	16022	16821	11778	27200	27800	Double	Double
2b	NESC Extreme Wind - Yaw 45°	27800	16700	24918	38864	37112	13508	20412	14292	16700	27800	Double	Double
2c	NESC Extreme Wind -Longitudinal 90°	27800	7500	28759	35022	31058	11304	23558	16496	7500	27800	Double	Double
3	NESC Extreme Ice with Concurrent Wind	55600	22700	54304	73260	67183	24453	44483	31147	22700	55600	Triple	Triple
4	NESC Medium	32800	14085	31746	43508	40090	14591	26005	18209	14085	32800	Triple	Triple

Formulas:

Ft=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2) **(+)**

Fc=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2) **(-)**

T_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*cos(alpha1)

V_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*sin(alpha1)

T_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*cos(alpha2)

V_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*sin(alpha2)

String Angle-Left: **alpha1=** **20**

String Angle-Right: **alpha2=** **35**

Wind Direction: both directions

By: CIM 6/3/2014

Checked: ANR 6/3/2014

Assumptions for Insulator Design: Per RUS1724E-200, Paragraph 8.9.1:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**50000**	[lbs]	Insulator type:	**glass**
NESC Heavy Strength Reduction Factor:	**0.4**	[-]		
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]		
NESC Heavy Insulator Strength	20000	[lbs]		
Rest of the Cases Insulator Strength :	32500	[lbs]		

Note: **NESC Heavy Transverse w/o OLF=** TR wind +TR tension=12430/2.5+20502/1.65=**17398 lbs** Transverse with OLF=TR wind+TR tension=12430+20502=32932 lbs=33 kips

NESC Medium Transverse w/o OLF= TR wind +TR tension=10180/2.5+16522/1.65=**14085 lbs** Transverse with OLF=TR wind+TR tension=10180+16522=26702 lbs=26.7 kips

APPENDIX AF- INSULATOR LOADINGS CHECK
POLE CONDUCTOR "V" STRING INSULATOR ASSEMBLY

Medium Angle Tower Suspension 10-30 deg

		WITHOUT OLF		Right Side	Left Side							Type of V-Insulator	
Load Case		Vertical Loads Fy lbs	Transverse Loads Fx lbs	Compression side string Fc lbs	Tension side string Ft lbs	Load Pt. A Trans. T_A	Load Pt. A Vert. V_A	Load Pt. B Trans. T_B	Load Pt. B Vert. V_B	Trans. Applied Load	Vert. Applied Load	Right Side	Left Side
1	NESC Heavy	**39133**	**41871**	30350	55920	54698	11626	12827	27507	41871	39133	**Triple**	**Triple**
2a	NESC Extreme Wind	**27800**	**48400**	17580	57077	55830	11867	7430	15933	48400	27800	Double	Double
2b	NESC Extreme Wind - Yaw 45°	**27800**	**33400**	20781	43125	42182	8966	8782	18834	33400	27800	Double	Double
2c	NESC Extreme Wind -Longitudinal 90°	**27800**	**22100**	23192	32614	31901	6781	9801	21019	22100	27800	Double	Double
3	NESC Extreme Ice with Concurrent Wind	**55600**	**53600**	44378	73972	72355	15380	18755	40220	53600	55600	**Triple**	**Triple**
4	NESC Medium	**32800**	**33807**	25713	45672	44674	9496	10867	23304	33807	32800	**Triple**	**Triple**

Formulas:

Ft=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2) **(+)**

Fc=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2) **(-)**

T_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*cos(alpha1)

V_A=(Fy*cos(alpha2)+Fx*sin(alpha2))/sin(alpha1+alpha2)*sin(alpha1)

T_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*cos(alpha2)

V_B=(Fy*cos(alpha1)-Fx*sin(alpha1))/sin(alpha1+alpha2)*sin(alpha2)

String Angle-Left: **alpha1=** **12**

String Angle-Right: **alpha2=** **65**

Wind Direction: both directions

By: CIM 6/3/2014

Checked: ANR 6/3/2014

Assumptions for Insulator Design: Per RUS1724E-200, Paragraph 8.9.1:

Overload Load Factor=1; Strength Reduction Factor: 0.4 (NESC Heavy); 0.65 (glass & porcelain-rest of the cases), 0.5 (polymer-rest of the cases)

Insulator Strength Rating:	**50000**	[lbs]	Insulator type:	**glass**
NESC Heavy Strength Reduction Factor:	**0.4**	[-]		
Rest of the Cases Strength Reduction Factor:	**0.65**	[-]		
NESC Heavy Insulator Strength	20000	[lbs]		
Rest of the Cases Insulator Strength :	32500	[lbs]		

Note: **NESC Heavy Transverse w/o OLF=** TR wind +TR tension=12430/2.5+60884/1.65=**41871 lbs**

NESC Medium Transverse w/o OLF= TR wind +TR tension=10180/2.5+49062/1.65=**33807 lbs**

Transverse with OLF=TR wind+TR tension=12430+60884=73314 lbs=73.4 kips

Transverse with OLF=TR wind+TR tension=10180+49062=59242 lbs=59.3 kips

APPENDIX AG- REQUIRED CLEARANCES & CORRESPONDING INSULATOR SWING ANGLES

Basic, Medium , Heavy Suspension 0-2 deg

Required Clearances				Left Crossarm Wind from Left	Right Crossarm Wind from Right
Mechanical	Electrical	+/- 600 kV DC Pole Conductor	+/- 53 KV DC Metal Return Conductor	+/- 53 KV DC MRC "I" String Insulator Swing Angle	+/- 53 KV DC MRC "I" String Insulator Swing Angle
60 ^{o} F, No Wind	Lightning Impulse Withstand Voltage	13.5'	2'	0 ^{o}	0 ^{o}
60 ^{o} F, Medium Wind: 6 psf	Switching Impulse Withstand Voltage	13.5'	2'	37 ^{o}	29 ^{o}
60 ^{o} F, Extreme Wind: 20.74 psf	Steady State, Normal Regime	5'	0.75'	69 ^{o}	66 ^{o}

Small Angle Suspension 2-10 deg

Required Clearances				Left Crossarm Wind from Left	Right Crossarm Wind from Right
Mechanical	Electrical	+/- 600 kV DC Pole Conductor	+/- 53 KV DC Metal Return Conductor	+/- 53 KV DC MRC "I" String Insulator Swing Angle	+/- 53 KV DC MRC "I" String Insulator Swing Angle
60 ^{o} F, No Wind	Lightning Impulse Withstand Voltage	13.5'	2'	39 ^{o}	-9 ^{o}
60 ^{o} F, Medium Wind: 6 psf	Switching Impulse Withstand Voltage	13.5'	2'	54 ^{o}	21 ^{o}
60 ^{o} F, Extreme Wind: 20.74 psf	Steady State, Normal Regime	5'	0.75'	74 ^{o}	63 ^{o}

APPENDIX AG- REQUIRED CLEARANCES & CORRESPONDING INSULATOR SWING ANGLES

Medium Angle Suspension 10-30 deg

				Left Crossarm Wind from Left	Right Crossarm Wind from Right
Required Clearances					
Mechanical	Electrical	+/- 600 kV DC Pole Conductor	+/- 53 KV DC Metal Return Conductor	+/- 53 KV DC MRC "I" String Insulator Swing Angle	+/- 53 KV DC MRC "I" String Insulator Swing Angle
60 ^{o} F, No Wind	Lightning Impulse Withstand Voltage	13.5'	2'	67 ^{o}	-39 ^{o}
60 ^{o} F, Medium Wind: 6 psf	Switching Impulse Withstand Voltage	13.5'	2'	72 ^{o}	-17 ^{o}
60 ^{o} F, Extreme Wind: 20.74 psf	Steady State, Normal Regime	5'	0.75'	81 ^{o}	43 ^{o}

Dead End 0-45 deg

				Left Crossarm Wind from Left	Right Crossarm Wind from Right	Left Crossarm Wind from Left	Right Crossarm Wind from Right
Required Clearances							
Mechanical	Electrical	+/- 600 kV DC Pole Conductor	+/- 53 KV DC Metal Return Conductor	+/- 600 KV DC Pole Conductor "I" Jumper String Insulator Swing Angle	+/- 600 KV DC Pole Conductor Jumper Loop Swing Angle	+/- 53 KV DC MRC "Jumper Loop Swing Angle	+/- 53 KV DC MRC Jumper Loop Swing Angle
60 ^{o} F, No Wind	Lightning Impulse Withstand Voltage	13.5'	2'	0 ^{o}	0 ^{o}	0 ^{o}	0 ^{o}
60 ^{o} F, Medium Wind: 6 psf	Switching Impulse Withstand Voltage	13.5'	2'	10 ^{o}	14 ^{o}	22 ^{o}	22 ^{o}
60 ^{o} F, Extreme Wind: 20.74 psf	Steady State, Normal Regime	5'	0.75'	32 ^{o}	41 ^{o}	58 ^{o}	58 ^{o}

APPENDIX AG- REQUIRED CLEARANCES & CORRESPONDING INSULATOR SWING ANGLES

Dead End 45-90 deg

				Left Crossarm Wind from Left	Right Crossarm Wind from Right	Left Crossarm Wind from Left	Right Crossarm Wind from Right
Required Clearances							
Mechanical	Electrical	+/- 600 kV DC Pole Conductor	+/- 53 KV DC Metal Return Conductor	+/- 600 KV DC Pole Conductor "I" Jumper String Insulator Swing Angle	+/- 600 KV DC Pole Conductor Jumper Loop Swing Angle	+/- 53 KV DC MRC "Jumper Loop Swing Angle	+/- 53 KV DC MRC Jumper Loop Swing Angle
60° F, No Wind	Lightning Impulse Withstand Voltage	13.5'	2'	0°	0°	0°	0°
60° F, Medium Wind: 6 psf	Switching Impulse Withstand Voltage	13.5'	2'	10°	14°	22°	22°
60° F, Extreme Wind: 20.74 psf	Steady State, Normal Regime	5'	0.75'	32°	41°	58°	58°