FIGURE 7.1
CALCULATION COVER SHEET

EDCN-02

TU ELECTRIC DESIGN ENGINEERING ORGANIZATION

CALCULATION COVER SHEET

9 PAGE NO. 1 of 18
TOTAL NO. OF PAGES 173

1 CALCULATION NO.: 16343-EE(B)-140

REV. NO.: 4

3 ORGANIZATION: SWEC

4 AFFECTED UNIT NUMBER:
☒ 1 ☐ 1 AND COMMON
☐ 2 ☐ BOTH

13 CONFIRMATION REQUIRED
☒ YES ☐ NO

5 CALCULATION CLASSIFICATION:
☒ CLASS I OR II
☐ NON-SAFETY

6 CALCULATION APPLIES TO A DESIGN MODIFICATION
☐ YES ☒ NO
IF YES, DM NO.: _____

7 DOES THE CALCULATION AFFECT A LICENSING DOCUMENT?
☐ YES ☒ NO IF YES, CORRESPONDENCE NO.: _____

8 TITLE: Ampacity of power cable wrapped with 330-660 installed as free air drop.

11 DESCRIPTION: Calculates cable ampacities for free air drops wrapped with Thermolag 330-660 in two different installation methods and varying product tolerance. Free air drop wrapped conditions are compared to tray and conduit conditions to establish maximum number of cables permitted under wrap.

12 DESIGN CHANGE TRENDING CODE 1 / 0 0 / A I / A

14 RESPONSIBLE ENGINEER(S), DATE:
Richard W. Blaybrough Jr 10/2/92
Richard W Blaybrough Jr.

15 CHECKER, DATE:
CARLOS M. CAMPA
Carlos M. Campa 10/2/92

17 DESIGN VERIFIER, DATE:
Ghulam R. Kebriaei
Ghulam R. Kebriaei 10/2/92

18 RESPONSIBLE SUPERVISING ENGINEER, DATE:
Henry J. Bee
Henry J. Bee 10-2-92

ECE 5.03

REV. 3
PAGE 7.1 - 1 OF 1

FIGURE 7.2
INDEX SHEET

TU ELECTRIC DESIGN ENGINEERING ORGANIZATION

INDEX SHEET

23 CALCULATION NO.:	22 PAGE
16345-EE(B)-140	1A of 18

25 REV. No.	26 PAGES REVISED	27 PAGES ADDED	28 PAGES DELETED
4 Rev 11/6/92	Pages 1, 1B - 6, 7 Rev 11/6/92	Pages 6A, 16 - 18	Pages 1B, 1C, 1F, 1H
	Pages 8 - 10, 11 11/6/92	Attach BB2 14 pages	
	Pages 12 - 15	Attach BB3 18 pages	

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SUMMARY OF CHANGES

Rev 1

Pages 5,7	Added "Assumption 8" stating the significance of factors A' and B', and provided Reference for same.
Pages 8,9	Revised Tables A and B because of changes made to factors A' and B'.
Attachment B1, pg 2	Revised "CABLE" matrix to clarify accuracy of Rdc25.
Attachment B1, pp 9,13,14	Revised factors A' and B', and related matrices.
Attachment B2, pp 1,2,3,5, 8 and 10	Revised matrices dependant upon above revisions.

Rev 2

Title page	Added Rev 2 sign-off
Page 1d, 1e	Added summary of Rev 2 changes
Page 1f	Added new "Review Statement for Safety Related Calculation" for Rev 2.
Page 2	Changed titles of attachments for clarity
Page 3-8	Modified text to agree with new attachment, re-numbering of attachment. Discussion added to cover calculation of ampacities based on 3, 4 and 5 inch conduits. Approach to account for diversity modified to more accurately reflect plant operation. Statement of "prelimary issue" deleted, since referenced document has been issued.

Page 9-12	Table A, B and text revised to reflect new results. Table C added to convey results in an alternate fashion for use by construction.
Attachment A	Heading revised for clarity
Attachment b1, pg 1,2	Heading revised for clarity
Attachment B1, pg 3,4	Revised approach to calculate number of cables in conduit to reflect approach in NEC and to calculate numner of cables in 3,4 and 5 inch conduits.
Attachment B1, pg 5	Text added for clarity.
Attachment B1, pg 6-7	New results.
Attachment B1, pg 8	Revised to reflect results of Attachment F
Attachment B1, pg 9	Results changed.
Attachment B2	Completely revised potions taken from Rev 1, Attachment B1. No change in methodology except to include thermal resistance of jacket in computation. Results have changed.
Attachment B3	Previously called Attachment B2 in Rev 1 . New results. Table headings revised for clarity.
Attachment C	Revised heading and text for clarity.
Attachment D	Revised heading for clarity.
Attachment F	Added to calulate ampacity diversity factors.

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STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

A 5010 85

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 16345	DIVISION & GROUP EE(B)	CALCULATION NO. 140	OPTIONAL TASK CODE XXX	PAGE 1g Rev 3

Rev 3

Title Page	~~Added~~ Rev 3 sign-off
page 1g	~~Added~~ summary of Rev 3 changes
Page 1h	~~Added~~ new "Review Statement"
Page 1e	Editorial
Page 2.A	Index changes
3-6, 21, 9, 10, 11, 12, 13-15	Include Att G2, G3, G1, H, which ~~were~~ created because Thermolag product thickness changed
Att B2 - pg 1,	Note product thickness for clarity
Att E pg 14	~~Added~~ reviewer - Rev 3 marketing check
Att G1, G2, G3,	New attachment to calculate new ampacities based on change in product thickness
Att H	New attachment to calculate percentage change in cable ampacity
~~Att~~ I	New - letter from TSI documenting maximum average product thickness of Thermolag wrap.

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OUTLINE

ATTACHMENT G1	Interim Calculation of cable ampacity of Thermolagged cable in Free Air Template 1-Modified for 8 cables	Total pg= 9
ATTACHMENT G2	Cable ampacity of thermolagged cable- 3/8 inch product in Free Air: template 2	Total pg= 14
ATTACHMENT G3	Ampacity Comparison Between Free Air Thermolagged cables (3/8 inch product) and Cable in Thermolagged Raceway	Total pg= 17
ATTACHMENT H	Comparison of Ampacities for 5/16" vs 3/8 " Thermolag product	Total pg= 5
ATTTACHMENT I	Letter from TSI 11/17/89	Total pg= 1

ATTACHMENT BB2 Cable ampacity of Thermolagged cable in free air (for three layers of Thermolag on bundles less than three inches) Total pg= 14 4

ATTACHMENT BB3 Comparison between free air Thermolagged cables (for three layers of Thermolag on bundles less than three inches) and cables in Thermolagged raceway Total pg= 18

OBJECTIVE OF CALCULATION

This calculation will determine the installation limits associated with wrapping free air drops of power cables with Thermolag 330-660. These limits provide the field the ability to approve a given installation involving power cables without having to check ampacity. The conclusion will state restrictions with regard to the number of cables in the wrap and may make the restrictions contingent on the cables already installed in thermolagged trays, conduit, etc.

METHODOLOGY

1. The ampacity of cables in free air when wrapped with Thermolag 330-660 will be modeled in similar fashion as cables in a conduit. An air gap between cable and Thermolag is assumed. References 15, 16, and 17 show how Thermolag is applied to cables in free air. The wrap will not be in contact with the cable, thereby, justifying the similarity of its installation with a conduit.

2. All thermal resistance values of the cable insulation, between the cable and wrap, of the wrap, and between the wrap and air will be developed using the equations from Reference 3 (J.H. Neher, and M.H. McGrath paper) and Reference 2 (K. Petty paper). Conservatively, no axial heat transfer is assumed.

3. MathCAD software will be used to input and arrange the source data which completely describes the cable parameters, e.g. conductor diameter, insulation thickness. These are shown in template - Attachment A, and the results are saved on a computer file in ASCII format for use by the templates Attachments B1, B2, G1 and G2. Attachment A will clearly describe the source of the input data.

4. MathCAD template Attachment B1 and G1 will calculate interim values for input into other templates. Specifically the number of cables and conductors in a bundle, effective bundle diameters, and the maximum number of cables which can fit into a conduit are calculated.

   Several conditions will be calculated: cable bundles consist of 1, 2, 3 or 5 cables, or cable bundles will be the maximum number of cables which can fit in either a 3, 4, 5, or 6 inch conduit. NEC definition of 40 percent cable fill in conduit will be used to calculate the maximum number of cables.

   Cable ampacity will be calculated for each possible bundle size discussed above using the approaches

outlined in Reference 3. Due to memory limitations this MathCAD template is sub-divided, with the results of ampacity calculation saved on a computer file in ASCII format and transferred to template Attachments B2, and G3. 2 3

5. The relationship between the bundle diameter for the cables and the diameter of the individual cables is used in calculating thermal resistance between cable wrap and air. This relationship is defined on template Attachment C and the results saved on a computer file in ASCII format and transferred into template Attachments B1 and G1. 2

6. The properties of Thermolag 330-660 are taken from Attachment D. Since the product requires two layers wrapped longitudinally, and each layer must overlap 2 to 4 inches, the total applied thickness will be taken as 4 times the product maximum thickness. For attachments G1, G2 and G3 product thickness data will be taken from Attachment I. 3

7. Some load diversity is considered for cable bundles greater than 3 cables, see Assumption No. 5. Diversity factors are developed and documented in MathCAD template Attachment F and used in MathCAD template Attachments B1 and G1. 2 3

The basic approach is to consider that cables 1 and 2 produce heat on the basis of 1.25 times full load current and subsequent cables produce heat on the basis of 1.0 times full load current. A diversity factor is arrived by dividing this effective heat production with that based on all cables producing heat at 1.25 times full load current. The diversity factor is used in MathCAD template Attachment B1. The actual number of conductors in the bundle are multiplied by this diversity factor to generate an effective number of conductors for use in the thermal resistance calculations. 3

8. Once the ampacity for various numbers of cable has been calculated in MathCAD template Attachments B2, and G2, it is compared against the ampacities for cables in a) Thermolagged trays-Maintained Space, b) Thermolagged trays-Random Space, c) Thermolagged Conduit-Box and d) Thermolagged Conduit-Shell. These ampacities will be taken from DBD-EE-52, Rev.3. 3

The maximum number of cables in a free air drop which can be contained under the wrap without exceeding the ampacity of the adjoining sections of thermolagged raceway will be clearly shown on MathCAD template Attachments B3, and G3. 3

9. Accuracy of file transfer between each MathCAD template will be verified by printing the files from templates and comparing results. Computational accuracy of MathCAD will be verified by having the Reviewer perform a manual check of a portion of the complete calculation, selected at random using source data as input. This manual check is included in this calculation as Attachment E.

10. Attachments A, B1, B2, B3, C, F, G1, G2, G3, and H0 are the print outputs of MathCAD, described by Reference 19. (3)

11. Attachments B1, B2, and B3 cover calculations for Thermolag product thickness of 5/16 inch. Attachments G1, G2, and G3 cover product thickness of 3/8 inch. (3)

12. Ampacity results in Attachment G2 were rounded to whole integers before ampacity comparison. This was not done in attachment B2. Ampacity comparison logic in Attachment G3 uses less than or equal to instead of less than from Attachment B3.

13. Attachment BB2 uses the PRN file from B1 to calculate ampacity for free air drops. It adds an extra layer of Thermolag for cable bundles less than three inches in diameter, per CPSES-M-2032 Rev. 0 and DCA 95794 Rev. 6. Attachment BB3 uses the ampacity from Attachment BB2 and compares it to tray and conduit Ampacity. (4)

14. In Attachment BB3 Thermolag tray ampacities are based on a 40% derating factor instead of 31% as was done in Attachments B3 and G3. Impacts on power cable size of 40% vs. 31% tray Thermolag derating factor is documented in Calc 2-EE-0053.*

    Thermolag conduit ampacities in Attachment BB3 are identical to those used in B3 and G3. This is because it covers 3 inch and larger size conduits. The thermolag conduit ampacity for 2 inch and smaller size has been changed(see calc. EE-CA-0000-3250).

ASSUMPTIONS

1. Trays and/or conduits are thermolagged on one or both sides. Conduits could be boxed or shell design.

2. Cable bundle sizes will vary, but never be larger than the number of cables that would fit in a 6 in. conduit.

* Confimation Required

3. An air gap is assumed between the wrap and the cable because the wrap is not flexible.

4. For maximum thickness of product, 4 "layers" of wrap are assumed. The wrap is applied longitudinally (eg., cigar wrap, with a 2 to 4 inch overlap for each layer). Two layers are applied, but conservatively most sections will have 4 layers because of the overlap. Also product thickness of 5/16 and 3/8 in. will be considered separately. (3)

5. Load diversity is considered for cable bundles containing more than 2 cables on the basis that third and higher number cables in the bundle carry only 1.0 times full load current at the same time as cables 1 and 2 carry 1.25 times full load. This is a reasonable assumption since: (2)

   a. DBD-EE-052 requires all power cable to have a minimum ampacity of 1.25 x full load current (FLA).

   b. In practice only a few cables in the entire plant (4) operate at 1.25 x FLA; the rest operate at 1.0 x FLA or less.

6. Thermolagged free air drops can be modelled as a conduit in the horizontal plane (conservatively, a model in the vertical direction would produce higher ampacities).

7. Cable diameters and insulation thicknesses based on ICEA thickness, and conductor diameters will produce conservative ampacities. It also produces the smallest possible cable diameter (smaller than that used in the database of CARDS).

8. The equation for Rsd, thermal resistance between cable and thermolag, uses empirically derived constants. Since none of the references tested thermolag, the basis for selecting these constants had to be established. These constants are assumed to depend exclusively on the thermal resistivity of conduit (or Thermolag). Reference 20 supports this by stating "It follows therefore that a considerable variation in B for cables in single-fibre ducts may be expected depending upon the relative thermal resistivities of the duct wall and the surrounding medium, and other data which has come to the author's attention confirms this. Thus the curve of Figure 3 for fibre duct should be considered as an upper limit." (21)

   The following Table has been developed from data contained in Reference 3. Interpolation of this data on the basis of thermal resistivities is done to develop the A' and B' constants for Thermolag 330-660 used in

MathCAD template Attachment B2, and G2, (3)

Material (In Air)	A	B	Thermal Resistivity (C-cm/Watt)
Fibre	5.6	0.33	480
Thermolag	4.5	0.27	232
Transite	4.4	0.26	200
Metal conduit	2.2	0.19	2

9. Three layers of 3/8" Thermolag are the maximum thickness on cable bundles of less than 3 inches in Attachments BB2 and BB3, resulting in a possible 6 layers due to overlap. (4)

10. DBD-052 will be revised to reflect new base-Thermolag ampacities for tray of 40% derating and 35% for conduits less than 2" in diameter.*

* Confirmation Required

SOURCES OF DATA/REFERENCES

1. DBD-EE-052 Rev. 3, Design Basis Document "Cable Philosophy and Sizing Criteria".

2. K.A.Petty,"Ampacity of Wrapped Cables" IEEE Transaction, PES, presented at 1986 Summer Meeting

3. J.H.Neher and M.H.McGrath. "The Calculation of the Temperature Rise and Load Capability of Cable Systems." In AIEE Transaction, Part III PAS, vol. 76. New York: American Institute of Electrical Engineers, October 1957, pp. 752-72

4. K.A. Petty, Power Plant Electrical Reference Series: Volume 4 Wire and Cable, Electric Power Research Institute, Palo Alto, CA, 1987, EL-5036 Volume 4

5. Power Cable Ampacities. New York: 1962. Republished by Institute of Electrical and Electronic Engineers, IPCEA P-46-426(ICEA/IEEE S-135-1-62,S-135-2-62)

6. Underground Systems Reference Book Washington, D.C., Edison Electric Institute, 1957

7. Ethylene Propylene Rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy. Washington, D.C.:National Electrical Manufacturers Association, 1983. ICEA S-68-516 (NEMA WC8-1983)

8. Rubber-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy. Washington, D.C.:National Electrical Manufacturers Association, 1980. ICEA S-19-81 (NEMA WC3-1980)

9. Cross-linked Thermosetting Polyethylene-insulated Wire and Cable for the Transmission and Distribution of Electrical Energy. Washington, D.C.:National Electrical Manufacturers Association, 1983. ICEA S-66-524 (NEMA WC7-1982)

10. Specification 2323-ES-13A, Rev. 1, "8 KV Insulated Power Cable"

11. Specification 2323-ES-13B.2, Rev. 1, "Low Voltage Power and Lighting Cable"

12. Brand-Rex "Wire & Cable Engineering Guide," Publication WC-82, dated 1982

13. DCA 60035, Rev. 4, "To Establish the Maximum Outside Diameter and Unit Weight for Cable Type W-014," dated

11/21/88 (note that pages 5 thru 10 contain above data for all cable considered in this calculation).

14. National Electrical Code, NFPA-70, 1987.

15. DCA 79272, Rev. 3, "Detail for Wrapping Air Drop Cable."

16. Drawing M1-1701, Sheets 3 and 7, "Thermolag Typical Details," dated April 1989.

17. Specification 2323-MS-38M, Rev. 2, "Cable Raceway Fire Barrier Materials."

18. Ampacities - Cables in Open-top Cable Trays. Washington, D.C., National Electrical Manufacturers Association, 1975. ICEA P-54-440, Rev 2 (NEMA WC 51-1975)

19. Mathsoft, Inc. User's Manual, "MathCAD, Version 2.0," 1987.

20. F.H.Buller and J.H.Neher, "The Thermal Resistance Between Cables and a Surrounding Pipe or Duct Wall," AIEE Transactions, Part I, Vol. 69, pp. 342-349, New York, 1950.

21. Letter from TSI 11/17/89 (See Attachment I)

22. Specification CPES-M-2032, Rev. 0, DCA 95794, Rev. 6

23. Calculation EE-CA-0000-3250, Rev. 0, "Cable Ampacity Derating - Double Shell Thermolag Conduit Design"

24. Calculation 2-EE-0053, Rev. 0, "Ampacity for Cables in Thermolagged Raceways"

CONCLUSION

1. The ampacity of power cables, installed in free air and wrapped with Thermolag 330-660 are shown on Table A below. These are for cables installed in 50 C ambiant air with a separation of one bundle diameter between other bundles. No entry indicates that resulting cable bundle would be too large (see Assumption 2).

TABLE A

Power Cable Ampacity For Cable Installed in Free Air and Wrapped with Thermolag 330-660
(2 Layers of) (5/16 in. product thickness)

Type Cable	No. of Cable in Bundle* 1	2	3	5	Various Bundle Size to Fit Conduit 3"	4"	5"	6"
1/C-500, 8 kV	368	348	316	289	369	369	369	348
1/C-350, 8 kV	299	281	255	233	299	299	281	255
1/C-4/O, 8 kV	223	209	190	173	223	223	209	172
1/C-750, 600 V	444	416	375	341	444	444	416	416
1/C-500 600 V	350	326	294	266	350	350	326	264
1/C-350 600 V	282	261	235	213	282	261	235	213
1/C-4/O 600 V	204	187	168	152	187	151	147	131
1/C-2/O 600 V	153	139	125	112	125	112	99	89
TRI-4/O 600 V	204	187	168	152	204	187	151	147
TRI-2/O 600 V	153	139	125	112	139	125	112	99
TRI-2 AWG 600 V	97	87	78	70	70	63	57	50
3/C-4 AWG 600 V	75	68	61	55	61	53	47	41
3/C-6 AWG 600 V	57	51	46	42	42	37	33	29
3/C-8 AWG 600 V	42	38	34	31	28	24	20	18
3/C-10 AWG 600 V	32	28	25	23	18	15	13	12
3/C-12 AWG 600 V	24	21	19	17	11	10	8	7
2/C-2 AWG 600 V	117	106	96	87	96	87	75	68
2/C-6 AWG 600 V	67	60	55	49	47	42	35	33
2/C-8 AWG 600 V	50	45	41	36	32	27	24	21
2/C-10 AWG 600 V	38	33	30	27	21	18	15	14
2/C-12 AWG 600 V	28	25	22	20	13	11	10	9

* All 1/C cables are assumed to be bundled in groups of 3. Therefore, when the above table indicates 3, a total of 3(3) or 9 single conductor cables would be wrapped.

2. Table B shows the maximum number of cables allowed in a bundle so that the ampacity of the cable is not less than

in adjoining thermolagged raceway. When Table A is used by Construction, no Engineering analysis of ampacity is required. No entry indicates that the raceway configuration is not applicable for the given size (see item 3 below).

When cable bundles of mixed sizes are encountered, use as the maximum number of cables the smaller number from Table B.

TABLE B

Maximum Number of Cables Under Wrap So That Wrapped Ampacity > Raceway Ampacity
(2 layers of (5/16 in product thickness))

Cable Size	Thermolag Tray MS	Thermolag Tray Random		Thermolag Conduit Box	Thermolag Conduit Shell
1/C-500, 8 kV	2	-		5	0
1/C-350, 8 kV	3	-		5	0
1/C-4/O, 8 kV	5	-		5	0
1/C-750, 600 V	2	1		5	0
1/C-500 600 V	3	3		5	0
1/C-350 600 V	5	3		5	0
1/C-4/O 600 V	5	9		9	0
1/C-2/0 600 V	5	12		12	0
TRI-4/O 600 V	5	3		6	0
TRI-2/O 600 V	5	5		5	0
TRI-2 AWG 600 V	16	11		16	0
3/C-4 AWG 600 V	-	10		15	0
3/C-6 AWG 600 V	-	13		19	19
3/C-8 AWG 600 V	-	21		21	0
3/C-10 AWG 600 V	-	32		32	20
3/C-12 AWG 600 V	-	51		18	5
2/C-2 AWG 600 V	9	9		13	13
2/C-6 AWG 600 V	-	10		23	23
2/C-8 AWG 600 V	-	23		34	23
2/C-10 AWG 600 V	-	35		51	35
2/C-12 AWG 600 V	-	56		36	5

Note: 1. All 1/C cables are assumed to be bundled in groups of 3. Therefore when the above table indicates 3, a total of 3/3) or 9 single conductor cables would be wrapped.

3. 8 KV cables in tray are installed with maintained spacing only (see DBD-EE-052, Section 4.1.1.5 c.). 600 V cable in tray are installed with maintained spacing for cable size 2 AWG and larger, and with random lay for all smaller sizes (see DBD-EE-052, Section 4.2.1.6 c.).

4. For assessment purposes, it may be easier in many cases to arrange Table B to indicate bundle sizes on a conduit size basis which are acceptable without requiring Engineering analysis. Table C presents this information assuming the conduit is 40 per cent filled (by area). The following should be used in conjunction with Table C.

   If cable bundle is going into an <u>over-filled conduit,</u> the next larger size conduit should be used.

   For a given size conduit, if Table C shows a "0" (meaning that condition is unacceptable) in low % fill conduits, it may still acceptable using the following analysis by Engineering:

   - Next smaller conduit size must be list in Table 1 as "1". <u>and</u>
   - Actual percent fill in conduit would be equivalent of 40 % or less when calculated on the basis of the smaller size conduit dimensions

In some cases, as the conduit size increases the bundle size became acceptable. This occured for thermolagged conduit when the NEC diversity multipliers changed. In order to avoid confusion; Table B does show higher number of cables is lower number of cables were unacceptable, and Table C expresses all larger conduit sizes as unacceptable.

Table C
Acceptable Bundle Size - Expressed in Terms of Conduit Size :
Wrapped Ampacity is Greater Than Thermolagged Raceway

(4) (2 Layers of) (5/16" product thickness) (3)

Conduit Size in.:	Thermolag Tray MS 3	MS 4	MS 5	MS 6	Tray RANDOM 3	RANDOM 4	RANDOM 5	RANDOM 6	Thermolag Conduit BOX 3	BOX 4	BOX 5	BOX 6	SHELL 3	SHELL 4	SHELL 5	SHELL 6
1/C-500, 8 kV	1	1	1	1	-	-	-	-	1	1	1	1	0	0	0	0
1/C-350, 8 kV	1	1	1	1	-	-	-	-	1	1	1	1	0	0	0	0
1/C-4/O, 8 kV	1	1	1	1	-	-	-	-	1	1	1	1	0	0	0	0
1/C-750, 600 V	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	0
1/C-500 600 V	1	1	1	0	1	1	1	0	1	1	1	1	0	0	0	0
1/C-350 600 V	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0
1/C-4/O 600 V	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	0
1/C-2/0 600 V	1	1	0	0	1	1	1	1	1	1	0	1	1	0	0	0
TRI-4/O 600 V	1	1	1	0	1	1	0	0	1	1	1	0	1	1	0	0
TRI-2/O 600 V	1	1	1	0	1	1	1	0	1	1	1	0	1	1	0	0
TRI-2 AWG 600 V	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0
3/C-4 AWG 600 V	-	-	-	-	1	1	1	0	1	1	1	1	1	1	0	0
3/C-6 AWG 600 V	-	-	-	-	1	1	1	0	1	1	1	1	1	1	0	0
3/C-8 AWG 600 V	-	-	-	-	1	1	1	0	1	1	1	0	1	0	0	0
3/C-10 AWG 600 V	-	-	-	-	1	1	1	0	1	1	0	0	0	0	0	0
3/C-12 AWG 600 V	-	-	-	-	1	1	1	0	1	0	0	0	0	0	0	0
2/C-2 AWG 600 V	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1
2/C-6 AWG 600 V	-	-	-	-	1	1	1	0	1	1	1	1	1	1	1	0
2/C-8 AWG 600 V	-	-	-	-	1	1	1	0	1	1	1	1	1	1	1	0
2/C-10 AWG 600 V	-	-	-	-	1	1	1	0	1	1	1	0	1	1	1	0
2/C-12 AWG 600 V	-	-	-	-	1	1	1	0	1	1	0	0	0	0	0	0

Note: 1 is an acceptable condition
0 is an unacceptable condition or requires detailed Engineering Analysis.

(2)

CPSES UNIT 1 1634S-EE(B)-140, REV 2 Page 12 of (13)
"Ampacity of Power Cable Wrap. W/Thermolag Inst. at Free Air Dp"

(1) (5) 18 (4)

5. A supplemental case has been analyzed for a maximum average thickness of 3/8 inch new ampacities have been calculated. **UNLESS SPECIFIC MEASUREMENTS HAVE BEEN TAKEN AND DOCUMENTED TABLE A,B,C SHALL NOT BE USED. THE FOLLOWING TABLES D,E,F SHOULD BE USED INSTEAD.**

6. If table A of Rev 2 was used in any calculation a 5/16 inch maximum average thickness must be confirmed or a reanalysis of the application is required. If table B or C was used in any application and the corresponding entry in Table E and F are bold (indicating a change has occurred) a 5/16 inch maximum average must be confirmed or reanalysis must be done. The change in ampacity between Table A and D are between 0.115 to 1.414 % decrease.

TABLE D

Power Cable Ampacity For Cable Installed in Free Air and Wrapped with Thermolag 330-60(3/8 in.)

Type Cable	No. of Cable in Bundle*					Various Bundle Size to Fit Conduit			
	1	2	3	5	8	3"	4"	5"	6"
1/C-500, 8 kV	367	344	312	285	255	367	367	367	344
1/C-350, 8 kV	297	278	252	230	206	297	297	278	252
1/C-4/O, 8 kV	222	207	188	171	153	222	222	207	170
1/C-750, 600 V	441	411	371	336	299	441	441	411	411
1/C-500 600 V	348	322	290	263	234	348	348	322	261
1/C-350 600 V	280	258	233	210	187	280	258	233	210
1/C-4/O 600 V	203	185	167	150	133	185	150	145	130
1/C-2/O 600 V	152	138	124	111	98	124	111	98	88
TRI-4/O 600 V	203	185	167	150	133	203	185	150	145
TRI-2/O 600 V	152	138	124	111	98	138	124	111	98
TRI-2 AWG 600 V	97	87	78	70	61	70	63	56	50
3/C-4 AWG 600 V	74	67	61	55	48	61	53	47	41
3/C-6 AWG 600 V	57	51	46	42	37	42	37	32	28
3/C-8 AWG 600 V	42	38	34	30	27	28	23	20	18
3/C-10 AWG 600 V	32	28	25	22	20	18	15	13	12
3/C-12 AWG 600 V	24	21	19	17	14	11	9	8	7
2/C-2 AWG 600 V	116	106	95	86	76	95	86	74	67
2/C-6 AWG 600 V	67	60	54	49	43	47	41	35	32
2/C-8 AWG 600 V	50	45	40	36	32	32	27	24	21
2/C-10 AWG 600 V	38	33	30	27	24	21	17	15	13
2/C-12 AWG 600 V	28	25	22	20	17	13	11	9	8

* All 1/C cables are assumed to be bundled in groups of 3.

Therefore, when the above table indicates 3, a total of 3(3) or 9 single conductor cables would be wrapped.

TABLE E

Maximum Number of Cables Under Wrap So That Wrapped Ampacity > Raceway Ampacity
(2 Layers of) (3/8 inch product) (4)

Cable Size	Thermolag Tray MS	Thermolag Tray Random		Thermolag Conduit Box	Thermolag Conduit Shell
1/C-500, 8 kV	2	-		5	0
1/C-350, 8 kV	3	-		5	0
1/C-4/0, 8 kV	5	-		5	0
1/C-750, 600 V	2	1		5	0
1/C-500 600 V	3	3		5	0
1/C-350 600 V	5	3		5	0
1/C-4/0 600 V	5	9		9	0
1/C-2/0 600 V	5	12		12	0
TRI-4/0 600 V	5	3		6	0
TRI-2/0 600 V	5	5		5	0
TRI-2 AWG 600 V	16	11		16	0
3/C-4 AWG 600 V	-	10		15	0
3/C-6 AWG 600 V	-	13		19	5
3/C-8 AWG 600 V	-	21		21	0
3/C-10 AWG 600 V	-	32		32	5
3/C-12 AWG 600 V	-	51		18	5
2/C-2 AWG 600 V	9	3		13	13
2/C-6 AWG 600 V	-	10		23	23
2/C-8 AWG 600 V	-	23		34	23
2/C-10 AWG 600 V	-	35		51	22
2/C-12 AWG 600 V	-	56		36	8*

Note: 1. All 1/C cables are assumed to be bundled in groups of 3. Therefore when the above table indicates 3, a total of 3(3) or 9 single conductor cables would be wrapped.

* This number increased from table B because of the change in the logic of the ampacity comparison.

Table F
Acceptable Bundle Size - Expressed in Terms of Conduit Size :
Wrapped Ampacity is Greater Than Thermolagged Raceway
(2 Layers) (3/8 inch product) 4

Conduit Size in.:	Thermolag Tray								Thermolag Conduit							
	MS				RANDOM				BOX				SHELL			
	3	4	5	6	3	4	5	6	3	4	5	6	3	4	5	6
1/C-500, 8 kV	1	1	1	1	-	-	-	-	1	1	1	1	0	0	0	0
1/C-350, 8 kV	1	1	1	1	-	-	-	-	1	1	1	1	0	0	0	0
1/C-4/O, 8 kV	1	1	1	1	-	-	-	-	1	1	1	1	0	0	0	0
1/C-750, 600 V	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	0
1/C-500 600 V	1	1	1	0	1	1	1	0	1	1	1	1	0	0	0	0
1/C-350 600 V	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0
1/C-4/O 600 V	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	0
1/C-2/0 600 V	1	1	0	0	1	1	1	1	1	1	1	0	1	0	0	0
TRI-4/O 600 V	1	1	1	0	1	1	1	0	1	1	1	1	0	0	0	0
TRI-2/O 600 V	1	1	1	0	1	1	1	0	1	1	1	0	1	1	0	0
TRI-2 AWG 600 V	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0
3/C-4 AWG 600 V	-	-	-	-	1	1	1	0	1	1	1	1	1	1	0	0
3/C-6 AWG 600 V	-	-	-	-	1	1	1	0	1	1	1	1	1	0	0	0
3/C-8 AWG 600 V	-	-	-	-	1	1	1	0	1	1	1	0	1	0	0	0
3/C-10 AWG 600 V	-	-	-	-	1	1	1	1*	1	1	1	0	1	0	0	0
3/C-12 AWG 600 V	-	-	-	-	1	1	1	0	1	0	0	0	1	0	0	0
2/C-2 AWG 600 V	1	1	1	0	1	1	0	0	1	1	1	1	1	1	1	1
2/C-6 AWG 600 V	-	-	-	-	1	1	0	0	1	1	1	1	1	1	1	1
2/C-8 AWG 600 V	-	-	-	-	1	1	1	0	1	1	1	1	1	1	1	1
2/C-10 AWG 600 V	-	-	-	-	1	1	1	0	1	1	1	0	1	1	1	0
2/C-12 AWG 600 V	-	-	-	-	1	1	1	0	1	1	0	0	1	1	0	0

Note: 1 is an acceptable condition
0 is an unacceptable condition or requires detailed Engineering Analysis.

* This number increased from Table C due to change in logic in cable ampacity (See Methodology No 12)

CPSES UNIT 1 16345-EE(B)-140, Rev 3 Page 15 of 65 18 4
"Ampacity of Power Cable Wrap. W/Thermolag Inst. as Free Air Dp"

4

TABLE G

Power Cable Ampacity for Cable Installed in Free Air and Wrapped with Three Layers of Thermolag 330-660 (3/8 Inch) for bundle sizes less than 3 inches

Type Cable	No. of Cable in Bundle*				Various Bundle Size to Fit Conduit			
	1	2	3	5	3"	4"	5"	6"
1/C-500, 8 kV	359	344	312	285	367	367	367	344
1/C-350, 8 kV	291	278	252	230	297	297	278	252
1/C-4/O, 8 kV	218	207	188	171	222	222	207	170
1/C-750, 600 V	431	411	371	336	441	441	411	411
1/C-500 600 V	341	322	290	263	348	348	322	261
1/C-350 600 V	275	258	233	210	280	258	233	210
1/C-4/O 600 V	200	185	167	150	185	150	145	130
1/C-2/O 600 V	150	135	121	111	124	111	98	88
TRI-4/O 600 V	200	185	167	150	203	185	150	145
TRI-2/O 600 V	150	135	121	111	138	124	111	98
TRI-2 AWG 600 V	96	85	76	68	70	63	56	50
3/C-4 AWG 600 V	74	66	60	53	61	53	47	41
3/C-6 AWG 600 V	56	50	45	41	42	37	32	28
3/C-8 AWG 600 V	42	37	34	30	28	23	20	18
3/C-10 AWG 600 V	31	28	25	22	18	15	13	12
3/C-12 AWG 600 V	23	20	18	16	11	9	8	7
2/C-2 AWG 600 V	115	104	94	84	95	86	74	67
2/C-6 AWG 600 V	66	59	53	48	47	41	35	32
2/C-8 AWG 600 V	50	44	40	36	32	27	24	21
2/C-10 AWG 600 V	38	33	30	26	21	17	15	13
2/C-12 AWG 600 V	28	24	22	20	13	11	9	8

* All 1/C cables are assumed to be bundled in groups of 3.

4

TABLE F

Maximum Number of Cables Under Wrap So That Wrapped Ampacity > Raceway Ampacity(2) For 3 Layers on Bundles less than 3" (3/8 inch product)

Cable Size	Thermolag Tray MS	Thermolag Tray Random		Thermolag Conduit Box	Thermolag Conduit Shell
1/C-500, 8 kV	2	-		5	5
1/C-350, 8 kV	3	-		5	5
1/C-4/O, 8 kV	4	-		5	5
1/C-750, 600 V	2	2		5	3
1/C-500 600 V	4	4		5	3
1/C-350 600 V	5	5		5	3
1/C-4/O 600 V	9	9		9	3
1/C-2/O 600 V	12	12		12	3
TRI-4/O 600 V	6	6		6	3
TRI-2/O 600 V	8	8		5	3
TRI-2 AWG 600 V	16	16		16	5
3/C-4 AWG 600 V	-	15		15	15
3/C-6 AWG 600 V	-	19		19	5
3/C-8 AWG 600 V	-	30		21	5
3/C-10 AWG 600 V	-	46		20	11
3/C-12 AWG 600 V	-	73		18	5
2/C-2 AWG 600 V	13	13		13	13
2/C-6 AWG 600 V	-	23		23	23
2/C-8 AWG 600 V	-	23		34	23
2/C-10 AWG 600 V	-	51		51	35
2/C-12 AWG 600 V	-	81		36	5

Note: 1. All 1/C cables are assumed to be bundled in groups of 3. Therefore when the above table indicates 3, a total of 3(3) or 9 single conductor cables would be wrapped.

2. Thermolag tray derating factor is 40% Thermolag shell conduit is 7.5% for all conduits except 2 inch and smaller conduit which is 35%.

Table I
Acceptable Bundle Size - Expressed in Terms of Conduit Size :
Wrapped Ampacity is Greater Than Thermolagged Raceway
For Three Layers of Thermonlag on Bundles Less Than 3 Inches (3/8 inch product)

	Thermolag Tray								Thermolag Conduit							
	MS				RANDOM				BOX				SHELL			
Conduit Size in.:	3	4	5	6	3	4	5	6	3	4	5	6	3	4	5	6
1/C-500, 8 kV	1	1	1	1	-	-	-	-	1	1	1	1	0	0	0	0
1/C-350, 8 kV	1	1	1	1	-	-	-	-	1	1	1	1	0	0	0	0
1/C-4/O, 8 kV	1	1	1	1	-	-	-	-	1	1	1	1	0	0	0	0
1/C-750, 600 V	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
1/C-500 600 V	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
1/C-350 600 V	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
1/C-4/O 600 V	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
1/C-2/0 600 V	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0
TRI-4/O 600 V	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0
TRI-2/O 600 V	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0
TRI-2 AWG 600 V	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
3/C-4 AWG 600 V	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	0
3/C-6 AWG 600 V	-	-	-	-	1	1	1	1	1	1	1	1	1	0	0	0
3/C-8 AWG 600 V	-	-	-	-	1	1	1	1	1	1	1	0	0	0	0	0
3/C-10 AWG 600 V	-	-	-	-	1	1	1	1	1	1	0	0	0	0	0	0
3/C-12 AWG 600 V	-	-	-	-	1	1	1	1	1	0	0	0	0	0	0	0
2/C-2 AWG 600 V	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2/C-6 AWG 600 V	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
2/C-8 AWG 600 V	-	-	-	-	1	1	1	0	1	1	1	1	1	1	1	1
2/C-10 AWG 600 V	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	0
2/C-12 AWG 600 V	-	-	-	-	1	1	1	1	1	1	0	0	0	0	0	0

Note: 1 is an acceptable condition
0 is an unacceptable condition or requires detailed Engineering Analysis.

4

ATTACHMENT A
CABLE PARAMETERS FOR COMANCHE PEAK

ORIGIN ≡ 1 This defines the upper left corner of matrices as 1,1 instead of default 0,0.

$$Dc := \begin{bmatrix} 0.813 \\ 0.681 \\ 0.528 \\ 0.998 \\ 0.813 \\ 0.681 \\ 0.528 \\ 0.418 \\ 0.528 \\ 0.418 \\ 0.292 \\ 0.232 \\ 0.184 \\ 0.146 \\ 0.116 \\ 0.092 \\ 0.292 \\ 0.184 \\ 0.146 \\ 0.116 \\ 0.092 \end{bmatrix}$$

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-2/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

Conductor diameter, inches
Source: ICEA S-68-516, Table 2-2

$$It := \begin{bmatrix} (25 + 140 + 25 + 10 + 80) \\ (25 + 140 + 25 + 10 + 80) \\ (25 + 140 + 25 + 10 + 80) \\ (80 + 65) \\ (65 + 65) \\ (65 + 65) \\ (55 + 45) \\ (55 + 45) \\ (55 + 45) \\ (55 + 45) \\ (45 + 30) \\ (45 + 30) \\ (45 + 30) \\ (45 + 15) \\ (30 + 15) \\ (30) \\ (45 + 30) \\ (45 + 30) \\ (45 + 15) \\ (30 + 15) \\ (30) \end{bmatrix}$$

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-2/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

Insulation/individual jacket/shield thickness applied over conductor, mils.
Source: ICEA S-68-516, Tables 3-1 and 4-3; for jacket of 3/C cable, Specifications 2323-ES-13A and -13B.2 was used. For 8 KV cable, semi-conducting thickness (25 mil) and shield thickness (10 mil) are included.

$$Jt := \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 80 \\ 80 \\ 60 \\ 60 \\ 60 \\ 80 \\ 60 \\ 60 \\ 60 \\ 60 \end{bmatrix}$$

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-2/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

Overall jacket thickness for 3/C cables, mils. Source: Specification 2323-ES-13B.2.

$$n' := \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 3 \\ 3 \\ 3 \\ 3 \\ 3 \\ 3 \\ 3 \\ 3 \\ 2 \\ 2 \\ 2 \\ 2 \\ 2 \\ 2 \end{bmatrix}$$

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-2/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

Number of conductors in cable

$$Yc := \begin{bmatrix} (0.05 + 0.01) \\ (0.02 + 0.01) \\ 0.01 \\ (0.1 + 0.03) \\ (0.05 + 0.01) \\ (0.02 + 0.01) \\ 0.01 \\ 0 \\ 0.01 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-2/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

Conductor skin + proximity effect (if any).
Source: EPRI, "Power Plant Reference Series," Vol.4, Tables 4.14 and 4.15.

$$\rho i := \begin{bmatrix} 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \\ 500 \end{bmatrix}$$

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-2/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

Thermal resistivity of insulation/individual jacket, C-cm/watt.
Source: ICEA P-46-426, pg. III.

$\rho j :=$

500	1/C-500,8 KV
500	1/C-350,8 KV
500	1/C-4/0,8 KV
500	1/C-750,600 V
500	1/C-500
500	1/C-350
500	1/C-4/0
500	1/C-2/0
500	TRI-4/0
500	TRI-2/0
500	TRI-2AWG
500	3/C-4AWG
500	3/C-6AWG
500	3/C-8AWG
500	3/C-10AWG
500	3/C-12AWG
500	2/C-2AWG
500	2/C-6AWG
500	2/C-8AWG
500	2/C-10AWG
500	2/C-12AWG

Thermal resistivity of overall jacket, C-cm/watt.
Source: ICEA P-46-426, pg. III.

$Ac :=$

253.4	1/C-500,8 KV
177.3	1/C-350,8 KV
107.2	1/C-4/0,8 KV
380.0	1/C-750,600 V
253.4	1/C-500
177.3	1/C-350
107.2	1/C-4/0
67.43	1/C-2/0
107.2	TRI-4/0
67.43	TRI-2/0
33.62	TRI-2AWG
21.15	3/C-4AWG
13.3	3/C-6AWG
8.37	3/C-8AWG
5.26	3/C-10AWG
3.31	3/C-12AWG
33.62	2/C-2AWG
13.3	2/C-6AWG
8.37	2/C-8AWG
5.26	2/C-10AWG
3.31	2/C-12AWG

Cross-sectional area of conductor, sq mm.
Source: ICEA P-46-426, Table I, page II.

$$Rdc25 := \frac{\begin{bmatrix} 0.0222 \\ 0.0320 \\ 0.0525 \\ 0.0148 \\ 0.0222 \\ 0.0320 \\ 0.0525 \\ 0.0843 \\ 0.0525 \\ 0.0843 \\ 0.169 \\ 0.269 \\ 0.427 \\ 0.679 \\ 1.080 \\ 1.720 \\ 0.169 \\ 0.427 \\ 0.679 \\ 1.080 \\ 1.720 \end{bmatrix}}{1000}$$

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-2/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

Conductor DC resistance at 25 deg. C, ohms/1000 ft.
Source: ICEA S-68-516, Table 2-13.
Note: Units for Rdc25 as input are Ω/ft

This series of equations calculates the diameter of the cable. The maximum diameters of the cables from the specifications have purposefully not been used, since these may give non-conservative results.

$i := 1 \ldots 21$

$$DiamIC_i := Dc_i + 2 \cdot \frac{It_i}{1000}$$

This is the diameter of the individual conductor, inch

$$Cdiam_i := if\left[n'_i \approx 2.2, \left\lceil DiamIC_i + \frac{Jt_i}{1000} \right\rceil, 0\right]$$

This is the diameter of the 2-conductor cables., inch

$$Cdiam_i := if\left[n'_i \approx 3, \left[\left\lceil 2 \cdot \frac{Jt_i}{1000} + 2.15 \cdot DiamIC_i \right\rceil\right], Cdiam_i\right]$$

This is the diameter of the 3/C cables, inch

$$Cdiam_i := if\left[n'_i \approx 1, 2.15 \cdot DiamIC_i, Cdiam_i\right]$$

This is the diameter of the single conductor cables. formed in a bundle of three cables inch

The factor, 2.15, to obtain the equivalent diameter of three conductor, or a triplex is taken from Reference 12 (Brand-Rex Publication WC-82).

A2

As a form of comparison only, Maximum Diameters for these cables from Reference 13 (DCA P[illegible]0035, Rev. 4) are identified below as MAX

O := 1 ..8

DiamIC

O					
1.373		2.952		1.55	1/C-500,8 KV
1.241		2.668		1.45	1/C-350,8 KV
1.088		2.339		1.23	1/C-4/0,8 KV
1.288		2.769		1.35	1/C-750,600 V
1.073		2.307		1.13	1/C-500
0.941	Cdiam =	2.023		0.99	1/C-350
0.728		1.565		0.77	1/C-4/0
0.618		1.329		0.66	1/C-2/0
		1.565		1.90	TRI-4/0
		1.329		1.62	TRI-2/0
		0.95	MAX :=	1.16	TRI-2AWG
		0.981		1.08	3/C-4AWG
		0.878		1.00	3/C-6AWG
		0.692		0.87	3/C-8AWG
		0.563		0.78	3/C-10AWG
		0.447		0.48	3/C-12AWG
		1.044		1.16	2/C-2AWG
		0.788		0.89	2/C-6AWG
		0.653		0.75	2/C-8AWG
		0.532		0.60	2/C-10AWG
		0.424		0.45	2/C-12AWG

Appropriate comparisons can be made as follows:

1/C cable compare MAX with DiamIC
2/C cable compare MAX with Cdiam
3/C cable compare MAX with Cdiam

All cable parameters are combined into a Matrix. This matrix, called CABLE, will be stored and used in other templates (Attachments B1 and B2).

CABLE$_{\langle 1 \rangle}$:= Rdc25

CABLE$_{\langle 2 \rangle}$:= Yc

CABLE$_{\langle 3 \rangle}$:= Dc

CABLE$_{\langle 4 \rangle}$:= Ac

CABLE$_{\langle 5 \rangle}$:= n'

CABLE$_{\langle 6 \rangle}$:= It

CABLE$_{\langle 7 \rangle}$:= Jt

CABLE$_{\langle 8 \rangle}$:= ρi

CABLE$_{\langle 9 \rangle}$:= ρj

CABLE$_{\langle 10 \rangle}$:= Diam1C

CABLE$_{\langle 11 \rangle}$:= Cdiam

A2

	Rdc25	Yc	Dc	Ac	n'	it	Jt	ρi	ρj	Diam1C	Cdiam
CABLE =	$2.22 \cdot 10^{-5}$	0.06	0.813	253.4	1	280	0	500	500	1.373	2.95195
	$3.2 \cdot 10^{-5}$	0.03	0.681	177.3	1	280	0	500	500	1.241	2.66815
	$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	1	280	0	500	500	1.088	2.3392
	$1.48 \cdot 10^{-5}$	0.13	0.998	380	1	145	0	500	500	1.288	2.7692
	$2.22 \cdot 10^{-5}$	0.06	0.813	253.4	1	130	0	500	500	1.073	2.30695
	$3.2 \cdot 10^{-5}$	0.03	0.681	177.3	1	130	0	500	500	0.941	2.02315
	$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	1	100	0	500	500	0.728	1.5652
	$8.43 \cdot 10^{-5}$	0	0.418	67.43	1	100	0	500	500	0.618	1.3287
	$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	3	100	0	500	500	0.728	1.5652
	$8.43 \cdot 10^{-5}$	0	0.418	67.43	3	100	0	500	500	0.618	1.3287
	$1.69 \cdot 10^{-4}$	0	0.292	33.62	3	75	0	500	500	0.442	0.9503
	$2.69 \cdot 10^{-4}$	0	0.232	21.15	3	75	80	500	500	0.382	0.9813
	$4.27 \cdot 10^{-4}$	0	0.184	13.3	3	75	80	500	500	0.334	0.8781
	$6.79 \cdot 10^{-4}$	0	0.146	8.37	3	60	60	500	500	0.266	0.6919
	0.00108	0	0.116	5.26	3	45	60	500	500	0.206	0.5629
	0.00172	0	0.092	3.31	3	30	60	500	500	0.152	0.4468
	$1.69 \cdot 10^{-4}$	0	0.292	33.62	2	75	80	500	500	0.442	1.044
	$4.27 \cdot 10^{-4}$	0	0.184	13.3	2	75	60	500	500	0.334	0.788
	$6.79 \cdot 10^{-4}$	0	0.146	8.37	2	60	60	500	500	0.266	0.652
	0.00108	0	0.116	5.26	2	45	60	500	500	0.206	0.532
	0.00172	0	0.092	3.31	2	30	60	500	500	0.152	0.424

PRNCOLWIDTH := 12 PRNPRECISION := 8

WRITEPRN(cable) := CABLE This stores matrix CABLE onto a file called CABLE.PRN in ASCII format.

ATTACHMENT B1
INTERIM CALCULATION OF CABLE AMPACITY OF THERMOLAGGED CABLE IN FREE AIR: TEMPLATE 1

This templates calculates interim values for input into Template Attachment B2. Specifically, number of cables and conductors and effective bundle diameters, and maximum number of cables which can fit into a conduit are calculated in this template.

CABLE INPUT DATA

PRNPRECISION := 8

CABLE := READPRN[cable prn] File: cable.prn was produced by template Attachment A1 and is documented separately.

ORIGIN = 1 defines the upper corner of a matrix as 1,1

$j := 1..7$ $i := 1..21$ $n'_{i,j} := 0$ $Cdiam_{i,j} := 0$

Matrix CABLE is comprised of the following indicated columns.

Rdc25 := CABLE<1> Yc := CABLE<2> Dc := CABLE<3> Ac := CABLE<4>

n' := CABLE<1> It := CABLE<5> Jt := CABLE<6> ρi := CABLE<7> ρj := CABLE<8>

Diam1C := CABLE<9> Cdiam := CABLE<10>

Where:

Rdc25	Conductor dc resistance at 25 deg C, Ω/ft
Yc	Conductor proximity/skin effect
Dc	Conductor diameter, in.
Ac	Conductor cross-sectional area, sq mm
n'	Number of conductors in cable
It	Insulation thickness, mils
Jt	Overall jacket thickness, mils
ρi	Insulation thermal resistivity, C-cm/w
ρj	Jacket thermal resistivity, C-cm/w
Diam1C	Diameter of 1/c cable or 1 cable of multi-conductor cable, in.
Cdiam	Overall diameter of cable, in.

CABLE PHYSICAL PROPERTIES

CABLE =

Rdc25 Ω/ft	Yc	Dc in.	Ac mm2	n'	It mil	Jt mil	ρi	ρj	Diam1C inch	Odiam inch
$2.22 \cdot 10^{-5}$	0.06	0.813	253.4	1	280	0	500	500	1.373	2.95195
$3.2 \cdot 10^{-5}$	0.03	0.681	177.3	1	280	0	500	500	1.241	2.66815
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	1	280	0	500	500	1.088	2.3392
$1.48 \cdot 10^{-5}$	0.13	0.998	380	1	145	0	500	500	1.288	2.7692
$2.22 \cdot 10^{-5}$	0.06	0.813	253.4	1	130	0	500	500	1.073	2.30695
$3.2 \cdot 10^{-5}$	0.03	0.681	177.3	1	130	0	500	500	0.941	2.02315
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	1	100	0	500	500	0.728	1.5652
$8.43 \cdot 10^{-5}$	0	0.418	67.43	1	100	0	500	500	0.618	1.3287
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	3	100	0	500	500	0.728	1.5652
$8.43 \cdot 10^{-5}$	0	0.418	67.43	3	100	0	500	500	0.618	1.3287
$1.69 \cdot 10^{-4}$	0	0.292	33.62	3	75	0	500	500	0.442	0.9503
$2.69 \cdot 10^{-4}$	0	0.232	21.15	3	75	80	500	500	0.382	0.9813
$4.27 \cdot 10^{-4}$	0	0.184	13.3	3	75	80	500	500	0.334	0.8781
$6.79 \cdot 10^{-4}$	0	0.146	8.37	3	60	60	500	500	0.266	0.6919
0.00108	0	0.116	5.26	3	45	60	500	500	0.206	0.5629
0.00172	0	0.092	3.31	3	30	60	500	500	0.152	0.4468
$1.69 \cdot 10^{-4}$	0	0.292	33.62	2	75	80	500	500	0.442	1.044
$4.27 \cdot 10^{-4}$	0	0.184	13.3	2	75	60	500	500	0.334	0.788
$6.79 \cdot 10^{-4}$	0	0.146	8.37	2	60	60	500	500	0.266	0.652
0.00108	0	0.116	5.26	2	45	60	500	500	0.206	0.532
0.00172	0	0.092	3.31	2	30	60	500	500	0.152	0.424

The above matrix is manually compared with the matrix CABLE of Attachment A to demonstrate successful data transfer.

II. BUNDLED CONDUCTOR DIAMETER

$j := 1..4$ $i := 1..21$

$N := (1\ \ 2\ \ 3\ \ 5)$ This is the number of cables in a bundle, except that 3 - single conductors are counted as one. The numbers were arbitrarily selected.

$N_{i,j} := N_{1,j}$

The following determines the maximum number of cables which can fit in a conduit using the 40% "fill by area" criteria (see Reference 14).

Acnd3 := 7.38 Acnd5 := 20 Area of a 3,4,5,6 inch conduit, Source: Reference 14 (NEC).

Acnd4 := 12.72 Acnd6 := 28.89

$$N_{i,5} := \text{if}\left[n'_{i,1} \ge 1, \text{floor}\left[\frac{0.4 \cdot Acnd3}{3 \cdot \pi \cdot \left(\frac{Diam1C_{i,1}}{4}\right)^2}\right], \text{floor}\left[\frac{0.4 \cdot Acnd3}{\pi \cdot \left(\frac{Cdiam_{i,1}}{4}\right)^2}\right]\right]$$

$$N_{i,6} := \text{if}\left[n'_{i,1} \ge 1, \text{floor}\left[\frac{0.4 \cdot Acnd4}{3 \cdot \pi \cdot \left(\frac{Diam1C_{i,1}}{4}\right)^2}\right], \text{floor}\left[\frac{0.4 \cdot Acnd4}{\pi \cdot \left(\frac{Cdiam_{i,1}}{4}\right)^2}\right]\right]$$

$$N_{i,7} := \text{if}\left[n'_{i,1} \ge 1, \text{floor}\left[\frac{0.4 \cdot Acnd5}{3 \cdot \pi \cdot \left(\frac{Diam1C_{i,1}}{4}\right)^2}\right], \text{floor}\left[\frac{0.4 \cdot Acnd5}{\pi \cdot \left(\frac{Cdiam_{i,1}}{4}\right)^2}\right]\right]$$

$$N_{i,8} := \text{if}\left[n'_{i,1} \ge 1, \text{floor}\left[\frac{0.4 \cdot Acnd6}{3 \cdot \pi \cdot \left(\frac{Diam1C_{i,1}}{4}\right)^2}\right], \text{floor}\left[\frac{0.4 \cdot Acnd6}{\pi \cdot \left(\frac{Cdiam_{i,1}}{4}\right)^2}\right]\right]$$

$j := 1 \ldots 8$

$N_{i,j} := if[N_{i,j} \le 0, 1, N_{i,j}]$ This ensures that N is never zero

Conduit Size: 3 4 5 6

$N =$

1	2	3	5	1	1	1	2
1	2	3	5	1	1	2	3
1	2	3	5	1	1	2	4
1	2	3	5	1	1	2	2
1	2	3	5	1	1	2	4
1	2	3	5	1	2	3	5
1	2	3	5	2	4	6	9
1	2	3	5	3	5	8	12
1	2	3	5	1	2	4	6
1	2	3	5	2	3	5	8
1	2	3	5	4	7	11	16
1	2	3	5	3	6	10	15
1	2	3	5	4	8	13	19
1	2	3	5	7	13	21	30
1	2	3	5	11	20	32	46
1	2	3	5	18	32	51	73
1	2	3	5	3	5	9	13
1	2	3	5	6	10	16	23
1	2	3	5	8	15	23	34
1	2	3	5	13	22	35	51
1	2	3	5	20	36	56	81

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-2/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

$WRITEPRN(N_{prn}) := N$ This stores the N matix in an ASCII file for use in Template Appendix B2 and B3

$NNFF := READPRN\left[\begin{matrix} NNFF \\ prn \end{matrix}\right]$ Matrix NNFF defines the relationship between the number of cables in a bundle and the multiplier to obtain bundle diameter (see template Attachment C for its development).

$x := 1 \ldots 85$

$$FF(o,p) := \sum_{x} \left[NNFF^{\langle 1 \rangle}_{x} \overset{R}{=} N_{o,p} \right] \cdot NNFF^{\langle 2 \rangle}_{x}$$

The above equation searches NNFF, finds the appropriate row and sets FF equal to the multipling variable in the second column of NNFF. This algorithm, as well as the data transfer of NNFF, is verified by manually comparing matrix N against NNFF to confirm the accuracy of the resulting FF and F.

$j := 1 \ldots 8$

$F_{i,j} := FF(i,j)$ Redefines FF as F.

No. of cables in a Bundle

N =

No. of Cables / Conduit Size								
1	2	3	5	3"	4"	5"	6"	
1	2	3	5	1	1	1	2	1/C-500,8 KV
1	2	3	5	1	1	2	3	1/C-350,8 KV
1	2	3	5	1	1	2	4	1/C-4/0,8 KV
1	2	3	5	1	1	2	2	1/C-750,600 V
1	2	3	5	1	1	2	4	1/C-500
1	2	3	5	1	2	3	5	1/C-350
1	2	3	5	2	4	6	9	1/C-4/0
1	2	3	5	3	5	8	12	1/C-2/0
1	2	3	5	1	2	4	6	TRI-4/0
1	2	3	5	2	3	5	8	TRI-2/0
1	2	3	5	4	7	11	16	TRI-2AWG
1	2	3	5	3	6	10	15	3/C-4AWG
1	2	3	5	4	8	13	19	3/C-6AWG
1	2	3	5	7	13	21	30	3/C-8AWG
1	2	3	5	11	20	32	46	3/C-10AWG
1	2	3	5	18	32	51	73	3/C-12AWG
1	2	3	5	3	5	9	13	2/C-2AWG
1	2	3	5	6	10	16	23	2/C-6AWG
1	2	3	5	8	15	23	34	2/C-8AWG
1	2	3	5	13	22	35	51	2/C-10AWG
1	2	3	5	20	36	56	81	2/C-12AWG

Equivalent multiplier to obtain bundle diameter = F * cable diameter.

F =

Number of Cables /				Conduit Size				
1	2	3	5	3"	4"	5"	6"	
1	2	2.15	2.7	1	1	1	2	1/C-500,8 KV
1	2	2.15	2.7	1	1	2	2.15	1/C-350,8 KV
1	2	2.15	2.7	1	1	2	2.14	1/C-4/0,8 KV
1	2	2.15	2.7	1	1	2	2	1/C-750,600 V
1	2	2.15	2.7	1	1	2	2.14	1/C-500
1	2	2.15	2.7	1	2	2.15	2.7	1/C-350
1	2	2.15	2.7	2	2.14	3	3.62	1/C-4/0
1	2	2.15	2.7	2.15	2.7	3.31	4.15	1/C-2/0
1	2	2.15	2.7	1	2	2.14	3	TRI-4/0
1	2	2.15	2.7	2	2.15	2.7	3.31	TRI-2/0
1	2	2.15	2.7	2.14	3	4	4.7	TRI-2AWG
1	2	2.15	2.7	2.15	3	4	4.7	3/C-4AWG
1	2	2.15	2.7	2.14	3.31	4.41	5	3/C-6AWG
1	2	2.15	2.7	3	4.41	5.31	6.41	3/C-8AWG
1	2	2.15	2.7	4	5.31	6.7	8	3/C-10AWG
1	2	2.15	2.7	5	6.7	8.41	10	3/C-12AWG
1	2	2.15	2.7	2.15	2.7	3.62	4.41	2/C-2AWG
1	2	2.15	2.7	3	4	4.7	6	2/C-6AWG
1	2	2.15	2.7	3.31	4.7	6	7	2/C-8AWG
1	2	2.15	2.7	4.41	5.62	7	8.41	2/C-10AWG
1	2	2.15	2.7	5.31	7	8.7	10.41	2/C-12AWG

$j := 1..8$

$n'_{i,1} := if[n'_{i,1} \neq 1,3,n'_{i,1}]$

This redefines the number of conductors for 1/C cable as 3 for N = 1.

ORIGIN = 1

$nn'_{i,j} := n'_{i,1} \cdot N_{i,j}$

This calculates the number of conductors under the wrap.

Actual number of Conductors inside Bundle

	Number of Cables / Conduit Size								
	1	2	3	5	3"	4"	5"	6"	
nn' =	3	6	9	15	3	3	3	6	1/C-500,8 KV
	3	6	9	15	3	3	6	9	1/C-350,8 KV
	3	6	9	15	3	3	6	12	1/C-4/0,8 KV
	3	6	9	15	3	3	6	6	1/C-750,600 V
	3	6	9	15	3	3	6	12	1/C-500
	3	6	9	15	3	6	9	15	1/C-350
	3	6	9	15	6	12	18	27	1/C-4/0
	3	6	9	15	9	15	24	36	1/C-2/0
	3	6	9	15	3	6	12	18	TRI-4/0
	3	6	9	15	6	9	15	24	TRI-2/0
	3	6	9	15	12	21	33	48	TRI-2AWG
	3	6	9	15	9	18	30	45	3/C-4AWG
	3	6	9	15	12	24	39	57	3/C-6AWG
	3	6	9	15	21	39	63	90	3/C-8AWG
	3	6	9	15	33	60	96	138	3/C-10AWG
	3	6	9	15	54	96	153	219	3/C-12AWG
	2	4	6	10	6	10	18	26	2/C-2AWG
	2	4	6	10	12	20	32	46	2/C-6AWG
	2	4	6	10	16	30	46	68	2/C-8AWG
	2	4	6	10	26	44	70	102	2/C-10AWG
	2	4	6	10	40	72	112	162	2/C-12AWG

nn' is the actual number of conductors inside a bundle
nnn' is the equivalent number of conductors for heat production basis

The following accounts for load diversity in larger cable bundles. See template Appendix F and the Methodology section for further explaination.

$nnn'_{i,j} := if\left[N_{i,j} \geq 3, 0.88 \cdot nn'_{i,j}, nn'_{i,j}\right]$ Adjust nn' for N=3

$nnn'_{i,j} := if\left[N_{i,j} \geq 4, 0.82 \cdot nn'_{i,j}, nnn'_{i,j}\right]$ Adjust nn' for N=4

$nnn'_{i,j} := if\left[N_{i,j} \geq 5, 0.784 \cdot nn'_{i,j}, nnn'_{i,j}\right]$ Adjust nn' for N=5

$nnn'_{i,j} := if\left[N_{i,j} \geq 6, 0.76 \cdot nn'_{i,j}, nnn'_{i,j}\right]$ Adjust nn' for N=6

$nnn'_{i,j} := if\left[N_{i,j} \geq 7, 0.743 \cdot nn'_{i,j}, nnn'_{i,j}\right]$ Adjust nn' for N=7 or greater, for conservatism no value smaller than 0.743 will be used

Equivalent number of conductors in Bundle

Number of Cables / Conduit Size

	1	2	3	5	3"	4"	5"	6"	
nnn' =	3	6	7.92	11.76	3	3	3	6	1/C-500,8 KV
	3	6	7.92	11.76	3	3	6	7.92	1/C-350,8 KV
	3	6	7.92	11.76	3	3	6	9.84	1/C-4/0,8 KV
	3	6	7.92	11.76	3	3	6	6	1/C-750,600 V
	3	6	7.92	11.76	3	3	6	9.84	1/C-500
	3	6	7.92	11.76	3	6	7.92	11.76	1/C-350
	3	6	7.92	11.76	6	9.84	13.68	20.06	1/C-4/0
	3	6	7.92	11.76	7.92	11.76	17.83	26.75	1/C-2/0
	3	6	7.92	11.76	3	6	9.84	13.68	TRI-4/0
	3	6	7.92	11.76	6	7.92	11.76	17.83	TRI-2/0
	3	6	7.92	11.76	9.84	15.6	24.52	35.66	TRI-2AWG
	3	6	7.92	11.76	7.92	13.68	22.29	33.44	3/C-4AWG
	3	6	7.92	11.76	9.84	17.83	28.98	42.35	3/C-6AWG
	3	6	7.92	11.76	15.6	28.98	46.81	66.87	3/C-8AWG
	3	6	7.92	11.76	24.52	44.58	71.33	102.53	3/C-10AWG
	3	6	7.92	11.76	40.12	71.33	113.68	162.72	3/C-12AWG
	2	4	5.28	7.84	5.28	7.84	13.37	19.32	2/C-2AWG
	2	4	5.28	7.84	9.12	14.86	23.78	34.18	2/C-6AWG
	2	4	5.28	7.84	11.89	22.29	34.18	50.52	2/C-8AWG
	2	4	5.28	7.84	19.32	32.69	52.01	75.79	2/C-10AWG
	2	4	5.28	7.84	29.72	53.5	83.22	120.37	2/C-12AWG

WRITEPRN(NNN prn) := nnn'

WRITEPRN(nn prn) := nn'

Both matices nnn' and nn' are saved to an ASCII file for later use by template Appendix B2 and B3

$CCdiam_{i,j} := Cdiam_{i,1} \cdot F_{i,j}$

This calculates the diameter of a bundle of cables, for various number of cables in the bundle.

Bundle diameter

No. of Cables / Conduit Size

	1	2	3	5	3"	4"	5"	6"	
CCdiam =	2.95	5.9	6.35	7.97	2.95	2.95	2.95	5.9	1/C-500,8 KV
	2.67	5.34	5.74	7.2	2.67	2.67	5.34	5.74	1/C-350,8 KV
	2.34	4.68	5.03	6.32	2.34	2.34	4.68	5.01	1/C-4/0,8 KV
	2.77	5.54	5.95	7.48	2.77	2.77	5.54	5.54	1/C-750,600 V
	2.31	4.61	4.96	6.23	2.31	2.31	4.61	4.94	1/C-500
	2.02	4.05	4.35	5.46	2.02	4.05	4.35	5.46	1/C-350
	1.57	3.13	3.37	4.23	3.13	3.35	4.7	5.67	1/C-4/0
	1.33	2.66	2.86	3.59	2.86	3.59	4.4	5.51	1/C-2/0
	1.57	3.13	3.37	4.23	1.57	3.13	3.35	4.7	TRI-4/0
	1.33	2.66	2.86	3.59	2.66	2.86	3.59	4.4	TRI-2/0
	0.95	1.9	2.04	2.57	2.03	2.85	3.8	4.47	TRI-2AWG
	0.98	1.96	2.11	2.65	2.11	2.94	3.93	4.61	3/C-4AWG
	0.88	1.76	1.89	2.37	1.88	2.91	3.87	4.39	3/C-6AWG
	0.69	1.38	1.49	1.87	2.08	3.05	3.67	4.44	3/C-8AWG
	0.56	1.13	1.21	1.52	2.25	2.99	3.77	4.5	3/C-10AWG
	0.45	0.89	0.96	1.21	2.23	2.99	3.76	4.47	3/C-12AWG
	1.04	2.09	2.24	2.82	2.24	2.82	3.78	4.6	2/C-2AWG
	0.79	1.58	1.69	2.13	2.36	3.15	3.7	4.73	2/C-6AWG
	0.65	1.3	1.4	1.76	2.16	3.06	3.91	4.56	2/C-8AWG
	0.53	1.06	1.14	1.44	2.35	2.99	3.72	4.47	2/C-10AWG
	0.42	0.85	0.91	1.14	2.25	2.97	3.69	4.41	2/C-12AWG

WRITEPRN(CCdiam prn) := CCdiam

This saves matrix CCdiam for use by template Appendix B2

ATTACHMENT B2
CABLE AMPACITY OF THERMOLAGGED CABLE
IN FREE AIR: TEMPLATE 2 5/16" product (3)

This templates calculates the thermal resistance terms and cable ampacity. The cable ampacity is input to template Attachment B3 for comparison with ampacity of the cable in adjacent raceways sections.

I. CABLE INPUT DATA

PRNPRECISION := 8

CABLE := READPRN[cable.prn] File: cable.prn was produced by template- Attaqchment A and is documented separataly.

ORIGIN = 1 defines the upper corner of a matrix as 1,1

j := 1 ..7 i := 1 ..21 $n'_{i,j}$:= 0 $Cdiam_{i,j}$:= 0 (2)

Matrix CABLE is comprised of the following indicated columns.

Rdc25 := CABLE<1> Yc := CABLE<2> Dc := CABLE<3> Ac := CABLE<4>

n' := CABLE<1> It := CABLE<5> Jt := CABLE<6> ρi := CABLE<7> ρj := CABLE<8>

ρj := CABLE<9> Diam1C := CABLE<10> Cdiam := CABLE<11>

Where:

Rdc25	Conductor dc resistance at 25 deg C, Ω/ft
Yc	Conductor proximity/skin effect
Dc	Conductor diameter, in.
Ac	Conductor cross-sectional area, sq mm
n'	Number of conductors in cable
It	Insulation thickness, mils
Jt	Overall jacket thickness, mils
ρi	Insulation thermal resistivity, C-cm/w
ρj	Jacket thermal resistivity, C-cm/w
Diam1C	Diameter of 1/c cable or 1 cable of multi-conductor cable, in.
Cdiam	Overall diameter of cable, in.

CABLE PHYSICAL PROPERTIES

CABLE =

Rdc25 Ω/ft	Yc	Dc in.	Ac mm2	n'	It mil	Jt mil	ρi	ρj	Diam1C inch	Odiam inch
$2.22 \cdot 10^{-5}$	0.06	0.813	253.4	1	280	0	500	500	1.373	2.95195
$3.2 \cdot 10^{-5}$	0.03	0.681	177.3	1	280	0	500	500	1.241	2.66815
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	1	280	0	500	500	1.088	2.3392
$1.48 \cdot 10^{-5}$	0.13	0.998	380	1	145	0	500	500	1.288	2.7692
$2.22 \cdot 10^{-5}$	0.06	0.813	253.4	1	130	0	500	500	1.073	2.30695
$3.2 \cdot 10^{-5}$	0.03	0.681	177.3	1	130	0	500	500	0.941	2.02315
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	1	100	0	500	500	0.728	1.5652
$8.43 \cdot 10^{-5}$	0	0.418	67.43	1	100	0	500	500	0.618	1.3287
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	3	100	0	500	500	0.728	1.5652
$8.43 \cdot 10^{-5}$	0	0.418	67.43	3	100	0	500	500	0.618	1.3287
$1.69 \cdot 10^{-4}$	0	0.292	33.62	3	75	0	500	500	0.442	0.9503
$2.69 \cdot 10^{-4}$	0	0.232	21.15	3	75	30	500	500	0.382	0.9813
$4.27 \cdot 10^{-4}$	0	0.184	13.3	3	75	80	500	500	0.334	0.8781
$6.79 \cdot 10^{-4}$	0	0.146	8.37	3	60	60	500	500	0.266	0.6919
0.00108	0	0.116	5.26	3	45	60	500	500	0.206	0.5629
0.00172	0	0.092	3.31	3	30	60	500	500	0.152	0.4468
$1.69 \cdot 10^{-4}$	0	0.292	33.62	2	75	80	500	500	0.442	1.044
$4.27 \cdot 10^{-4}$	0	0.184	13.3	2	75	60	500	500	0.334	0.788
$6.79 \cdot 10^{-4}$	0	0.146	8.37	2	60	60	500	500	0.266	0.652
0.00108	0	0.116	5.26	2	45	60	500	500	0.206	0.532
0.00172	0	0.092	3.31	2	30	60	500	500	0.152	0.424

The above matrix is manually compared with the matrix CABLE of Attachment A to demonstrate successful data transfer.

N, nnn', and CCdiam were developed in template- Attachment B1

N := READPRN(N prn) nnn' := READPRN(NNN prn)

CCdiam := READPRN(CCdiam prn)

No. of cables in a Bundle

No. of cables				/ Conduit Size 3 "	4 "	5 "	6"
1	2	3	5	1	1	1	2
1	2	3	5	1	1	2	3
1	2	3	5	1	1	2	4
1	2	3	5	1	1	2	2
1	2	3	5	1	1	2	4
1	2	3	5	1	2	3	5
1	2	3	5	2	4	6	9
1	2	3	5	3	5	8	12
1	2	3	5	1	2	4	6
1	2	3	5	2	3	5	8
1	2	3	5	4	7	11	16
1	2	3	5	3	6	10	15
1	2	3	5	4	8	13	19
1	2	3	5	7	13	21	30
1	2	3	5	11	20	32	46
1	2	3	5	18	32	51	73
1	2	3	5	3	5	9	13
1	2	3	5	6	10	16	23
1	2	3	5	8	15	23	34
1	2	3	5	13	22	35	51
1	2	3	5	20	36	56	81

N =

Equivalent No. of conductors in a Bundle

nnn' =

No. of cables	1	2	3	5	Conduit Size 3"	4"	5"	6"
	3	6	7.92	11.76	3	3	3	6
	3	6	7.92	11.76	3	3	6	7.92
	3	6	7.92	11.76	3	3	6	9.84
	3	6	7.92	11.76	3	3	6	6
	3	6	7.92	11.76	3	3	6	9.84
	3	6	7.92	11.76	3	6	7.92	11.76
	3	6	7.92	11.76	6	9.84	13.68	20.06
	3	6	7.92	11.76	7.92	11.76	17.83	26.75
	3	6	7.92	11.76	3	6	9.84	13.68
	3	6	7.92	11.76	6	7.92	11.76	17.83
	3	6	7.92	11.76	9.84	15.6	24.52	35.66
	3	6	7.92	11.76	7.92	13.68	22.29	33.44
	3	6	7.92	11.76	9.84	17.83	28.98	42.35
	3	6	7.92	11.76	15.6	28.98	46.81	66.87
	3	6	7.92	11.76	24.52	44.58	71.33	102.53
	3	6	7.92	11.76	40.12	71.33	113.68	162.72
	2	4	5.28	7.84	5.28	7.84	13.37	19.32
	2	4	5.28	7.84	9.12	14.86	23.78	34.18
	2	4	5.28	7.84	11.89	22.29	34.18	50.52
	2	4	5.28	7.84	19.32	32.69	52.01	75.79
	2	4	5.28	7.84	29.72	53.5	83.22	120.37

Diameter of cable Bundle

CCdiam =

No. of cables	1	2	3	5	Conduit Size 3"	4"	5"	6"
	2.95	5.9	6.35	7.97	2.95	2.95	2.95	5.9
	2.67	5.34	5.74	7.2	2.67	2.67	5.34	5.74
	2.34	4.68	5.03	6.32	2.34	2.34	4.68	5.01
	2.77	5.54	5.95	7.48	2.77	2.77	5.54	5.54
	2.31	4.61	4.96	6.23	2.31	2.31	4.61	4.94
	2.02	4.05	4.35	5.46	2.02	4.05	4.35	5.46
	1.57	3.13	3.37	4.23	3.13	3.35	4.7	5.67
	1.33	2.66	2.86	3.59	2.86	3.59	4.4	5.51
	1.57	3.13	3.37	4.23	1.57	3.13	3.35	4.7
	1.33	2.66	2.86	3.59	2.66	2.86	3.59	4.4
	0.95	1.9	2.04	2.57	2.03	2.85	3.8	4.47
	0.98	1.96	2.11	2.65	2.11	2.94	3.93	4.61
	0.88	1.76	1.89	2.37	1.88	2.91	3.87	4.39
	0.69	1.38	1.49	1.87	2.08	3.05	3.67	4.44
	0.56	1.13	1.21	1.52	2.25	2.99	3.77	4.5
	0.45	0.89	0.96	1.21	2.23	2.99	3.76	4.47
	1.04	2.09	2.24	2.82	2.24	2.82	3.78	4.6
	0.79	1.58	1.69	2.13	2.36	3.15	3.7	4.73
	0.65	1.3	1.4	1.76	2.16	3.06	3.91	4.56
	0.53	1.06	1.14	1.44	2.35	2.99	3.72	4.47
	0.42	0.85	0.91	1.14	2.25	2.97	3.69	4.41

III. Calculation of thermal resistance terms

$j := 1 .. 8$

$$Ri_{i,j} := 0.012 \cdot \rho_i \cdot \log\left[\frac{Diam1C_i}{Dc_i}\right]$$

thermal resistance of insulation
C-ft/watt
Source: Reference 3 (Nehr-McGrath), equation 38.

Thermal Resistance of Insulation

	No. of cables / Conduit Size								
	1	2	3	5	3"	4"	5"	6"	
Ri =	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1/C-500,8 KV
	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1/C-350,8 KV
	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1/C-4/0,8 KV
	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1/C-750,600 V
	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1/C-500
	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1/C-350
	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1/C-4/0
	1	1	1	1	1	1	1	1	1/C-2/0
	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	TRI-4/0
	1	1	1	1	1	1	1	1	TRI-2/0
	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	TRI-2AWG
	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	3/C-4AWG
	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3/C-6AWG
	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3/C-8AWG
	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	3/C-10AWG
	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	3/C-12AWG
	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	2/C-2AWG
	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2/C-6AWG
	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2/C-8AWG
	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2/C-10AWG
	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	2/C-12AWG

Thermal Resistance of the Jacket on 2/C and 3/C cable

$$Rj_{i,j} := \left[Jt_i > 0\right]\cdot\left[0.012\cdot n'_{i,1}\cdot \rho j_i\cdot \log\left[\frac{Cdiam_{i,1}}{Cdiam_{i,1} - 2\cdot Jt_i\cdot 10^{-3}}\right]\right]$$

Thermal resistance of jacket, C-ft/watt Source: Derived from equation 38 in Reference 3 (Nehr-McGrath) This first part of the expression is a logical statement to only calculate Rj if a jacket exists.

Thermal Resistance of Jacket

Rj =

No. of cables / Conduit Size							
1	2	3	5	3"	4"	5"	6"
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39
1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57
1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49
1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87
2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73

$A' := 4.5$ $B' := 0.27$ factors used in Rsd, developed constants in Table VII of Reference 3 (Nehr-McGrath). See Methodology 8

$$Rsd_{i,j} := nnn'_{i,j} \cdot \frac{A'}{CCdiam_{i,j} + B'}$$

thermal resistance between cable and 330-660, C-ft/watt this assumes an airgap between the two surfaces. Equation 41A from Reference 3, (Nehr-McGrath).

$Rsd =$

4.2	4.4	5.4	6.4	4.2	4.2	4.2	4.4	1/C-500,8 KV
4.6	4.8	5.9	7.1	4.6	4.6	4.8	5.9	1/C-350,8 KV
5.2	5.5	6.7	8	5.2	5.2	5.5	8.4	1/C-4/0,8 KV
4.4	4.6	5.7	6.8	4.4	4.4	4.6	4.6	1/C-750,600 V
5.2	5.5	6.8	8.1	5.2	5.2	5.5	8.5	1/C-500
5.9	6.3	7.7	9.2	5.9	6.3	7.7	9.2	1/C-350
7.4	7.9	9.8	11.8	7.9	12.2	12.4	15.2	1/C-4/0
8.4	9.2	11.4	13.7	11.4	13.7	17.2	20.8	1/C-2/0
7.4	7.9	9.8	11.8	7.4	7.9	12.2	12.4	TRI-4/0
8.4	9.2	11.4	13.7	9.2	11.4	13.7	17.2	TRI-2/0
11.1	12.4	15.4	18.7	19.2	22.5	27.1	33.9	TRI-2AWG
10.8	12.1	15	18.1	15	19.2	23.9	30.8	3/C-4AWG
11.8	13.3	16.5	20	20.6	25.3	31.5	40.9	3/C-6AWG
14	16.3	20.3	24.8	29.9	39.3	53.4	64	3/C-8AWG
16.2	19.3	24.1	29.6	43.8	61.6	79.4	96.7	3/C-10AWG
18.8	23.2	29	35.8	72.1	98.4	127	154.5	3/C-12AWG
6.8	7.6	9.4	11.4	9.4	11.4	14.9	17.8	2/C-2AWG
8.5	9.8	12.1	14.7	15.6	19.5	26.9	30.8	2/C-6AWG
9.8	11.4	14.2	17.4	22	30.1	36.8	47	2/C-8AWG
11.2	13.5	16.8	20.7	33.2	45.1	58.6	71.9	2/C-10AWG
13	16.1	20.1	24.9	53	74.3	94.6	115.6	2/C-12AWG

THERMAL RESISTANCE OF THERMOLAG 330-660 WRAP

Btu/hr = B B := .2931 watts Ft := 30.4785 cm

$F := \frac{5}{9}$ This is to convert degree F to degrees C

$K := (0.249)\cdot\frac{B}{Ft}\cdot\frac{1}{F}$ See Attachment D (conductivity)

$\rho w := \frac{1}{K}$

$\rho w = 232.01$ thermal resistivity of 330-660 wrap, C-Cm/watt

Twrap := 4·0.3123 thickness of wrap, inch (4 layers of maximum thickness, see Attachment D)

Twrap = 1.249

$$Rw_{i,j} := 0.012\cdot\pi\cdot\rho w\cdot\log\left[\frac{CCdiam_{i,j} + 2\cdot Twrap}{CCdiam_{i,j}}\right]$$

Thermal resistance of thermolag wrap, thermal Ω/ft
Source: Reference 2, equation 6

Thermal Resistance of Wrap

No. of cables / Conduit Size								
1	2	3	5	3"	4"	5"	6"	
2.2	2.6	3.2	3.9	2.2	2.2	2.2	2.6	1/C-500,8 KV
2.4	2.8	3.5	4.2	2.4	2.4	2.8	3.5	1/C-350,8 KV
2.6	3.1	3.9	4.7	2.6	2.6	3.1	4.8	1/C-4/0,8 KV
2.3	2.7	3.4	4.1	2.3	2.3	2.7	2.7	1/C-750,600 V
2.7	3.1	3.9	4.8	2.7	2.7	3.1	4.9	1/C-500
2.9	3.5	4.3	5.4	2.9	3.5	4.3	5.4	1/C-350
3.5	4.3	5.3	6.6	4.3	6.6	7.1	8.9	1/C-4/0
3.8	4.8	6	7.5	6	7.5	9.7	12.1	1/C-2/0
3.5	4.3	5.3	6.6	3.5	4.3	6.6	7.1	TRI-4/0
3.8	4.8	6	7.5	4.8	6	7.5	9.7	TRI-2/0
4.7	6.1	7.6	9.7	9.5	11.9	15	19.2	TRI-2AWG
4.6	6	7.5	9.4	7.5	10.2	13.3	17.5	3/C-4AWG
4.9	6.4	8.1	10.2	10.1	13.4	17.4	23.1	3/C-6AWG
5.5	7.5	9.4	12.1	14.9	21	29.4	36.1	3/C-8AWG
6.1	8.5	10.7	13.8	22.1	32.7	43.8	54.7	3/C-10AWG
6.8	9.7	12.3	16	36.4	52.3	70.1	87.4	3/C-12AWG
3	3.8	4.8	6	4.8	6	8.2	10.1	2/C-2AWG
3.5	4.6	5.8	7.4	8	10.5	14.8	17.5	2/C-6AWG
3.8	5.2	6.5	8.4	11.1	16.1	20.4	26.7	2/C-8AWG
4.2	5.8	7.4	9.6	16.9	24	32.3	40.7	2/C-10AWG
4.7	6.6	8.4	11	26.8	39.5	52	65.3	2/C-12AWG

THERMAL RESISTANCE BETWEEN THE THERMOLAG AND AMBIENT AIR

$Dwrap_{i,j} := 2 \cdot Twrap + CCdiam_{i,j}$ Overall diameter of wrap, in.

Diameter Over the Wrap

No. of cables / Conduit Size								
1	2	3	5	3	4"	5 "	6"	
5.5	8.4	8.8	10.5	5.5	5.5	5.5	8.4	1/C-500,8 KV
5.2	7.8	8.2	9.7	5.2	5.2	7.8	8.2	1/C-350,8 KV
4.8	7.2	7.5	8.8	4.8	4.8	7.2	7.5	1/C-4/0,8 KV
5.3	8	8.5	10	5.3	5.3	8	8	1/C-750,600 V
4.8	7.1	7.5	8.7	4.8	4.8	7.1	7.4	1/C-500
4.5	6.5	6.8	8	4.5	6.5	6.8	8	1/C-350
4.1	5.6	5.9	6.7	5.6	5.8	7.2	8.2	1/C-4/0
3.8	5.2	5.4	6.1	5.4	6.1	6.9	8	1/C-2/0
4.1	5.6	5.9	6.7	4.1	5.6	5.8	7.2	TRI-4/0
3.8	5.2	5.4	6.1	5.2	5.4	6.1	6.9	TRI-2/0
3.4	4.4	4.5	5.1	4.5	5.3	6.3	7	TRI-2AWG
3.5	4.5	4.6	5.1	4.6	5.4	6.4	7.1	3/C-4AWG
3.4	4.3	4.4	4.9	4.4	5.4	6.4	6.9	3/C-6AWG
3.2	3.9	4	4.4	4.6	5.5	6.2	6.9	3/C-8AWG
3.1	3.6	3.7	4	4.8	5.5	6.3	7	3/C-10AWG
2.9	3.4	3.5	3.7	4.7	5.5	6.3	7	3/C-12AWG
3.5	4.6	4.7	5.3	4.7	5.3	6.3	7.1	2/C-2AWG
3.3	4.1	4.2	4.6	4.9	5.7	6.2	7.2	2/C-6AWG
3.2	3.8	3.9	4.3	4.7	5.6	6.4	7.1	2/C-8AWG
3	3.6	3.6	3.9	4.8	5.5	6.2	7	2/C-10AWG
2.9	3.3	3.4	3.6	4.7	5.5	6.2	6.9	2/C-12AWG

$Dwrap =$

(2)

$\epsilon := 0.89$ emissivity of Thermolag 330-660 (see Attachment D)

$$Rwn_{i,j} := \frac{9.5 \cdot nnn'_{i,j}}{1 + 1.7 \cdot Dwrap_{i,j} \cdot (\epsilon + 0.41)}$$

Thermal resistance between wrap and ambient air, thermal ft-ft (C-ft/watt)
Source: Reference 3 (Nahr-McGrath, equation 42A)

Thermal Resistance of Wrap to Air

No. of cables / Conduit Size								
1	2	3	5	3"	4"	5"	6"	
2.2	2.9	3.7	4.6	2.2	2.2	2.2	2.9	1/C-500,8 KV
2.3	3.1	3.9	5	2.3	2.3	3.1	3.9	1/C-350,8 KV
2.4	3.4	4.3	5.5	2.4	2.4	3.4	5.3	1/C-4/0,8 KV
2.3	3	3.8	4.8	2.3	2.3	3	3	1/C-750,600 V
2.5	3.4	4.3	5.5	2.5	2.5	3.4	5.4	1/C-500
2.6	3.7	4.7	6	2.6	3.7	4.7	6	1/C-350
2.9	4.2	5.4	7	4.2	6.7	7.7	10	1/C-4/0
3	4.6	5.9	7.7	5.9	7.7	10.4	13.6	1/C-2/0
2.9	4.2	5.4	7	2.9	4.2	6.7	7.7	TRI-4/0
3	4.6	5.9	7.7	4.6	5.9	7.7	10.4	TRI-2/0
3.3	5.3	6.8	9.2	8.5	11.6	15.6	20.7	TRI-2AWG
3.3	5.2	6.7	9	6.7	10	13.9	19	3/C-4AWG
3.4	5.5	7	9.5	8.8	13.1	18.3	24.8	3/C-6AWG
3.5	6	7.7	10.5	13.3	20.8	30.4	38.9	3/C-8AWG
3.7	6.3	8.2	11.3	20.3	32.3	45.6	59.1	3/C-10AWG
3.8	6.7	8.7	12.2	33.3	51.6	72.8	94.3	3/C-12AWG
2.2	3.4	4.4	5.8	4.4	5.8	8.5	11	2/C-2AWG
2.3	3.8	4.9	6.6	7.4	10.5	15.4	19.1	2/C-6AWG
2.4	4	5.2	7.2	10	15.9	21.4	28.9	2/C-8AWG
2.5	4.3	5.5	7.7	15.7	23.7	33.5	43.9	2/C-10AWG
2.5	4.5	5.9	8.2	24.6	38.9	53.9	70.3	2/C-12AWG

Rwa =

THERMAL RESISTANCE BETWEEN CONDUCTOR AND AMBIENT AIR

Rthl := Ri + Rj + Rsd + Rw + Rwa thermal resistance between the conductor and outside ambient air, thermal Ω-ft (C-ft/watt)

Thermal Resistance Between Conductor and Air

Rthl =

No. of cables / Conduit Size								
1	2	3	5	3 "	4"	5 "	6"	
10	11.2	13.6	16.3	10	10	10	11.2	1/C-500,8 KV
10.9	12.3	14.9	17.9	10.9	10.9	12.3	14.9	1/C-350,8 KV
12.1	13.8	16.7	20.1	12.1	12.1	13.8	20.4	1/C-4/0,8 KV
9.7	11.1	13.6	16.4	9.7	9.7	11.1	11.1	1/C-750,600 V
11.1	12.8	15.7	19.2	11.1	11.1	12.8	19.5	1/C-500
12.2	14.3	17.6	21.4	12.2	14.3	17.6	21.4	1/C-350
14.5	17.3	21.3	26.3	17.3	26.4	28	34.9	1/C-4/0
16.3	19.6	24.3	30	24.3	30	38.3	47.5	1/C-2/0
14.5	17.3	21.3	26.3	14.5	17.3	26.4	28	TRI-4/0
16.3	19.6	24.3	30	19.6	24.3	30	38.3	TRI-2/0
20.1	24.9	31	38.6	38.3	47	58.8	74.6	TRI-2AWG
21.4	26	31.9	39.3	31.9	42	53.8	70	3/C-4AWG
23.1	28.4	34.8	42.9	42.5	54.8	70.3	91.9	3/C-6AWG
26.2	32.8	40.4	50.4	61.2	84	116.2	142.1	3/C-8AWG
29.4	37.5	46.4	58.1	89.5	129.9	172.2	213.9	3/C-10AWG
33.2	43.3	53.7	67.7	145.5	206	273.7	340	3/C-12AWG
13.9	16.8	20.5	25.2	20.5	25.2	33.6	40.9	2/C-2AWG
16.7	20.6	25.2	31.1	33.3	42.9	59.5	69.9	2/C-6AWG
18.6	23.3	28.6	35.5	45.7	64.7	81.2	105.2	2/C-8AWG
20.7	26.4	32.6	40.7	68.7	95.6	127.2	159.2	2/C-10AWG
23.2	30.3	37.4	47.2	107.5	155.7	203.5	254.2	2/C-12AWG

$RRdc25_{i,j} := Rdc25_i$ $YYc_{i,j} := Yc_i$ Converts vector into matrix.

Tc := 90 conductor temperature, deg. C (see DBD-EE-52)

Ta := 50 ambient temperature, deg. C (see DBD-EE-52)

Cable ampacity of Thermolag 330-660 Wrapped Cable in Free Air

$$Iamp_{i,j} := \sqrt{(Tc - Ta) \cdot \frac{234.5 + 25}{\left[Rthl_{i,j} \cdot RRdc25_{i,j} \cdot \left[1 + YYc_{i,j}\right]\right] \cdot (234.5 + Tc)}}$$

Source: Reference 3 (Nahr-McGrath, equation 9, with Rthl = Rca', delta TD = 0, Rdc expressed at temperature Tc).

WRITEPRN(iamp_prn) := Iamp This saves Iamp in an ASCII file for use in template Attachment B3

Cable Ampacity of Wrapped Cable in Free Air

No. of cables / Conduit Size								
1	2	3	5	3"	4"	5"	6"	
369	348	316	289	369	369	369	348	1/C-500,8 KV
299	281	255	233	299	299	281	255	1/C-350,8 KV
223	209	190	173	223	223	209	172	1/C-4/0,8 KV
444	416	375	341	444	444	416	416	1/C-750,600 V
350	326	294	266	350	350	326	264	1/C-500
282	261	235	213	282	261	235	213	1/C-350
204	187	168	152	187	151	147	131	1/C-4/0
153	139	125	112	125	112	99	89	1/C-2/0
204	187	168	152	204	187	151	147	TRI-4/0
153	139	125	112	139	125	112	99	TRI-2/0
97	87	78	70	70	63	57	50	TRI-2AWG
75	68	61	55	61	53	47	41	3/C-4AWG
57	51	46	42	42	37	33	29	3/C-6AWG
42	38	34	31	28	24	20	18	3/C-8AWG
32	28	25	23	18	15	13	12	3/C-10AWG
24	21	19	17	11	10	8	7	3/C-12AWG
117	106	96	87	96	87	75	68	2/C-2AWG
67	60	55	49	47	42	35	33	2/C-6AWG
50	45	41	36	32	27	24	21	2/C-8AWG
38	33	30	27	21	18	15	14	2/C-10AWG
28	25	22	20	13	11	10	9	2/C-12AWG

Iamp =

ATTACHMENT B3

AMPACITY COMPARISON BETWEEN FREE AIR THERMOLAGGED CABLES AND CABLES IN THERMOLAGGED RACEWAYS

5/16" product thickness (3)

This templates compares the ampacity of thermolagged cables in free air with those of thermolagged raceway: maintained spaced tray, ransod filled tray, Thermolag 330-1 enclosed conduit (both box and shell design)

I. CABLE INPUT DATA

(2)

PRNPRECISION := 8

Iamp := READPRN(iamp)

N := READPRN(N) nn' := READPRN(NN)

The above files were produced by template Attachment B1 : N and nn'; Attachment B2: Iamp.

ORIGIN := 1 defines the upper corner of a matrix as 1,1

j := 1 ..8 i := 1 ..21

ATTACHMENT B3 'Ampacity Comparison Between Free Air Thermologged Cables and Cables in Thermologged Raceways'

Cable Ampacity of Wrapped Cable in Free Air

No. of Cables /				Conduit Size				
1	2	3	5	3"	4"	5"	6"	
369	348	316	289	369	369	369	348	1/C-500,8 KV
299	281	255	233	299	299	281	255	1/C-350,8 KV
223	209	190	173	223	223	209	172	1/C-4/0,8 KV
444	416	375	341	444	444	416	416	1/C-750,600 V
350	326	294	266	350	350	326	264	1/C-500
282	261	235	213	282	261	235	213	1/C-350
204	187	168	152	187	151	147	131	1/C-4/0
153	139	125	112	125	112	99	89	1/C-2/0
204	187	168	152	204	187	151	147	TRI-4/0
153	139	125	112	139	125	112	99	TRI-2/0
97	87	78	70	70	63	57	50	TRI-2AWG
75	68	61	55	61	53	47	41	3/C-4AWG
57	51	46	42	42	37	33	29	3/C-6AWG
42	38	34	31	28	24	20	18	3/C-8AWG
32	28	25	23	18	15	13	12	3/C-10AWG
24	21	19	17	11	10	8	7	3/C-12AWG
117	106	96	87	96	87	75	68	2/C-2AWG
67	60	55	49	47	42	35	33	2/C-6AWG
50	45	41	36	32	27	24	21	2/C-8AWG
38	33	30	27	21	18	15	14	2/C-10AWG
28	25	22	20	13	11	10	9	2/C-12AWG

Iamp =

Number of Cables in a Bundle

No. of Cables /				Conduit Size			
1	2	3	5	3	4"	5"	6"	
1	2	3	5	1	1	1	2	1/C-500,8 KV
1	2	3	5	1	1	2	3	1/C-350,8 KV
1	2	3	5	1	1	2	4	1/C-4/0,8 KV
1	2	3	5	1	1	2	2	1/C-750,600 V
1	2	3	5	1	1	2	4	1/C-500
1	2	3	5	1	2	3	5	1/C-350
1	2	3	5	2	4	6	9	1/C-4/0
1	2	3	5	3	5	8	12	1/C-2/0
1	2	3	5	1	2	4	6	TRI-4/0
1	2	3	5	2	3	5	8	TRI-2/0
1	2	3	5	4	7	11	16	TRI-2AWG
1	2	3	5	3	6	10	15	3/C-4AWG
1	2	3	5	4	8	13	19	3/C-6AWG
1	2	3	5	7	13	21	30	3/C-8AWG
1	2	3	5	11	20	32	46	3/C-10AWG
1	2	3	5	18	32	51	73	3/C-12AWG
1	2	3	5	3	5	9	13	2/C-2AWG
1	2	3	5	6	10	16	23	2/C-6AWG
1	2	3	5	8	15	23	34	2/C-8AWG
1	2	3	5	13	22	35	51	2/C-10AWG
1	2	3	5	20	36	56	81	2/C-12AWG

N =

Note: 1/C cable are bundled in groups of three. Therefore, if N=3 than the actual number of cables for 1/C is 3 x 3 = 9

Number of Conductors in a Bundle

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
3	6	9	15	3	3	3	6	1/C-500,8 KV
3	6	9	15	3	3	6	9	1/C-350,8 KV
3	6	9	15	3	3	6	12	1/C-4/0,8 KV
3	6	9	15	3	3	6	6	1/C-750,600 V
3	6	9	15	3	3	6	12	1/C-500
3	6	9	15	3	6	9	15	1/C-35
3	6	9	15	6	12	18	27	1/C-4/0
3	6	9	15	9	15	24	36	1/C-2/0
3	6	9	15	3	6	12	18	TRI-4/0
3	6	9	15	6	9	15	24	TRI-2/0
3	6	9	15	12	21	33	48	TRI-2AWG
3	6	9	15	9	18	30	45	3/C-4AWG
3	6	9	15	12	24	39	57	3/C-6AWG
3	6	9	15	21	39	63	90	3/C-8AWG
3	6	9	15	33	60	96	138	3/C-10AWG
3	6	9	15	54	96	153	219	3/C-12AWG
2	4	6	10	6	10	18	26	2/C-2AWG
2	4	6	10	12	20	32	46	2/C-6AWG
2	4	6	10	16	30	46	68	2/C-8AWG
2	4	6	10	26	44	70	102	2/C-10AWG
2	4	6	10	40	72	112	162	2/C-12AWG

nn' =

2

ATTACHMENT B3 "Ampacity Comparison Between Free Air Thermolagged Cables and Cables in Thermolagged Raceways"

Ampacities of Thermolagged Maintained Spaced Tray

Ampacity of thermolag covered 600 V cable with maintained spacing in a 50 C ambient see Reference 1 (DBD-EE-052) and Reference 18.

Development of Thermolagged Tray ampacities for 8 kV cable:

$$It := \begin{bmatrix} 515 \\ 386 \\ 265 \end{bmatrix}$$

1/C-500, 8KV
1/C-350, 8KV
1/C-4/0, 8KV

Values obtained from Reference 18, Table 33 where depth > diameter.

$IthMS8kv := 0.90 \cdot 0.69 \cdot It$ where: 0.90 is multiplier for correcting ambient temperature from 40 C to 50 C (Ref. 18, page i).
0.69 is thermolag derating factor (Ref. 1).

$$IthMS8kv = \begin{bmatrix} 319.8 \\ 239.7 \\ 164.6 \end{bmatrix}$$

$$IthMS := \begin{bmatrix} 320 \\ 240 \\ 165 \\ 391 \\ 270 \\ 199 \\ 148 \\ 100 \\ 148 \\ 100 \\ 50 \\ 999 \\ 999 \\ 999 \\ 999 \\ 999 \\ 69 \\ 999 \\ 999 \\ 999 \\ 999 \end{bmatrix}$$

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-2/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

These ampacities were input from: 8 Kv Cable - calculated results of IthMS8kv shown above; 600 V cables - from DBD-EE-052. A value of 999 is entered when no ampacities are appropriate because the cables would not be installed in maintained spaced trays

$$IIthMS_{i,j} := IthMS_{i}$$

$$AMPCHK_{i,j} := if\left[IIthMS_{i,j} < Iamp_{i,j}, 1, 0\right]$$

CHECK OF CABLE AMPACITY ADEQUACY
WITH MAINTAINED SPACING IN TRAY

Ampacity Comparison with MS Tray

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
1	1	0	0	1	1	1	1	1/C-500,8 KV
1	1	1	0	1	1	1	1	1/C-350,8 KV
1	1	1	1	1	1	1	1	1/C-4/0,8 KV
1	1	0	0	1	1	1	1	1/C-750,600 V
1	1	1	0	1	1	1	0	1/C-500
1	1	1	1	1	1	1	1	1/C-350
1	1	1	1	1	1	0	0	1/C-4/0
1	1	1	1	1	1	0	0	1/C-2/0
1	1	1	1	1	1	1	0	TRI-4/0
1	1	1	1	1	1	1	0	TRI-2/0
1	1	1	1	1	1	1	1	TRI-2AWG
0	0	0	0	0	0	0	0	3/C-4AWG
0	0	0	0	0	0	0	0	3/C-6AWG
0	0	0	0	0	0	0	0	3/C-8AWG
0	0	0	0	0	0	0	0	3/C-10AWG
0	0	0	0	0	0	0	0	3/C-12AWG
1	1	1	1	1	1	1	0	2/C-2AWG
0	0	0	0	0	0	0	0	2/C-6AWG
0	0	0	0	0	0	0	0	2/C-8AWG
0	0	0	0	0	0	0	0	2/C-10AWG
0	0	0	0	0	0	0	0	2/C-12AWG

AMPCHK =

NOTE:
1 - Adequate cable ampacity
0 - Inadequate cable ampacity

$$CaLimit_{i,j} := if\left[AMPCHK_{i,j} \approx 1, \left[N_{i,j}\right], 0\right]$$

$$CaLimit_{i,j} := if\left[Iamp_{i,j} \approx 999, 0, CaLimit_{i,j}\right]$$

ATTACHMENT B3 "Ampacity Comparison Between Free Air Thermolagged Cables and Cables in Thermolagged Raceways"

Limit of Number of Cable in Bundle:
Not to Exceed Ampacity of Cable in
MS Thermolagged Tray

CaLimit =

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
1	2	0	0	1	1	1	2	1/C-500,8 KV
1	2	3	0	1	1	2	3	1/C-350,8 KV
1	2	3	5	1	1	2	4	1/C-4/0,8 KV
1	2	0	0	1	1	2	2	1/C-750,600 V
1	2	3	0	1	1	2	0	1/C-500
1	2	3	5	1	2	3	5	1/C-350
1	2	3	5	2	4	0	0	1/C-4/0
1	2	3	5	3	5	0	0	1/C-2/0
1	2	3	5	1	2	4	0	TRI-4/0
1	2	3	5	2	3	5	0	TRI-2/0
1	2	3	5	4	7	11	16	TRI-2AWG
0	0	0	0	0	0	0	0	3/C-4AWG
0	0	0	0	0	0	0	0	3/C-6AWG
0	0	0	0	0	0	0	0	3/C-8AWG
0	0	0	0	0	0	0	0	3/C-10AWG
0	0	0	0	0	0	0	0	3/C-12AWG
1	2	3	5	3	5	9	0	2/C-2AWG
0	0	0	0	0	0	0	0	2/C-6AWG
0	0	0	0	0	0	0	0	2/C-8AWG
0	0	0	0	0	0	0	0	2/C-10AWG
0	0	0	0	0	0	0	0	2/C-12AWG

The limit to the number of cables under a wrap, use maximum number in a given row. Three 1/C cables are considered as one (1) 3/C cable.

ATTACHMENT B3 'Ampacity Comparison Between Free Air Thermolagged Cables and Cables in Thermolagged Raceways'

Ampacities of Thermolagged Random Lay Tray

		Ampacity of thermolag covered cable with random lay (no maintained spacing), see Reference 1 (DBD-EE-052)
IthRS :=	999	1/C-500,8 KV
	999	1/C-350.8 KV
	999	1/C-4/0,8 KV
	420	1/C-750,600 V
	290	1/C-500
	215	1/C-350
	130	1/C-4/0
	88	1/C-2/0
	157	TRI-4/0
	106	TRI-2/0
	54	TRI-2AWG
	44	3/C-4AWG
	32	3/C-6AWG
	20	3/C-8AWG
	12	3/C-10AWG
	8	3/C-12AWG
	75	2/C-2AWG
	36	2/C-6AWG
	24	2/C-8AWG
	15	2/C-10AWG
	9	2/C-12AWG

$$IIthRS_{i,j} := IthRS_{i}$$

$$AMPCHK_{i,j} := if\left[IIthRS_{i,j} < Iamp_{i,j}, 1, 0\right]$$

Ampacity Comparison with Random TH-Tray

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
0	0	0	0	0	0	0	0	1/C-500,8 KV
0	0	0	0	0	0	0	0	1/C-350,8 KV
0	0	0	0	0	0	0	0	1/C-4/0,8 KV
1	0	0	0	1	1	0	0	1/C-750,600 V
1	1	1	0	1	1	1	0	1/C-500
1	1	1	0	1	1	1	0	1/C-350
1	1	1	1	1	1	1	1	1/C-4/0
1	1	1	1	1	1	1	1	1/C-2/0
1	1	1	0	1	1	0	0	TRI-4/0
1	1	1	1	1	1	1	0	TRI-2/0
1	1	1	1	1	1	1	0	TRI-2AWG
1	1	1	1	1	1	1	0	3/C-4AWG
1	1	1	1	1	1	1	0	3/C-6AWG
1	1	1	1	1	1	1	0	3/C-8AWG
1	1	1	1	1	1	1	0	3/C-10AWG
1	1	1	1	1	1	1	0	3/C-12AWG
1	1	1	1	1	1	1	0	2/C-2AWG
1	1	1	1	1	1	0	0	2/C-4AWG
1	1	1	1	1	1	1	0	2/C-8AWG
1	1	1	1	1	1	1	0	2/C-10AWG
1	1	1	1	1	1	1	0	2/C-12AWG

AMPCHK =

NOTE:
1 - Adequate cable ampacity
0 - Inadequate cable ampacity

$$CaLimit_{i,j} := if\left[AMPCHK_{i,j} \approx 1, \left[\left[N_{i,j}\right]\right], 0\right]$$

$$CaLimit_{i,j} := if\left[Iamp_{i,j} \approx 999, 0, CaLimit_{i,j}\right]$$

Limit of Number of Cable in Bundle:
Not to Exceed Ampacity of Cable in
Random Lay Thermolagged Tray

CaLimit =

No. of Cables / Conduit Size 1	2	3	5	3	4"	5"	6"	
0	0	0	0	0	0	0	0	1/C-500,8 KV
0	0	0	0	0	0	0	0	1/C-350,8 KV
0	0	0	0	0	0	0	0	1/C-4/0,8 KV
1	0	0	0	1	1	0	0	1/C-750,600 V
1	2	3	0	1	1	2	0	1/C-500
1	2	3	0	1	2	3	0	1/C-350
1	2	3	5	2	4	6	9	1/C-4/0
1	2	3	5	3	5	8	12	1/C-2/0
1	2	3	0	1	2	0	0	TRI-4/0
1	2	3	5	2	3	5	0	TRI-2/0
1	2	3	5	4	7	11	0	TRI-2AWG
1	2	3	5	3	6	10	0	3/C-4AWG
1	2	3	5	4	8	13	0	3/C-6AWG
1	2	3	5	7	13	21	0	3/C-8AWG
1	2	3	5	11	20	32	0	3/C-10AWG
1	2	3	5	18	32	51	0	3/C-12AWG
1	2	3	5	3	5	9	0	2/C-2AWG
1	2	3	5	6	10	0	0	2/C-6AWG
1	2	3	5	8	15	23	0	2/C-8AWG
1	2	3	5	13	22	35	0	2/C-10AWG
1	2	3	5	20	36	56	0	2/C-12AWG

The limit to the number of cables under a wrap, use maximum number in a given row. Three 1/C cables are considered as one (1) 3/C cable.

ATTACHMENT B3 'Ampacity Comparison Between Free Air Thermolagged Cables and Cables in Thermolagged Raceways'

Ampacities of Cable in Thermolagged Conduit(Box Design)

Reference 1 (DBD-EE-052)
ampacity for three conductors in conduit, enclosed in Thermolag 330-660, Box Design

$$IthCD := \begin{bmatrix} 338 \\ 277 \\ 205 \\ 428 \\ 341 \\ 275 \\ 190 \\ 146 \\ 199 \\ 146 \\ 93 \\ 65 \\ 49 \\ 37 \\ 26 \\ 20 \\ 88 \\ 49 \\ 37 \\ 26 \\ 20 \end{bmatrix}$$

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-3/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

The following equations produce multipying factors for multiple cables in a conduit

$$CDamp_{i,j} := 0$$

$$CDamp_{i,j} := if\left[nn'_{i,j} < 3.01, 1, CDamp_{i,j}\right]$$

$$CDamp_{i,j} := if\left[nn'_{i,j} > 3.01, 0.8, CDamp_{i,j}\right]$$

$$CDamp_{i,j} := if\left[nn'_{i,j} > 6.01, 0.7, CDamp_{i,j}\right]$$

$$CDamp_{i,j} := if\left[nn'_{i,j} > 24.01, 0.6, CDamp_{i,j}\right]$$

$$CDamp_{i,j} := if\left[nn'_{i,j} > 42.1, 0.5, CDamp_{i,j}\right]$$

Conduit Ampacity Multiplying Factors
For More than 3 conductors in a Conduit

$CDamp =$

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
1	0.8	0.7	0.7	1	1	1	0.8	1/C-500,8 KV
1	0.8	0.7	0.7	1	1	0.8	0.7	1/C-350,8 KV
1	0.8	0.7	0.7	1	1	0.8	0.7	1/C-4/0,8 KV
1	0.8	0.7	0.7	1	1	0.8	0.8	1/C-750,600 V
1	0.8	0.7	0.7	1	1	0.8	0.7	1/C-500
1	0.8	0.7	0.7	1	0.8	0.7	0.7	1/C-350
1	0.8	0.7	0.7	0.8	0.7	0.7	0.6	1/C-4/0
1	0.8	0.7	0.7	0.7	0.7	0.7	0.6	1/C-2/0
1	0.8	0.7	0.7	1	0.8	0.7	0.7	TRI-4/0
1	0.8	0.7	0.7	0.8	0.7	0.7	0.7	TRI-2/0
1	0.8	0.7	0.7	0.7	0.7	0.6	0.5	TRI-2AWG
1	0.8	0.7	0.7	0.7	0.7	0.6	0.5	3/C-4AWG
1	0.8	0.7	0.7	0.7	0.7	0.6	0.5	3/C-6AWG
1	0.8	0.7	0.7	0.7	0.6	0.5	0.5	3/C-8AWG
1	0.8	0.7	0.7	0.6	0.5	0.5	0.5	3/C-10AWG
1	0.8	0.7	0.7	0.5	0.5	0.5	0.5	3/C-12AWG
1	0.8	0.8	0.7	0.8	0.7	0.7	0.6	2/C-2AWG
1	0.8	0.8	0.7	0.7	0.7	0.6	0.5	2/C-6AWG
1	0.8	0.8	0.7	0.7	0.6	0.5	0.5	2/C-8AWG
1	0.8	0.8	0.7	0.6	0.5	0.5	0.5	2/C-10AWG
1	0.8	0.8	0.7	0.6	0.5	0.5	0.5	2/C-12AWG

NEC multi-plying factor for multiple conductors in conduit

ATTACHMENT B3 'Ampacity Comparison Between Free Air Thermolagged Cables and Cables in Thermolagged Raceways'

$$IIthCD_{i,j} := CDamp_{i,j} \cdot IthCD_{i}$$

Thermolagged Ampacities in Conduit(Box Design)

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
338	270	237	237	338	338	338	270	1/C-500,8 KV
277	222	194	194	277	277	222	194	1/C-350,8 KV
205	164	144	144	205	205	164	144	1/C-4/0,8 KV
428	342	300	300	428	428	342	342	1/C-750,600 V
341	273	239	239	341	341	273	239	1/C-500
275	220	193	193	275	220	193	193	1/C-350
199	159	139	139	159	139	139	119	1/C-4/0
146	117	102	102	102	102	103	88	1/C-2/0
199	159	139	139	199	159	139	139	TRI-4/0
146	117	102	102	117	102	102	102	TRI-2/0
93	74	65	65	65	65	56	47	TRI-2AWG
65	52	46	46	46	46	39	33	3/C-4AWG
49	39	34	34	34	34	29	25	3/C-6AWG
37	30	26	26	26	22	19	19	3/C-8AWG
26	21	18	18	16	13	13	13	3/C-10AWG
20	16	14	14	10	10	10	10	3/C-12AWG
88	70	70	62	70	62	62	53	2/C-2AWG
49	39	39	34	34	34	29	25	2/C-6AWG
37	30	30	26	26	22	19	19	2/C-8AWG
26	21	21	18	16	13	13	13	2/C-10AWG
20	16	16	14	12	10	10	10	2/C-12AWG

$IIthCD =$

$$AMPCHK_{i,j} := if\left[IIthCD_{i,j} < Iamp_{i,j}, 1, 0\right]$$

Ampacity Comparison equation

Ampacity Comparison with Thermolagged Conduit (Box Design)

AMPCHK =

No. of Cables / Conduit Size 1	2	3	5	3	4"	5"	6"	
1	1	1	1	1	1	1	1	1/C-500,8 KV
1	1	1	1	1	1	1	1	1/C-350,8 KV
1	1	1	1	1	1	1	1	1/C-4/0,8 KV
1	1	1	1	1	1	1	1	1/C-750,600 V
1	1	1	1	1	1	1	1	1/C-500
1	1	1	1	1	1	1	1	1/C-350
1	1	1	1	1	1	1	1	1/C-4/0
1	1	1	1	1	1	0	1	1/C-2/0
1	1	1	1	1	1	1	1	TRI-4/0
1	1	1	1	1	1	1	0	TRI-2/0
1	1	1	1	1	0	1	1	TRI-2AWG
1	1	1	1	1	1	1	1	3/C-4AWG
1	1	1	1	1	1	1	1	3/C-6AWG
1	1	1	1	1	1	1	0	3/C-8AWG
1	1	1	1	1	1	1	0	3/C-10AWG
1	1	1	1	1	0	0	0	3/C-12AWG
1	1	1	1	1	1	1	1	2/C-2AWG
1	1	1	1	1	1	1	1	2/C-6AWG
1	1	1	1	1	1	1	1	2/C-8AWG
1	1	1	1	1	1	1	1	2/C-10AWG
1	1	1	1	1	1	0	0	2/C-12AWG

NOTE:
1 - Adequate cable ampacity
0 - Inadequate cable ampacity

$$CaLimit_{i,j} := if\left[AMPCHK_{i,j} \approx 1, \left[N_{i,j}\right], 0\right]$$

$$CaLimit_{i,j} := if\left[Iamp_{i,j} \approx 999, 0, CaLimit_{i,j}\right]$$

ATTACHMENT B3 'Ampacity Comparison Between Free Air Thermolagged Cables and Cables in Thermolagged Raceways'

Limit of Number of Cable in Bundle:
Not to Exceed Ampacity of Cable in
Thermolagged Conduit (Box Design)

CaLimit =

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
1	2	3	5	1	1	1	2	1/C-500,8 KV
1	2	3	5	1	1	2	3	1/C-350,8 KV
1	2	3	5	1	1	2	4	1/C-4/0,8 KV
1	2	3	5	1	1	2	2	1/C-750,600 V
1	2	3	5	1	1	2	4	1/C-500
1	2	3	5	1	2	3	5	1/C-350
1	2	3	5	2	4	6	9	1/C-4/0
1	2	3	5	3	5	0	12	1/C-2/0
1	2	3	5	1	2	4	6	TRI-4/0
1	2	3	5	2	3	5	0	TRI-2/0
1	2	3	5	4	0	11	16	TRI-2AWG
1	2	3	5	3	6	10	15	3/C-4AWG
1	2	3	5	4	8	13	19	3/C-6AWG
1	2	3	5	7	13	21	0	3/C-8AWG
1	2	3	5	11	20	32	0	3/C-10AWG
1	2	3	5	18	0	0	0	3/C-12AWG
1	2	3	5	3	5	9	13	2/C-2AWG
1	2	3	5	6	10	16	23	2/C-6AWG
1	2	3	5	8	15	23	34	2/C-8AWG
1	2	3	5	13	22	35	51	2/C-10AWG
1	2	3	5	20	36	0	0	2/C-12AWG

The limit to the number of cables under a wrap, use maximum number in a given row. Three 1/C cables are considered as one (1) 3/C cable.

Ampacities of Cable in Themolagged Conduit (Shell Design)

$$IIthCDshell := \frac{0.925}{0.8} \cdot IIthCD$$

Reference 1 (DRD-ZE-052, Rev 3 page 22, Section 4.1.2.6 g.) provides relative factors for shell vs box design.

Thermolagged Ampacities in Conduit (Shell Design)

No. of Cables				Conduit Size				
1	2	3	5	3"	4"	5"	6"	
391	313	274	274	391	391	391	313	1/C-500,8 KV
320	256	224	224	320	320	256	224	1/C-350,8 KV
237	190	166	166	237	237	190	166	1/C-4/0,8 KV
495	396	346	346	495	495	396	396	1/C-750,600 V
394	315	276	276	394	394	315	276	1/C-500
318	254	223	223	318	254	223	223	1/C-350
230	184	161	161	184	161	161	138	1/C-4/0
169	135	118	118	118	118	118	101	1/C-2/0
230	184	161	161	230	184	161	161	TRI-4/0
169	135	118	118	135	118	118	118	TRI-2/0
108	86	75	75	75	75	65	54	TRI-2AWG
75	60	53	53	53	53	45	38	3/C-4AWG
57	45	40	40	40	40	34	28	3/C-6AWG
43	34	30	30	30	26	21	21	3/C-8AWG
30	24	21	21	15	15	15	15	3/C-10AWG
23	19	16	16	12	12	12	12	3/C-12AWG
102	81	81	71	81	71	71	61	2/C-2AWG
57	45	45	40	40	40	34	28	2/C-6AWG
43	34	34	30	30	26	21	21	2/C-8AWG
30	24	24	21	18	15	15	15	2/C-10AWG
23	19	19	16	14	12	12	12	2/C-12AWG

$$IIthCDshell = \begin{bmatrix} 391 & 313 & 274 & 274 & 391 & 391 & 391 & 313 \\ 320 & 256 & 224 & 224 & 320 & 320 & 256 & 224 \\ 237 & 190 & 166 & 166 & 237 & 237 & 190 & 166 \\ 495 & 396 & 346 & 346 & 495 & 495 & 396 & 396 \\ 394 & 315 & 276 & 276 & 394 & 394 & 315 & 276 \\ 318 & 254 & 223 & 223 & 318 & 254 & 223 & 223 \\ 230 & 184 & 161 & 161 & 184 & 161 & 161 & 138 \\ 169 & 135 & 118 & 118 & 118 & 118 & 118 & 101 \\ 230 & 184 & 161 & 161 & 230 & 184 & 161 & 161 \\ 169 & 135 & 118 & 118 & 135 & 118 & 118 & 118 \\ 108 & 86 & 75 & 75 & 75 & 75 & 65 & 54 \\ 75 & 60 & 53 & 53 & 53 & 53 & 45 & 38 \\ 57 & 45 & 40 & 40 & 40 & 40 & 34 & 28 \\ 43 & 34 & 30 & 30 & 30 & 26 & 21 & 21 \\ 30 & 24 & 21 & 21 & 15 & 15 & 15 & 15 \\ 23 & 19 & 16 & 16 & 12 & 12 & 12 & 12 \\ 102 & 81 & 81 & 71 & 81 & 71 & 71 & 61 \\ 57 & 45 & 45 & 40 & 40 & 40 & 34 & 28 \\ 43 & 34 & 34 & 30 & 30 & 26 & 21 & 21 \\ 30 & 24 & 24 & 21 & 18 & 15 & 15 & 15 \\ 23 & 19 & 19 & 16 & 14 & 12 & 12 & 12 \end{bmatrix}$$

ATTACHMENT B3 'Ampacity Comparison Between Free Air Thermolagged Cables and Cables in Thermolagged Raceways'

$$AMPCHK_{i,j} := if\left[IIthCDshell_{i,j} < Iamp_{i,j}, 1, 0\right]$$

Ampacity Comparison with Thermolagged Conduit (Shell Design)

No. of Cables / Conduit				Conduit Size				
1	2	3	5	3	4"	5"	5"	
0	1	1	1	0	0	0	1	1/C-500,8 KV
0	1	1	1	0	0	1	1	1/C-350,8 KV
0	1	1	1	0	0	1	1	1/C-4/0,8 KV
0	1	1	0	0	0	1	1	1/C-750,600 V
0	1	1	0	0	0	1	0	1/C-500
0	1	1	0	0	1	1	0	1/C-350
0	1	1	0	1	0	0	0	1/C-4/0
0	1	1	0	1	0	0	0	1/C-2/0
0	1	1	0	0	1	0	0	TRI-4/0
0	1	1	0	1	1	0	0	TRI-2/0
0	1	1	0	0	0	0	0	TRI-2AWG
0	1	1	1	1	1	1	1	3/C-4AWG
1	1	1	1	1	0	0	1	3/C-6AWG
0	1	1	1	0	0	0	0	3/C-8AWG
1	1	1	1	1	1	0	0	3/C-10AWG
1	1	1	1	0	0	0	0	3/C-12AWG
1	1	1	1	1	1	1	1	2/C-2AWG
1	1	1	1	1	1	1	1	2/C-6AWG
1	1	1	1	1	1	1	0	2/C-8AWG
1	1	1	1	1	1	1	0	2/C-10AWG
1	1	1	1	0	0	0	0	2/C-12AWG

$AMPCHK =$

NOTE:
1 = Adequate cable ampacity
0 = Inadequate cable ampacity

$$CaLimit_{i,j} := if\left[AMPCHK_{i,j} \approx 1, \left[N_{i,j}\right], 0\right]$$

$$CaLimit_{i,j} := if\left[Iamp_{i,j} \approx 999, 0, CaLimit_{i,j}\right]$$

ATTACHMENT B3 "Ampacity Comparison Between Free Air Thermolagged Cables and Cables in Thermolagged Raceways"

Limit of Number of Cable in Bundle:
Not to Exceed Ampacity of Cable in
Thermolagged Conduit (Shell Design)

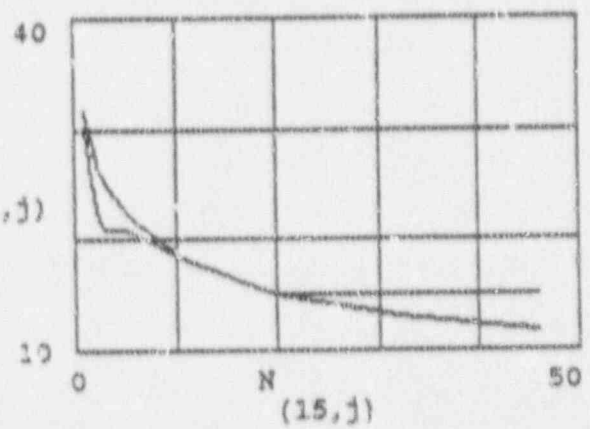
CaLimit =

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
0	2	3	5	0	0	0	2	1/C-500,8 KV
0	2	3	5	0	0	2	3	1/C-350,8 KV
0	2	3	5	0	0	2	4	1/C-4/0,8 KV
0	2	3	0	0	0	2	2	1/C-750,600 V
0	2	3	0	0	0	2	0	1/C-500
0	2	3	0	0	2	3	0	1/C-350
0	2	3	0	2	0	0	0	1/C-4/0
0	2	3	0	3	0	0	0	1/C-2/0
0	2	3	0	0	2	0	0	TRI-4/0
0	2	3	0	2	3	0	0	TRI-2/0
0	2	3	0	0	0	0	0	TRI-2AWG
0	2	3	5	3	6	10	15	3/C-4AWG
1	2	3	5	4	0	0	19	3/C-6AWG
0	2	3	5	0	0	0	0	3/C-8AWG
1	2	3	5	11	20	0	0	3/C-10AWG
1	2	3	5	0	0	0	0	3/C-12AWG
1	2	3	5	3	5	9	13	3/C-2AWG
1	2	3	5	6	10	16	23	2/C-6AWG
1	2	3	5	8	15	23	0	2/C-8AWG
1	2	3	5	13	22	35	0	2/C-10AWG
1	2	3	5	0	0	0	0	2/C-12AWG

The limit to the number of cables under a wrap, use maximum number in a given row. Three 1/C cables are considered as one (1) 3/C cable.

A

IIthCDshell$_{(15,j)}$, Iamp$_{(15,j)}$



2

ATTACHMENT C

CABLE BUNDLE MULTIPLYING FACTORS

The relationship between the bundle diameter and cable diameter of individual cable is shown in matrix NNFF1, NNFF2, NNFF3, and NNFF4. These are taken from Reference 2 (Brand-Rex Publication WC-82, Table 34).

2

NNFF1 :=

No.	
1	1
2	2
3	2.15
4	2.14
5	2.7
6	3
7	3
8	3.31
9	3.62
10	4
11	4
12	4.15
13	4.41
14	4.41
15	4.7
16	4.7
17	5
18	5
19	5
20	5.31
21	5.31
22	5.62
23	6
24	6
25	6

NNFF2 :=

No.	F
26	6
27	6.15
28	6.41
29	6.41
30	6.41
31	6.7
32	6.7
33	6.7
34	7
35	7
36	7
37	7
38	7.31
39	7.31
40	7.31
41	7.62
42	7.62
43	7.62
44	8
45	8
46	8
47	8
48	8.15
49	8.15
50	8.41

NNFF3 :=

No.	F
51	8.41
52	8.41
53	8.7
54	8.7
55	8.7
56	8.7
57	9
58	9
59	9
60	9
61	9
62	9.31
63	9.31
64	9.31
65	9.31
66	9.62
67	9.62
68	9.62
69	9.62
70	10
71	10
72	10
73	10
74	10
75	10.2

NNFF4 :=

No.	F
76	10.2
77	10.2
78	10.41
79	10.41
80	10.41
81	10.41
82	10.41
83	10.7
84	10.7
85	10.7

2

ORIGIN ≡ 1 i := 1 ..25 j := 1 ..10 m := 1 ..2

NNFF := NNFF1 NNFF$_{(25+i),m}$:= NNFF2$_{i,m}$

NNFF$_{(50+i),m}$:= NNFF3$_{i,m}$

NNFF$_{(75+j),m}$:= NNFF4$_{j,m}$

WRITEPRN(NNFF) := NNFF This stores this matrix in an ASCII file for input to template Appendix B1

"THERMO-LAG 330-660 EMISSIVITY AND THERMAL CONDUCTIVITY" A1

14 March 1989

TU Electric
P.O. Box 1001
Glen Rose, Texas 76043

Attention: Mr. Max Jones

Subject: THERMO-LAG 330-660 Flexi Blanket

Dear Mr. Jones:

The following is in followup to my letter of March 9, 1989, at the request of Mr. Tim Wright.

The THERMO-LAG 330-660 Flexi Blanket typically exhibits the following properties:

Surface Emissivity	0.89
Thermal Conductivity	2.49×10^{-1} BTU/Ft/Hr/F°

If you have any questions, please do not hesitate to contact me.

Yours truly,

R.A. Lohman
Assistant to the President

RAL/sas

ACCEPTABLE MARGINAL QUALITY
INIT AVE DATE 10/2/92

THERMAL SCIENCE, INC. • 2200 CASSENS DR. • ST. LOUIS, MO 63026 • (314) 349-1233
Telex Domestic 44-2384 • Overseas 209901 • Telecopier (314) 349-1207

CNAC NO. 16345-EE(B)-140
"THERMOLOG 330-660 EMISSIVITY AND THERMAL CONDUCTIVITY" (B)

330-660 -- 21 layer, thickness of each layer 1/4"

ACCEPTABLE MARGINAL QUALITY
INIT JVH DATE 10/2/92

Specific Ceramic Materials	Material Thickness		Longitudinal Overlaps		Lateral Overlaps		Joint Types	Fastener Types	Fastener Spacing	W.H. Bolt Spacing		Insulating Blanket Coverage		RES Blanket Length	Ceramic to Bearing Cut Edge (RES)		RES Bending Compression	RES Ultimate Bending Compression	RES Local Compression
	Min	Max	Min	Max	Min	Max			Row 5 & 8	Min	Max	Min	Max	Max	Min	Max	Max	Max	Max
Thermo-Log 330-1 Perforated Sections and Panels	0.5"	0.75"	NA	NA	NA	NA	Butt	Hi Temp Rivets and 0.5" x 0.05" SS Bands	12"	①	12"	9"	11"	NA	NA	NA	NA	NA	NA
Thermo-Log 330-660 External (Fire side) Layer	0.1875"	0.3125"	2" ④	4" ⑤	2" ⑥	NA	Butt	0.5" x 0.05" SS Bands	6"	①	12"	9"	11"	NA	NA	NA	NA	NA	NA
Thermo-Log 330-660 Internal (non-fire side) Layer	0.1875"	0.3125"	2"	4"	NA	NA	Butt	0.5" x 0.05" SS Bands	6"	①	12"	9"	11"	NA	NA	NA	NA	NA	NA
Reusable Energy Shield (RES) "Nomex" Blanket	1.25"	1.75"	2"	4"	2"	4"	Overlap and Non-Lateral and Longitudinal	0.5" x 0.05" SS Bands	3"	②	9"	2"	4"	0.5"	1"	0.75"	0.75"	1.5"	1"

Notes: ① Minimum W.H. bolt spacing shall be per 2323-33-30

② Bolt distance from bolted edge per 2323-115-388

③ Bolt distance from bolted edge per 2323-116-388

④ External longitudinal overlap shall be 180° opposite the inter longitudinal crossing

⑤ Minimum blanket seam overlap at internal blanket seam

A 5010 88

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE
16345	EE(B)	190, Rev 2	XXX	1 OF 19

ATTACHMENT E

MANUAL CONFIRMATION OF CALCULATION, REV. 2, BY REVIEWER

THIS ATTACHMENT PROVIDES A MANUAL CHECK OF THE MATHCAD TEMPLATES USED IN THE PREPARATION OF THE MAIN BODY OF THE CALCULATION. THIS ATTACHMENT USES THE IDENTICAL ALGORITHMS USED IN THE MAIN BODY OF THE CALCULATION. SOURCE INPUT DATA IS USED RATHER THAN THAT TAKEN FROM THE PRESENTATION FORMAT. IN THIS MANNER, "ROUND-OFF" ERRORS ARE AVOIDED.

TO PROVIDE CONSISTANCY WITH THE MANUAL CHECK OF THE PREVIOUS ISSUE OF THIS CALCULATION, THE SAME CABLES ARE CHOSEN FOR ANALYSIS. THEY ARE;

1. 1/C - 4/0 AWG, 8KV
2. 3/C - 6 AWG, 600V
3. 2/C - 10 AWG, 600V

ALL CALCULATIONS CONSIDER 6" CONDUIT.

THE FOLLOWING SOURCE DATA IS IDENTIFIED FOR THE ABOVE CABLES:

	CABLE TYPE		
	1/C - 4/0, 8KV	3/C - 6AWG	2/C - 10 AWG
ATTRIBUTE	CASE 1	CASE 2	CASE 3
$R_{dc\ 25}$	0.0525×10^{-3}	0.427×10^{-3}	1.090×10^{-3}
Y_c	0.01	0	0
D_c	0.528	0.184	0.116
A_c	107.2	13.3	5.26
n'	1	3	2
I_t	280×10^{-3}	75×10^{-3}	45×10^{-3}
J_t	0	80	60
p_{is}	500	500	500
p_j	500	500	500

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

A 5010 66

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE
16345	EE(B)	140, REV 2	XXX	2 OF 19

ATTACH E

CABLE DIAMETERS:

CASE 1: Diam 1 $= 0.528 + 2\times(25+140+25+10+10)\times10^{-3}$
$= 0.528 + 0.560$
$= 1.088$ in ✓

CASE 2: Diam 2 $= 2\times80\times10^{-3} + 2.15\times(0.184 + 2\times(45+30)\times10^{-3})$
$= 0.160 + 2.15\times0.334$
$= 0.160 + 0.7181$
$= 0.8781$ in ✓

CASE 3: Diam 3 $= 2\times(0.116 + 2\times(30+15)\times10^{-3} + 60\times10^{-3})$
$= 2\times(0.116 + 0.090 + 0.060)$
$= 2\times0.266$
$= 0.532$ in ✓

NOTE: FOR CASE 1, 3 CONDUCTORS HAVE A DIAMETER OF $2.15\times1.088 = 2.3392$

CALCULATE THE MAXIMUM NUMBER OF CABLE IN A 6" CONDUIT

CASE 1: $N_{MAX} = INT\left(\frac{0.4\times28.89}{\left(\frac{\pi\times(1.088)^2}{4}\right)}\right)$

$= INT\left(\frac{46.224}{3.7189}\right)$

$= INT\ (12.42)$

$= 12$

NOTE: SINCE ONE CONDUCTOR CABLES ARE CONSIDERED IN GROUPS OF THREE, THE NUMBER OF "GROUPS OF THREE" IS:

$\frac{12}{3} = 4$

ATTACH E

CASE 2: $N_{MAX} = INT\left(\frac{0.4 \times 28.89}{\left(\frac{\pi \times (0.8781)^2}{4}\right)}\right)$

$= INT\left(\frac{46.224}{2.4229}\right)$

$= INT(19.082)$

$= 19$

CASE 3: $N_{MAX} = INT\left(\frac{0.4 \times 28.89}{\left(\frac{\pi \times (0.532)^2}{4}\right)}\right)$

$= INT\left(\frac{46.224}{0.8891}\right)$

$= INT(51.987)$

$= 51$

BUNDLE DIAMETER FACTORS:

CASE 1:	4	CONDUCTORS (12÷3)	→ 2.14
CASE 2:	19	CONDUCTORS	→ 5
CASE 3:	51	CONDUCTORS	→ 8.41

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 4
16395	EE(B)	140, REV 2	XXX	OF 14

ATTACH E

CALCULATE DIVERSITY:

CASE 1: 12 CONDUCTORS (4 GROUPS OF 3 CONDUCTORS)

SINCE ANY SINGLE GROUP OF THREE CONDUCTORS WILL BE CARRYING THE SAME CURRENT (3 PHASE SYSTEM), CONSIDER 4 CONDUCTORS WHEN CALCULATING DIVERSITY, THEREFORE:

DIVERSITY = 0.82 × 12
= 9.84 CONDUCTORS @ 1.25 × FLA

CASE 2: 57 CONDUCTORS (19 GROUPS OF 3 CONDUCTORS)

DIVERSITY = 0.743 × 19 × 3
= 42.351 CONDUCTORS @ 1.25 × FLA

CASE 3: 104 CONDUCTORS (51 GROUPS OF 2 CONDUCTORS)

DIVERSITY = 0.743 × 51 × 2
= 75.786 CONDUCTORS @ 1.25 × FLA

CALCULATE BUNDLE DIAMETER:

CASE 1: DIAM = 2.14 × 2.3392
(cc) = 5.006

CASE 2: DIAM = 5 × 0.8781
(cc) = 4.3905

CASE 3: DIAM = 8.41 × 0.532
(cc) = 4.471

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

A 5010 05

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE
16345	EE(B)	140, REV. 2	XXX	5 / 14

ATTACH E

CALCULATE THERMAL RESISTANCE OF JACKET

CASE 1: THIS CABLE CONFIGURATION HAS NO JACKET, THEREFORE:

$R_j = 0$

CASE 2: $R_j = 0.012 \times 3 \times 500 \times \log\left(\frac{0.8781}{0.8781 - 2 \times 0.080}\right)$

$= 0.012 \times 3 \times 500 \times 8.7359$

$= 1.5725$

CASE 3: $R_j = 0.012 \times 2 \times 500 \times \log\left(\frac{0.532}{0.532 - 2 \times 0.060}\right)$

$= 0.012 \times 2 \times 500 \times 0.1110$

$= 1.3322$

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

A 5010 86

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 16345	DIVISION & GROUP EE (B)	CALCULATION NO. 140, REV 2	OPTIONAL TASK CODE XXX	PAGE 6 OF 19

ATTACH E

CALCULATE THERMAL RESISTANCE OF INSULATION

CASE 1: $R_i = 0.012 \times 500 \times \log\left(\frac{1.08F}{0.528}\right)$

$= 0.012 \times 500 \times 0.31399$

$= 1.8839$

CASE 2: $R_i = 0.012 \times 500 \times \log\left(\frac{0.184 + 2 \times (45+30) \times 10^{-3}}{0.184}\right)$

$= 0.012 \times 500 \times 0.25893$

$= 1.5536$

CASE 3: $R_i = 0.012 \times 500 \times \log\left(\frac{0.116 + 2 \times (30+15) \times 10^{-3}}{0.116}\right)$

$= 0.012 \times 500 \times 0.24941$

$= 1.49646$

CALCULATE THERMAL RESISTANCE BETWEEN CABLE AND THERMOLAG 330-660

$A' = 4.5$

$B' = 0.27$

CASE 1: $R_{sl} = 9.84 \times \frac{4.5}{5.01 + 0.27}$

$= 8.3864$

CASE 2: $R_{sl} = 42.35 \times \frac{4.5}{4.39 + 0.27}$

$= 40.8953$

CASE 3: $R_{sl} = 75.79 \times \frac{4.5}{4.47 + 0.27}$

$= 71.9525$

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

A 5010 85

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE
16345	EE (B)	140, Rev. 2	XXX	7 OF 14

ATTACH E

CALCULATE THERMAL RESISTANCE OF 330-660 WRAP

CASE 1: $R_w = 0.012 \times 9.84 \times 232.01 \times \log\left(\frac{5.01 + 2 \times 1.249}{5.01}\right)$

$= 0.012 \times 9.84 \times 232.01 \times 0.17567$

$= 4.8131$

CASE 2: $R_w = 0.012 \times 42.35 \times 232.01 \times \log\left(\frac{4.39 + 2 \times 1.249}{4.39}\right)$

$= 0.012 \times 42.35 \times 232.01 \times 0.19563$

$= 23.0661$

CASE 3: $R_w = 0.012 \times 75.79 \times 232.01 \times \log\left(\frac{4.47 + 2 \times 1.249}{4.47}\right)$

$= 0.012 \times 75.79 \times 232.01 \times 0.19280$

$= 40.6826$

CALCULATE OUTSIDE DIAMETER OF 330-660 WRAP

CASE 1: DIAM = $2 \times 1.249 + 5.01$

$= 7.508$

CASE 2: DIAM = $2 \times 1.249 + 4.39$

$= 6.888$

CASE 3: DIAM = $2 \times 1.249 + 4.47$

$= 6.968$

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 16345	DIVISION & GROUP EE (B)	CALCULATION NO. 140, REV 2	OPTIONAL TASK CODE XXX	PAGE 8 OF 14

ATTACH E

EMISSIVITY OF 330-660 = 0.89

CALCULATE THERMAL RESISTANCE BETWEEN 330-660 AND AMBIENT AIR

CASE 1: $R_{wa} = \frac{9.5 \times 9.84}{1 + 1.7 \times 7.508 \times (0.89 + 0.41)}$

$= 93.48 / 17.5927$

$= 5.3136$

CASE 2: $R_{wa} = \frac{9.5 \times 42.35}{1 + 1.7 \times 6.888 \times (.89 + 0.41)}$

$= 402.325 / 16.2225$

$= 24.8005$

CASE 3: $R_{wa} = \frac{9.5 \times 75.79}{1 + 1.7 \times 6.968 \times (.89 + 0.41)}$

$= 720.005 / 16.3993$

$= 43.9047$

CALCULATE THERMAL RESISTANCE BETWEEN CONDUCTOR AND AMBIENT AIR

CASE 1: $R_{th,1} = 1.8839 + 8.3864 + 4.8131 + 5.3136 + 0$

$= 20.3970$

CASE 2: $R_{th,1} = 1.5531 + 40.8959 + 23.0661 + 24.8005 + 1.5725$

$= 91.8886$

CASE 3: $R_{th,1} = 1.4965 + 71.9525 + 40.6826 + 43.9047 + 1.3222$

$= 159.3685$

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CALCULATION SHEET

A 5010 68

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE
16395	EE (B)	140, REV 2	XXX	9 OF 19

ATTACH E

CALCULATE OF WRAPPED CABLE BUNDLES IN FREE AIR

$$\text{CASE 1:}\quad I_{amp} = \left[(90-50) \times \frac{234.5+25}{(20.3970 \times 5.25\times10^{-5} \times (1+0.01) \times (234.5+90)} \right]^{1/2}$$

$$= \left[\frac{10380}{0.35096} \right]^{1/2}$$

$$= 171.9760$$

$$\text{CASE 2:}\quad I_{amp} = \left[\frac{10380}{91.8886 \times 4.27\times10^{-4} \times (1+\Phi) \times 329.5} \right]^{1/2}$$

$$= \left[\frac{10380}{12.7322} \right]^{1/2}$$

$$= 28.5526$$

$$\text{CASE 3:}\quad I_{amp} = \left[\frac{10380}{159.3685 \times 0.00108 \times (1+\Phi) \times 329.5} \right]^{1/2}$$

$$= \left[\frac{10380}{55.8523} \right]^{1/2}$$

$$= 13.6326$$

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CALCULATION SHEET

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE
16345	EE (B)	140, REV 2	XXXX	10 OF 19

ATTACH E

DETERMINING AMPACITY OF 330-660 COVERED CABLES IN TRAY WITH MAINTAINED SPACING

AMPACITY OF 8KV CABLES WHERE DEPTH > DIAMETER

CASE 1: I_t (1/C-4/0) = 265 AMP

I_t (1/C-4/0) = 265 × 0.9 × 0.69

= 164.565

SINCE 164.55 < 171.976 AMPCHK = 1

CASE 2: FROM DBD-EE-052, NO 3/C-6 AWG CABLES ARE INSTALLED IN A MAINTAINED SPACING CONFIGURATION. THEREFORE:

AMPCHK = 0

CASE 3: DITTO CASE 2, THEREFORE:

AMPCHK = 0

DETERMINE THE NUMBER OF ALLOWABLE WRAPPED CABLES IN FREE AIR:

CASE 1: 4 (12 CONDUCTORS ÷ 3) *

CASE 2: 0

CASE 3: 0

* FROM PREVIOUSLY CALCULATED VALUES

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CALCULATION SHEET

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE
16345	EE(B)	141, 2EV2	XXX	11 OF 14

ATTACH E

DETERMINE AMPACITY OF 330-660 COVERED CABLES IN TRAY WITH RANDOM LAY

CASE 1: NO 1/C-4/0 CABLES ARE INSTALLED IN TRAY WITH RANDOM LAY, THEREFORE:

AMPCHK = Ø

CASE 2: $I_{thRS} = 32$

SINCE $32 > 28.5526$

AMPCHK = Ø

CASE 3: $I_{thRS} = 15$

SINCE $15 > 13.6326$

AMPCHK = Ø

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CALCULATION SHEET

A 5010.86

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 12 OF 14
16395	EE(B)	140, Rev 2	XXX	

ATTACH 4E

DETERMINE AMPACITY OF CABLES IN CONDUIT COVERED WITH 330-660, B&W DESIGN

CASE 1: $I_{TR.CD} = 205$

12 CONDUCTORS IN CONDUIT,
THEREFORE AMPACITY MULTIPLIER = 0.7

$II_{TR.CD} = 205 \times 0.7 = 143.5$

SINCE $143.5 < 171.976$, AMPCHK = 1

CASE 2: $I_{TR.CD} = 49$

57 CONDUCTORS IN CONDUIT,
THEREFORE AMPACITY MULTIPLIER = 0.5

$II_{TR.CD} = 49 \times 0.5 = 24.5$

SINCE $24.5 < 28.5526$, AMPCHK = 1

CASE 3: $I_{TR.CD} = 26$

102 CONDUCTORS IN CONDUIT,
THEREFORE AMPACITY MULTIPLIER = 0.5

$II_{TR.CD} = 26 \times 0.5 = 13$

SINCE $13 < 13.6826$, AMPCHK = 1

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CALCULATION SHEET

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE
16345	EE(B)	140, REV 2	XXX	13 OF 19

ATTACH 4E

DETERMINE THE NUMBER OF ALLOWABLE WRAPPED CABLES IN FREE AIR:

CASE 1: 4 (12 CONDUCTORS ÷ 3) *

CASE 2: 19 *

CASE 3: 51 *

* FROM PREVIOUSLY CALCULATED VALUES

CALCULATE AMPACITY OF CABLE IN CONDUIT COVERED WITH 330-660 SHELL DESIGN

RATIO OF SHELL AMPACITY TO BOX AMPACITY

Ratio = 0.925/0.8 = 1.15625

CASE 1 1.15625 × 143.5 = 165.922

CASE 2 1.15625 × 24.5 = 28.3281

CASE 3 1.15625 × 13 = 15.031

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CALCULATION SHEET

A 5010 M

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE
16345	EE(B)	140, REV 2	XXX	14 OF 19

ATTACH E

DETERMINE AMPACITY OF CABLES IN CONDUIT COVERED WITH 330-660, SHELL DESIGN.

CASE 1: SINCE 165,922 < 171,976 AMPCHK = 1

CASE 2: SINCE 28,3281 < 28,6572 AMPCHK = 1

CASE 3: SINCE 15,031 > 13,6899 AMPCHK = 0

DETERMINE THE NUMBER OF ALLOWABLE WRAPPED CABLES IN FIRE AR:

CASE 1: 4 (12 CONDUCTORS ÷ 3) *

CASE 2: 19 *

CASE 3: 0

* FROM PREVIOUSLY CALCULATED VALUE

DETERMINE THE % REDUCTION IN AMPACITY FOR USE OF 0.375 INCH AVG THICKNESS THERMO-LAG VS. 0.3125 INCH AVG THICKNESS (ATTACHMENT H)

			FROM ATTACH. H
CASE 1:	$\frac{171.922 - 170.039}{171.922}$	= 1.095	1.10
CASE 2:	$\frac{28.553 - 28.246}{28.553}$	= 1.075	1.08
CASE 3:	$\frac{13.638 - 13.487}{13.638}$	= 1.107	1.11

ATTACHMENT F
DEVELOPMENT OF AMPACITY DIVERSITY FACTORS

ORIGIN ≡ 1

As discussed in the methodology, as the number of cable contained within a wrap increases it becomes advantageous to account for diversity of loading. All power cables are sized per DBD-EE-052, which requires the cables to have a minimum ampacity of 1.25 times full load current. In large groups of cables it is practical to consider only a few cables are operating at 1.25 times full load current and the remaining cables are carrying 1.0 times full load current.

This attachment will calculate the equivalent heat produces by varies number of cable bundle sizes. An equivalent N'- number of cables will be calculated representing equivalent heat production.

2

N := 1 ..10 The number of cables in a bundle .

$Heat_N := 1.25^2 \cdot N$ This is heat production per unit I-full load current assuming all cables carry 1.25 times full load current, watt

$Heat'_1 := Heat_1$ This is the prjected heat production of just one cable in a bundle

$Heat'_2 := Heat_2$ This is the projected heat production of two cable in a bundle

k := 3 ..10

$Heat'_k := Heat'_2 + (k - 2) \cdot 1^2$ This is the projected heat production of three to 10 cables in a bundle. Cables 3 to 10 carry 1.0 times full load current.

ATTACHMENT F

$$N' := \frac{Heat'_N}{Heat_N}$$

This is the diversity multiplier to obtaine equivalent number of cables/conductors in a bundle for on an equivalent heat production basis. This will be used in Attachment B1A. As N approaches ∞, N' approaches 0.64.

N	Heat N	Heat' N	N' N	N
1	1.563	1.563	1	1
2	3.125	3.125	1	2
3	4.688	4.125	0.88	3
4	6.25	5.125	0.82	4
5	7.813	6.125	0.784	5
6	9.375	7.125	0.76	6
7	10.938	8.125	0.743	7
8	12.5	9.125	0.73	8
9	14.063	10.125	0.72	9
10	15.625	11.125	0.712	10

This templatas calculatas interim values for input into Template Attachment G2. Specifically, number of cables and conductors and effective bundle diameters, and maximum number of cables which can fit into a conduit are calculated in this template.

I. CABLE INPUT DATA

PRNPRECISION := 8

CABLE := READPRN[cable prn] File: cable.prn was produced by template Attachment A1 and is documented separately.

ORIGIN = 1 defines the upper corner of a matrix as 1,1

j := 1 ..7 i := 1 ..21 $n'_{i,j}$:= 0 $Cdiam_{i,j}$:= 0

Matrix CABLE is comprised of the following indicated columns.

Rdc25 := CABLE<1> Yc := CABLE<2> Dc := CABLE<3> Ac := CABLE<4>

n' := CABLE<1> It := CABLE<5> Jt := CABLE<6> ρi := CABLE<7> ρj := CABLE<8>

DiamIC := CABLE<9> Cdiam := CABLE<10> <11>

Where:

Rdc25	Conductor dc resistance at 25 deg C, Ω/ft
Yc	Conductor proximity/skin effect
Dc	Conductor diameter, in.
Ac	Conductor cross-sectional area, sq mm
n'	Number of conductors in cable
It	Insulation thickness, mils
Jt	Overall jacket thickness, mils
ρi	Insulation thermal resistivity, C-cm/W
ρj	Jacket thermal resistivity, C-cm/W
DiamIC	Diameter of 1/c cable or 1 cable of multi-conductor cable, in.
Cdiam	Overall diameter of cable, in.

CABLE PHYSICAL PROPERTIES

CABLE =

Rdc25 Ω/ft	Yc	Dc in.	Ac mm2	n'	It mil	Jt mil	ρi	ρj	DiamIC inch	Cdiam inch
$2.22 \cdot 10^{-5}$	0.06	0.813	253.4	1	280	0	500	500	1.373	2.95195
$3.2 \cdot 10^{-5}$	0.03	0.681	177.3	1	280	0	500	500	1.241	2.66815
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	1	280	0	500	500	1.088	2.3392
$1.48 \cdot 10^{-5}$	0.13	0.995	380	1	145	0	500	500	1.288	2.7692
$2.22 \cdot 10^{-5}$	0.06	0.813	253.4	1	130	0	500	500	1.073	2.30695
$3.2 \cdot 10^{-5}$	0.03	0.681	177.3	1	130	0	500	500	0.941	2.02315
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	1	100	0	500	500	0.728	1.5652
$8.43 \cdot 10^{-5}$	0	0.418	67.43	1	100	0	500	500	0.618	1.3287
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	3	100	0	500	500	0.728	1.5652
$8.43 \cdot 10^{-5}$	0	0.418	67.43	3	100	0	500	500	0.618	1.3287
$1.69 \cdot 10^{-4}$	0	0.292	33.62	3	75	0	500	500	0.442	0.9503
$2.69 \cdot 10^{-4}$	0	0.232	21.15	3	75	80	500	500	0.382	0.9813
$4.27 \cdot 10^{-4}$	0	0.184	13.3	3	75	80	500	500	0.334	0.8781
$6.79 \cdot 10^{-4}$	0	0.146	8.37	3	60	60	500	500	0.266	0.6919
0.00108	0	0.116	5.26	3	45	60	500	500	0.206	0.5629
0.00172	0	0.092	3.31	3	30	60	500	500	0.152	0.4468
$1.69 \cdot 10^{-4}$	0	0.292	33.62	2	75	80	500	500	0.442	1.044
$4.27 \cdot 10^{-4}$	0	0.184	13.3	2	75	60	500	500	0.334	0.788
$6.79 \cdot 10^{-4}$	0	0.146	8.37	2	60	60	500	500	0.266	0.652
0.00108	0	0.116	5.26	2	45	60	500	500	0.206	0.532
0.00172	0	0.092	3.31	2	30	60	500	500	0.152	0.424

The above matrix is manually compared with the matrix CABLE of Attachment A to demonstrate successful data transfer.

II. BUNDLED CONDUCTOR DIAMETER

$j := 1..5$ $i := 1..21$

$N := (1\ 2\ 3\ 5\ 8)$ This is the number of cables in a bundle, except that 3 - single conductors are counted as one. The numbers were arbitrarily selected.

$N_{i,j} := N_{1,j}$

The following determines the maximum number of cables which can fit in a conduit using the 40% "fill by area" criteria (see Reference 14).

$Acnd3 := 7.38$ $Acnd5 := 20$ Area of a 3,4,5,6 inch conduit, Source: Reference 14 (NEC).

$Acnd4 := 12.72$ $Acnd6 := 28.89$

$$N_{i,6} := \text{if}\left[n'_{i,1} \le 1, \text{floor}\left[\frac{0.4 \cdot Acnd3}{3 \cdot \pi \cdot \left(\frac{Diam1C_{i,1}}{4}\right)^2}\right], \text{floor}\left[\frac{0.4 \cdot Acnd3}{\pi \cdot \left(\frac{Cdiam_{i,1}}{4}\right)^2}\right]\right]$$

$$N_{i,7} := \text{if}\left[n'_{i,1} \le 1, \text{floor}\left[\frac{0.4 \cdot Acnd4}{3 \cdot \pi \cdot \left(\frac{Diam1C_{i,1}}{4}\right)^2}\right], \text{floor}\left[\frac{0.4 \cdot Acnd4}{\pi \cdot \left(\frac{Cdiam_{i,1}}{4}\right)^2}\right]\right]$$

$$N_{i,8} := \text{if}\left[n'_{i,1} \le 1, \text{floor}\left[\frac{0.4 \cdot Acnd5}{3 \cdot \pi \cdot \left(\frac{Diam1C_{i,1}}{4}\right)^2}\right], \text{floor}\left[\frac{0.4 \cdot Acnd5}{\pi \cdot \left(\frac{Cdiam_{i,1}}{4}\right)^2}\right]\right]$$

$$N_{i,9} := \text{if}\left[n'_{i,1} \le 1, \text{floor}\left[\frac{0.4 \cdot Acnd6}{3 \cdot \pi \cdot \left(\frac{Diam1C_{i,1}}{4}\right)^2}\right], \text{floor}\left[\frac{0.4 \cdot Acnd6}{\pi \cdot \left(\frac{Cdiam_{i,1}}{4}\right)^2}\right]\right]$$

$j := 1..9$

$N_{i,j} := if\left[N_{i,j} = 0, 1, N_{i,j}\right]$ This ensures that N is never zero

Conduit Size:	3	4	5	6	
N =	1	1	1	2	1/C-500,8 KV
	1	1	2	3	1/C-350,8 KV
	1	1	2	4	1/C-4/0,8 KV
	1	1	2	2	1/C-750,600 V
	1	1	2	4	1/C-500
	1	2	3	5	1/C-350
	2	4	6	9	1/C-4/0
	3	5	8	12	1/C-2/0
	1	2	4	6	TRI-4/0
	2	3	5	8	TRI-2/0
	4	7	11	16	TRI-2AWG
	3	6	10	15	3/C-4AWG
	4	6	13	19	3/C-6AWG
	7	13	21	30	3/C-8AWG
	11	20	32	46	3/C-10AWG
	18	32	51	73	3/C-12AWG
	3	5	9	13	2/C-2AWG
	6	10	16	23	2/C-6AWG
	8	15	23	34	2/C-8AWG
	13	32	35	51	2/C-10AWG
	20	36	56	81	2/C-12AWG

$WRITEPRN\left[N_{prn}\right] := N$ This stores the N matix in an ASCII file for use in Template Appendix G2 and G3

No. of cables in a Bundle

N =

No. of Cables					Conduit Size				
1	2	3	5	8	3"	4"	5"	6"	
1	2	3	5	8	1	1	1	2	1/C-500,8 KV
1	2	3	5	8	1	1	2	3	1/C-350,8 KV
1	2	3	5	8	1	1	2	4	1/C-4/0,8 KV
1	2	3	5	8	1	1	2	2	1/C-750,600 V
1	2	3	5	8	1	1	2	4	1/C-500
1	2	3	5	8	1	2	3	5	1/C-350
1	2	3	5	8	2	4	6	9	1/C-4/0
1	2	3	5	8	3	5	8	12	1/C-2/0
1	2	3	5	8	1	2	4	6	TRI-4/0
1	2	3	5	8	2	3	5	8	TRI-2/0
1	2	3	5	8	4	7	11	15	TRI-2AWG
1	2	3	5	8	3	6	10	15	3/C-4AWG
1	2	3	5	8	4	8	13	19	3/C-6AWG
1	2	3	5	8	7	13	21	30	3/C-8AWG
1	2	3	5	8	11	20	32	46	3/C-10AWG
1	2	3	5	8	18	32	51	73	3/C-12AWG
1	2	3	5	8	3	5	9	13	2/C-2AWG
1	2	3	5	8	6	10	16	23	2/C-6AWG
1	2	3	5	8	8	15	23	34	2/C-8AWG
1	2	3	5	8	13	22	35	51	2/C-10AWG
1	2	3	5	8	20	36	56	81	2/C-12AWG

Equivalent multiplier to obtain bundle diameter = F * cable diameter.

F =

Number of Cables					Conduit Size				
1	2	3	5	8	3"	4"	5"	6"	
1	2	2.15	2.7	3.31	1	1	1	2	1/C-500,8 KV
1	2	2.15	2.7	3.31	1	1	2	2.15	1/C-350,8 KV
1	2	2.15	2.7	3.31	1	1	2	2.14	1/C-4/0,8 KV
1	2	2.15	2.7	3.31	1	1	2	2	1/C-750,600 V
1	2	2.15	2.7	3.31	1	1	2	2.14	1/C-500
1	2	2.15	2.7	3.31	1	2	2.15	2.7	1/C-350
1	2	2.15	2.7	3.31	2	2.14	3	3.62	1/C-4/0
1	2	2.15	2.7	3.31	2.15	2.7	3.31	4.15	1/C-2/0
1	2	2.15	2.7	3.31	1	2	2.14	3	TRI-4/0
1	2	2.15	2.7	3.31	2	2.15	2.7	3.31	TRI-2/0
1	2	2.15	2.7	3.31	2.14	3	4	4.7	TRI-2AWG
1	2	2.15	2.7	3.31	2.15	3	4	4.7	3/C-4AWG
1	2	2.15	2.7	3.31	2.14	3.31	4.41	5	3/C-6AWG
1	2	2.15	2.7	3.31	3	4.41	5.31	6.41	3/C-8AWG
1	2	2.15	2.7	3.31	4	5.31	6.7	8	3/C-10AWG
1	2	2.15	2.7	3.31	5	6.7	8.41	10	3/C-12AWG
1	2	2.15	2.7	3.31	2.15	2.7	3.62	4.41	2/C-2AWG
1	2	2.15	2.7	3.31	3	4	4.7	6	2/C-6AWG
1	2	2.15	2.7	3.31	3.31	4.7	6	7	2/C-8AWG
1	2	2.15	2.7	3.31	4.41	5.62	7	8.41	2/C-10AWG
1	2	2.15	2.7	3.31	5.31	7	8.7	10.41	2/C-12AWG

$j := 1 \ldots 9$

$n'_{i,1} := if[n'_{i,1} = 1,3,n'_{i,1}]$

This redefines the number of conductors for 1/C cable as 3 for N = 1.

ORIGIN = 1

$nn'_{i,j} := n'_{i,1} \cdot N_{i,j}$

This calculates the number of conductors under the wrap.

Actual number of Conductors Inside Bundle

Number of Cables / Conduit Size									
	1	2	3	5	8	3"	4"	5"	6"	
nn' =	3	6	9	15	24	3	3	3	6	1/C-500,8 KV
	3	6	9	15	24	3	3	6	9	1/C-350,8 KV
	3	6	9	15	24	3	3	6	12	1/C-4/0,8 KV
	3	6	9	15	24	3	3	6	6	1/C-750,600 V
	3	6	9	15	24	3	3	6	12	1/C-500
	3	6	9	15	24	3	6	9	15	1/C-350
	3	6	9	15	24	6	12	18	27	1/C-4/0
	3	6	9	15	24	9	15	24	36	1/C-2/0
	3	6	9	15	24	3	6	12	18	TRI-4/0
	3	6	9	15	24	6	9	15	24	TRI-2/0
	3	6	9	15	24	12	21	33	48	TRI-2AWG
	3	6	9	15	24	9	18	30	45	3/C-4AWG
	3	6	9	15	24	12	24	39	57	3/C-6AWG
	3	6	9	15	24	21	39	63	90	3/C-8AWG
	3	6	9	15	24	33	60	96	138	3/C-10AWG
	3	6	9	15	24	54	96	153	219	3/C-12AWG
	2	4	6	10	16	6	10	18	26	2/C-2AWG
	2	4	6	10	16	12	20	32	46	2/C-6AWG
	2	4	6	10	16	16	30	46	68	2/C-8AWG
	2	4	6	10	16	26	44	70	102	2/C-10AWG
	2	4	6	10	16	40	72	112	162	2/C-12AWG

nn' is the actual number of conductors inside a bundle
nnn' is the equivalent number of conductors for heat production basis

The following accounts for load diversity in larger cable bundles. See template Appendix F and the Methodology section for further explaination.

$nnn'_{i,j} := if\left[N_{i,j} \geq 3, 0.88 \cdot nn'_{i,j}, nn'_{i,j}\right]$ Adjust nn' for N=3

$nnn'_{i,j} := if\left[N_{i,j} \geq 4, 0.82 \cdot nn'_{i,j}, nnn'_{i,j}\right]$ Adjust nn' for N=4

$nnn'_{i,j} := if\left[N_{i,j} \geq 5, 0.784 \cdot nn'_{i,j}, nnn'_{i,j}\right]$ Adjust nn' for N=5

$nnn'_{i,j} := if\left[N_{i,j} \geq 6, 0.76 \cdot nn'_{i,j}, nnn'_{i,j}\right]$ Adjust nn' for N=6

$nnn'_{i,j} := if\left[N_{i,j} \geq 7, 0.743 \cdot nn'_{i,j}, nnn'_{i,j}\right]$ Adjust nn' for N=7 or greater, for conservatism no value smaller than 0.743 will be used

Equivalent number of conductors in Bundle

Number of Cables / Conduit Size									
	1	2	3	5	8	3"	4"	5"	6"	
nnn' =	3	6	7.92	11.76	17.83	3	3	3	6	1/C-500,8 KV
	3	6	7.92	11.76	17.83	3	3	6	7.92	1/C-350,8 KV
	3	6	7.92	11.76	17.83	3	3	6	9.84	1/C-4/0,8 KV
	3	6	7.92	11.76	17.83	3	3	6	6	1/C-750,600 V
	3	6	7.92	11.76	17.83	3	3	6	9.84	1/C-500
	3	6	7.92	11.76	17.83	3	6	7.92	11.76	1/C-350
	3	6	7.92	11.76	17.83	6	9.84	13.58	20.06	1/C-4/0
	3	6	7.92	11.76	17.83	7.92	11.76	17.83	26.75	1/C-2/0
	3	6	7.92	11.76	17.83	3	6	9.84	13.68	TRI-4/0
	3	6	7.92	11.76	17.83	6	7.92	11.76	17.83	TRI-2/0
	3	6	7.92	11.76	17.83	9.84	13.6	24.52	35.66	TRI-2AWG
	3	6	7.92	11.76	17.83	7.92	13.68	22.29	33.44	3/C-4AWG
	3	6	7.92	11.76	17.83	9.84	17.83	28.98	42.35	3/C-6AWG
	3	6	7.92	11.76	17.83	15.6	28.98	46.81	66.87	3/C-8AWG
	3	6	7.92	11.76	17.83	24.52	44.58	71.33	102.53	3/C-10AWG
	3	6	7.92	11.76	17.83	40.12	71.33	113.68	162.72	3/C-12AWG
	2	4	5.28	7.84	11.89	5.28	7.84	13.37	19.32	2/C-2AWG
	2	4	5.28	7.84	11.89	9.12	14.86	23.78	34.18	2/C-6AWG
	2	4	5.28	7.84	11.89	11.89	22.29	34.18	50.52	2/C-8AWG
	2	4	5.28	7.84	11.89	19.32	32.69	52.01	78.79	2/C-10AWG
	2	4	5.28	7.84	11.89	29.72	53.5	83.22	120.37	2/C-12AWG

WRITEPRN(NNN prn) := nnn'

WRITEPRN(nn prn) := nn'

Both matices nnn' and nn' are saved to an ASCII file for later use by template Appendix G2 and G3

$$CCdiam_{i,j} := Cdiam_{i,1} \cdot F_{i,j}$$

This calculates the diameter of a bundle of cables, for various number of cables in the bundle.

Bundle diameter

No. of Cables / Conduit Size

	1	2	3	5	8	3"	4"	5"	6"	
CCdiam =	2.95	5.9	6.35	7.97	9.77	2.95	2.95	2.95	5.9	1/C-500,8 KV
	2.67	5.34	5.74	7.2	8.83	2.67	2.67	5.34	5.74	1/C-350,8 KV
	2.34	4.68	5.03	6.32	7.74	2.34	2.34	4.68	5.01	1/C-4/0,8 KV
	2.77	5.54	5.95	7.48	9.17	2.77	2.77	5.54	5.54	1/C-750,600 V
	2.31	4.61	4.96	6.23	7.64	2.31	2.31	4.61	4.94	1/C-500
	2.02	4.05	4.35	5.46	6.7	2.02	4.05	4.35	5.46	1/C-350
	1.57	3.13	3.37	4.23	5.18	3.13	3.35	4.7	5.67	1/C-4/0
	1.33	2.66	2.86	3.59	4.4	2.86	3.59	4.4	5.61	1/C-2/0
	1.57	3.13	3.37	4.23	5.18	1.57	3.13	3.35	4.7	TRI-4/0
	1.33	2.66	2.86	3.59	4.4	2.66	2.86	3.59	4.4	TRI-2/0
	0.95	1.9	2.04	2.57	3.15	2.03	2.85	3.8	4.47	TRI-2AWG
	0.98	1.96	2.11	2.65	3.25	2.11	2.94	3.93	4.61	3/C-4AWG
	0.88	1.76	1.89	2.37	2.91	1.88	2.91	3.87	4.39	3/C-6AWG
	0.69	1.38	1.49	1.87	2.29	2.08	3.05	3.67	4.44	3/C-8AWG
	0.56	1.13	1.21	1.52	1.86	2.25	2.99	3.77	4.5	3/C-10AWG
	0.45	0.89	0.96	1.21	1.48	2.23	2.99	3.76	4.47	3/C-12AWG
	1.04	2.09	2.24	2.82	3.46	2.24	2.82	3.78	4.6	2/C-2AWG
	0.79	1.58	1.69	2.13	2.61	2.36	3.15	3.7	4.73	2/C-6AWG
	0.65	1.3	1.4	1.76	2.16	2.16	3.06	3.91	4.56	2/C-8AWG
	0.53	1.06	1.14	1.44	1.76	2.35	2.99	3.72	4.47	2/C-10AWG
	0.42	0.85	0.91	1.14	1.4	2.25	2.97	3.69	4.41	2/C-12AWG

WRITEPRN(CCdiam prn) := CCdiam

This saves matrix CCdiam for use by template Appendix G2

This templates calculates the thermal resistance terms and cable ampacity. The cable ampacity is input to template Attachment G3 for comparison with ampacity of the cable in adjacent raceways sections.

I. CABLE INPUT DATA

PRNPRECISION := 6

CABLE := READPRN[cable prn] File: cable.prn was produced by template- Attachment A and is documented separately.

ORIGIN = 1 defines the upper corner of a matrix as 1,1

j := 1 ..7 i := 1 ..21 $n'_{i,j}$:= 0 $Cdiam_{i,j}$:= 0

Matrix CAPLE is comprised of the following indicated columns.

Rdc25 := CABLE<1> Yc := CABLE<2> Dc := CABLE<3> Ac := CABLE<4>

n' := CABLE<1> It := CABLE<5> Jt := CABLE<6> ρi := CABLE<7> ρj := CABLE<8>

Diam1C := CABLE<9> Cdiam := CABLE<10> <11>

Where:

Rdc25	Conductor dc resistance at 25 deg C, Ω/ft
Yc	Conductor proximity/skin effect
Dc	Conductor diameter, in.
Ac	Conductor cross-sectional area, sq mm
n'	Number of conductors in cable
It	Insulation thickness, mils
Jt	Overall jacket thickness, mils
ρi	Insulation thermal resistivity, C-cm/W
ρj	Jacket thermal resistivity, C-cm/W
Diam1C	Diameter of 1/c cable or 1 cable of multi-conductor cable, in.
Cdiam	Overall diameter of cable, in.

CABLE PHYSICAL PROPERTIES

CABLE =

Rdc25 Ω/ft	Yc	Dc in.	Ac mm2	n'	It mil	Jt mil	ρi	ρj	DiamIC inch	Cdiam inch
$2.22 \cdot 10^{-5}$	0.06	0.813	253.4	1	280	0	500	500	1.373	2.95195
$3.2 \cdot 10^{-5}$	0.03	0.681	177.3	1	280	0	500	500	1.241	2.66815
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	1	280	0	500	500	1.088	2.3392
$1.48 \cdot 10^{-5}$	0.1	0.998	380	1	145	0	500	500	1.288	2.7692
$2.22 \cdot 10^{-5}$	0.06	0.813	253.4	1	130	0	500	500	1.073	2.30695
$3.2 \cdot 10^{-5}$	0.03	0.681	177.3	1	130	0	500	500	0.941	2.02315
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	1	100	0	500	500	0.728	1.5652
$8.43 \cdot 10^{-5}$	0	0.418	67.43	1	100	0	500	500	0.618	1.3287
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	3	100	0	500	500	0.728	1.5652
$8.43 \cdot 10^{-5}$	0	0.418	67.43	3	100	0	500	500	0.618	1.3287
$1.69 \cdot 10^{-4}$	0	0.292	33.62	3	75	0	500	500	0.442	0.9503
$2.69 \cdot 10^{-4}$	0	0.232	21.15	3	75	80	500	500	0.382	0.9813
$4.27 \cdot 10^{-4}$	0	0.184	13.3	3	75	80	500	500	0.334	0.8781
$6.79 \cdot 10^{-4}$	0	0.146	8.37	3	60	60	500	500	0.266	0.6919
0.00108	0	0.116	5.26	3	45	60	500	500	0.206	0.5629
0.00172	0	0.092	3.31	3	30	60	500	500	0.152	0.4468
$1.69 \cdot 10^{-4}$	0	0.292	33.62	2	75	80	500	500	0.442	1.044
$4.27 \cdot 10^{-4}$	0	0.184	13.3	2	75	60	500	500	0.334	0.788
$6.79 \cdot 10^{-4}$	0	0.146	8.37	2	60	60	500	500	0.266	0.652
0.00108	0	0.116	5.26	2	45	60	500	500	0.206	0.532
0.00172	0	0.092	3.31	2	30	60	500	500	0.152	0.424

The above matrix is manually compared with the matrix CABLE of Attachment A to demonstrate successful data transfer.

N, nnn', and CCdiam were developed in template- Attachment G1

N := READPRN(N prn) nnn' := READPRN(NNN prn)

CCdiam := READPRN(CCdiam prn)

No. of cables in a Bundle

N =

No. of cables / Conduit Size								
1	2	3	5	8	3"	4"	5"	6"
1	2	3	5	8	1	1	1	2
1	2	3	5	8	1	1	2	3
1	2	3	5	8	1	1	2	4
1	2	3	5	8	1	1	2	2
1	2	3	5	8	1	1	2	4
1	2	3	5	8	1	2	3	5
1	2	3	5	8	2	4	6	9
1	2	3	5	8	3	5	8	12
1	2	3	5	8	1	2	4	6
1	2	3	5	8	2	3	5	8
1	2	3	5	8	4	7	11	16
1	2	3	5	8	3	6	10	15
1	2	3	5	8	4	8	13	19
1	2	3	5	8	7	13	21	30
1	2	3	5	8	11	20	32	46
1	2	3	5	8	18	32	51	73
1	2	3	5	8	3	5	9	13
1	2	3	5	8	6	10	16	23
1	2	3	5	8	8	15	23	34
1	2	3	5	8	13	22	35	51
1	2	3	5	8	20	36	56	81

Equivalent No. of conductors in a Bundle

nnn' =

No. of cables			/ Conduit Size					
1	2	3	5	8	3 "	4"	5 "	6"
3	6	7.92	11.76	17.83	3	3	3	6
3	6	7.92	11.76	17.83	3	3	6	7.92
3	6	7.92	11.76	17.83	3	3	6	9.84
3	6	7.92	11.76	17.83	3	3	6	6
3	6	7.92	11.76	17.83	3	3	6	9.84
3	6	7.92	11.76	17.83	3	6	7.92	11.76
3	6	7.92	11.76	17.83	6	9.84	13.68	20.06
3	6	7.92	11.76	17.83	7.92	11.76	17.83	26.75
3	6	7.92	11.76	17.83	3	6	9.84	13.68
3	6	7.92	11.76	17.83	6	7.92	11.76	17.83
3	6	7.92	11.76	17.83	9.84	15.6	24.52	35.66
3	6	7.92	11.76	17.83	7.92	13.68	22.29	33.44
3	6	7.92	11.76	17.83	9.84	17.83	28.98	42.35
3	6	7.92	11.76	17.83	15.6	28.98	46.81	66.87
3	6	7.92	11.76	17.83	24.52	44.58	71.33	102.53
3	6	7.92	11.76	17.83	40.12	71.33	113.68	162.72
2	4	5.28	7.84	11.89	5.28	7.84	13.27	19.32
2	4	5.28	7.84	11.89	9.12	14.86	23.78	34.18
2	4	5.28	7.84	11.89	14.89	22.29	34.18	50.52
2	4	5.28	7.84	11.89	19.32	32.69	52.01	75.79
2	4	5.28	7.84	11.89	29.72	53.5	83.22	120.37

Diameter of cable Bundle

CCdiam =

No. of cables / Conduit Size								
1	2	3	5	8	3 "	4"	5 "	6"
2.95	5.9	6.35	7.97	9.77	2.95	2.95	2.95	5.9
2.67	5.34	5.74	7.2	8.83	2.67	2.67	5.34	5.74
2.34	4.68	5.03	6.32	7.74	2.34	2.34	4.68	5.01
2.77	5.54	5.95	7.48	9.17	2.77	2.77	5.54	5.54
2.31	4.61	4.96	6.23	7.64	2.31	2.31	4.61	4.94
2.02	4.05	4.35	5.46	6.7	2.02	4.05	4.35	5.46
1.57	3.13	3.37	4.23	5.18	3.13	3.35	4.7	5.67
1.33	2.66	2.86	3.59	4.4	2.86	3.59	4.4	5.51
1.57	3.13	3.37	4.23	5.18	1.57	3.13	3.35	4.7
1.33	2.66	2.86	3.59	4.4	2.66	2.86	3.59	4.4
0.95	1.9	2.04	2.57	3.15	2.03	2.85	3.8	4.47
0.98	1.96	2.11	2.65	3.25	2.11	2.94	3.93	4.61
0.88	1.76	1.89	2.37	2.91	1.88	2.91	3.87	4.39
0.69	1.38	1.49	1.87	2.29	2.08	3.05	3.67	4.44
0.56	1.13	1.21	1.52	1.86	2.25	2.99	3.77	4.5
0.45	0.89	0.96	1.21	1.48	2.23	2.99	3.76	4.47
1.04	2.09	2.24	2.82	3.46	2.24	2.82	3.78	4.6
0.79	1.58	1.69	2.13	2.61	2.36	3.15	3.7	4.73
0.65	1.3	1.4	1.76	2.16	2.16	3.06	3.91	4.56
0.53	1.06	1.14	1.44	1.76	2.35	2.99	3.72	4.47
0.42	0.85	0.91	1.14	1.4	2.25	2.97	3.69	4.41

III. Calculation of thermal resistance terms

$j := 1 \ldots 9$

$$Ri_{i,j} := 0.012 \cdot \rho i_i \cdot \log\left[\frac{Diam1C_i}{Dc_i}\right]$$

thermal resistance of insulation
C-ft/watt
Source: Reference 3 (Nehr-McGrath), equation 38.

Thermal Resistance of Insulation

No. of cables / Conduit Size									
1	2	3	5	8	3"	4"	5"	6"	
1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1/C-500,8 KV
1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1/C-350,8 KV
1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1/C-4/0,8 KV
0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1/C-750,600 V
0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1/C-500
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1/C-350
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1/C-4/0
1	1	1	1	1	1	1	1	1	1/C-2/0
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	TRI-4/0
1	1	1	1	1	1	1	1	1	TRI-2/0
1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	TRI-2AWG
1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	3/C-4AWG
1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3/C-6AWG
1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3/C-8AWG
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	3/C-10AWG
1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	3/C-12AWG
1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	2/C-2AWG
1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2/C-6AWG
1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2/C-8AWG
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2/C-10AWG
1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	2/C-12AWG

$Ri =$

Thermal Resistance of the Jacket on 2/C and 3/C cable

$$Rj_{i,j} := \left[Jt_i > 0\right] \cdot \left[0.012 \cdot n'_{i,1} \cdot \rho j_i \cdot \log\left[\frac{Cdiam_{i,1}}{Cdiam_{i,1} - 2 \cdot Jt_i \cdot 10^{-3}}\right]\right]$$

Thermal resistance of jacket, C-ft/watt Source: Derived from equation 38 in Reference 3 (Nehr-McGrath) This first part of the expression is a logical statement to only calculate Rj if a jacket exists.

Thermal Resistance of Jacket

Rj =

No. of cables / Conduit Size: 1	2	3	5	8	3"	4"	5"	6"
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39
1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57
1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49
1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87
2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73

A' := 4.5 B' := 0.27 factors used in Rsd, developed constants in Table VII of Reference 3 (Nehr-McGrath). See Methodology 8 .

$$Rsd_{i,j} := nnn'_{i,j} \cdot \frac{A'}{CCdiam_{i,j} + B'}$$

thermal resistance between cable and 330-660, C-ft/watt this assumes an airgap between the two surfaces. Equation 41A from Reference 3, (Nehr-McGrath).

Rsd =

4.2	4.4	5.4	6.4	8	4.2	4.2	4.2	4.4	1/C-500,8 KV
4.6	4.8	5.9	7.1	8.8	4.6	4.6	4.8	5.9	1/C-350,8 KV
5.2	5.5	6.7	8	10	5.2	5.2	5.5	8.4	1/C-4/0,8 KV
4.4	4.6	5.7	6.8	8.5	4.4	4.4	4.6	4.6	1/C-750,600 V
5.2	5.5	6.8	8.1	10.1	5.2	5.2	5.5	8.5	1/C-500
5.9	6.3	7.7	9.2	11.5	5.9	6.3	7.7	9.2	1/C-350
7.4	7.9	9.8	11.8	14.7	7.9	12.2	12.4	15.2	1/C-4/0
8.4	9.2	11.4	13.7	17.2	11.4	13.7	17.2	20.8	1/C-2/0
7.4	7.9	9.8	11.8	14.7	7.4	7.9	12.2	12.4	TRI-4/0
8.4	9.2	11.4	13.7	17.2	9.2	11.4	13.7	17.2	TRI-2/0
11.1	12.4	15.4	18.7	23.5	19.2	22.5	27.1	33.9	TRI-2AWG
10.8	12.1	15	18.1	22.8	15	19.2	23.9	30.8	3/C-4AWG
11.8	13.3	16.5	20	25.3	20.6	25.3	31.5	40.9	3/C-6AWG
14	16.3	20.3	24.8	31.3	29.9	39.3	53.4	64	3/C-8AWG
16.2	19.3	24.1	29.6	37.6	43.8	61.6	79.4	96.7	3/C-10AWG
18.8	23.2	29	35.8	45.9	72.1	98.4	127	154.5	3/C-12AWG
6.8	7.6	9.4	11.4	14.4	9.4	11.4	14.9	17.8	2/C-2AWG
8.5	9.8	12.1	14.7	18.6	15.6	19.5	26.9	30.8	2/C-6AWG
9.8	11.4	14.2	17.4	22	22	30.1	36.8	47	2/C-8AWG
11.2	13.5	16.8	20.7	26.3	33.2	45.1	58.6	71.9	2/C-10AWG
13	16.1	20.1	24.9	32	53	74.3	94.6	115.6	2/C-12AWG

'Cable ampacity of thermolagged cable-3/8 inch product is Free Air template 2"

THERMAL RESISTANCE OF THERMOLAG 330-660 WRAP

Btu/hr = B B := .2931 watts Ft := 30.4785 cm

F := 5/9 This is to convert degree F to degrees C

$K := (0.249)\cdot\frac{B}{Ft}\cdot\frac{1}{F}$ See Attachment D (conductivity)

$\rho w := \frac{1}{K}$

$\rho w = 232.01$ thermal resistivity of 330-660 wrap,C-Cm/watt

$Twrap := 4\cdot\frac{3}{8}$ thickness of wrap, inch (4 layers of maximum average thickness, see Attachment I)

Twrap = 1.5

$$Rw_{i,j} := 0.012\cdot nrm1_{i,j}\cdot\rho w\cdot\log\left[\frac{CCdiam_{i,j} + 2\cdot Twrap}{CCdiam_{i,j}}\right]$$

Thermal resistance of thermolag wrap, thermal Ω/ft
Source: Reference 2, equation 6

Thermal Resistance of Wrap

No. of cables / Conduit Size									
1	2	3	5	8	3 "	4"	5 "	6"	
2.5	3	3.7	4.5	5.8	2.5	2.5	2.5	3	1/C-500,8 KV
2.7	3.2	4	5	6.3	2.7	2.7	3.2	4	1/C-350,8 KV
3	3.6	4.5	5.5	7.1	3	3	3.6	5.6	1/C-4/0,8 KV
2.7	3.1	3.9	4.8	6.1	2.7	2.7	3.1	3.1	1/C-750,600 V
3	3.6	4.5	5.6	7.1	3	3	3.6	5.6	1/C-500
Rw = 3.3	4	5	6.2	8	3.3	4	5	6.2	1/C-350
3.9	4.9	6.1	7.6	9.8	4.9	7.6	8.2	10.3	1/C-4/0
4.3	5.5	6.9	8.6	11.2	6.9	8.6	11.2	14	1/C-2/0
3.9	4.9	6.1	7.6	9.8	3.9	4.9	7.6	8.2	TRI-4/0
4.3	5.5	6.9	8.6	11.2	5.5	6.9	8.6	11.2	TRI-2/0
5.2	6.9	8.7	11	14.4	10.8	13.6	17.2	22.2	TRI-2AWG
5.1	6.7	8.5	10.8	14.1	8.5	11.6	15.3	20.3	3/C-4AWG
5.4	7.2	9.1	11.6	15.3	11.4	15.3	20.1	26.7	3/C-6AWG
6.1	8.4	10.6	13.6	18.1	16.9	24	33.8	41.8	3/C-8AWG
6.7	9.4	11.9	15.5	20.7	25.1	37.5	50.5	63.3	3/C-10AWG
7.4	10.7	13.6	17.8	23.9	41.3	59.9	80.7	101.1	3/C-12AWG
3.3	4.3	5.4	6.9	9	5.4	6.9	9.4	11.7	2/C-2AWG
3.8	5.2	6.5	8.3	11	9	12	17.1	20.3	2/C-6AWG
4.2	5.8	7.3	9.4	12.5	12.5	18.4	23.5	30.9	2/C-8AWG
4.6	6.5	8.2	10.7	14.3	19.2	27.5	37.2	47	2/C-10AWG
5.1	7.3	9.3	12.2	16.4	30.4	45.2	59.9	75.5	2/C-12AWG

THERMAL RESISTANCE BETWEEN THE THERMOLAG AND AMBIENT AIR

$Dwrap_{i,j} := 2 \cdot Twrap + CCdiam_{i,j}$ Overall diameter of wrap, in.

Diameter Over the Wrap

$Dwrap =$

No. of cables / Conduit Size									
1	2	3	5	8	3	4"	5"	6"	
6	8.9	9.3	11	12.8	6	6	6	8.9	1/C-500,8 KV
5.7	8.3	8.7	10.2	11.8	5.7	5.7	8.3	8.7	1/C-350,8 KV
5.3	7.7	8	9.3	10.7	5.3	5.3	7.7	8	1/C-4/0,8 KV
5.8	8.5	9	10.5	12.2	5.8	5.8	8.5	8.5	1/C-750,600 V
5.3	7.6	8	9.2	10.6	5.3	5.3	7.6	7.9	1/C-500
5	7	7.3	8.5	9.7	5	7	7.3	8.5	1/C-350
4.6	6.1	6.4	7.2	8.2	6.1	6.3	7.7	8.7	1/C-4/0
4.3	5.7	5.9	6.6	7.4	5.9	6.6	7.4	8.5	1/C-2/0
4.6	6.1	6.4	7.2	8.2	4.6	6.1	6.3	7.7	TRI-4/0
4.3	5.7	5.9	6.6	7.4	5.7	5.9	6.6	7.4	TRI-2/0
4	4.3	5	5.6	6.1	5	5.9	6.8	7.5	TRI-2AWG
4	5	5.1	5.6	6.2	5.1	5.9	6.9	7.6	3/C-4AWG
3.9	4.8	4.9	5.4	5.9	4.9	5.9	6.9	7.4	3/C-6AWG
3.7	4.4	4.5	4.9	5.3	5.1	6.1	6.7	7.4	3/C-8AWG
3.6	4.1	4.2	4.5	4.9	5.3	6	6.8	7.5	3/C-10AWG
3.4	3.9	4	4.2	4.5	5.2	6	6.8	7.5	3/C-12AWG
4	5.1	5.2	5.8	6.5	5.2	5.8	6.8	7.6	2/C-2AWG
3.8	4.6	4.7	5.1	5.6	5.4	6.2	6.7	7.7	2/C-6AWG
3.7	4.3	4.4	4.8	5.2	5.2	6.1	6.9	7.6	2/C-8AWG
3.5	4.1	4.1	4.4	4.8	5.3	6	6.7	7.5	2/C-10AWG
3.4	3.8	3.9	4.1	4.4	5.3	6	6.7	7.4	2/C-12AWG

$\epsilon := 0.89$ emissivity of Thermolag 330-660 (see Attachment D)

$$Rwa_{i,j} := \frac{9.5 \cdot nnn'_{i,j}}{1 + 1.7 \cdot Dwrap_{i,j} \cdot (\epsilon + 0.41)}$$

Thermal resistance between wrap and ambient air, thermal Ω-ft (C-ft/watt)
Source: Reference 3 (Nahr-McGrath, equation 42A)

Thermal Resistance of Wrap to Air

No. of cables / Conduit Size									
1	2	3	5	8	3"	4"	5"	6"	
2	2.8	3.5	4.4	5.8	2	2	2	2.8	1/C-500,8 KV
2.1	2.9	3.7	4.7	6.2	2.1	2.1	2.9	3.7	1/C-350,8 KV
2.2	3.2	4	5.2	6.8	2.2	2.2	3.2	5	1/C-4/0,8 KV
2.1	2.9	3.6	4.6	6.1	2.1	2.1	2.9	2.9	1/C-750,600 V
2.2	3.2	4	5.2	6.9	2.2	2.2	3.2	5	1/C-500
2.4	3.4	4.4	5.7	7.6	2.4	3.4	4.4	5.7	1/C-350
2.6	3.9	5	6.6	8.9	3.9	6.2	7.2	9.5	1/C-4/0
2.7	4.2	5.4	7.2	9.8	5.4	7.2	9.8	12.8	1/C-2/0
2.6	3.9	5	6.6	8.9	2.6	3.9	5.2	7.2	TRI-4/0
2.7	4.2	5.4	7.2	9.8	4.2	5.4	7.2	9.8	TRI-2/0
2.9	4.8	6.2	8.4	11.6	7.7	10.6	14.5	19.4	TRI-2AWG
2.9	4.8	6.1	8.3	11.4	6.1	9.2	13	17.8	3/C-4AWG
3	5	6.4	8.7	12.2	7.9	12.1	17	23.2	3/C-6AWG
3.1	5.3	6.9	9.5	13.3	12.1	19.2	26.2	36.4	3/C-8AWG
3.2	5.6	7.3	10.2	14.4	18.5	29.7	42.4	55.4	3/C-10AWG
3.3	5.9	7.7	10.9	15.5	30.2	47.6	67.8	88.3	3/C-12AWG
1.9	3.1	4	5.4	7.4	4	5.4	7.9	10.3	2/C-2AWG
2	3.4	4.4	6	8.4	6.7	9.7	14.3	18	2/C-6AWG
2.1	3.6	4.7	6.5	9.1	9.2	14.7	19.9	27.1	2/C-8AWG
2.2	3.8	4.9	6.9	9.8	14.3	21.8	31.2	41.1	2/C-10AWG
2.2	4	5.2	7.3	10.5	22.4	35.8	50.1	65.8	2/C-12AWG

Rwa =

THERMAL RESISTANCE BETWEEN CONDUCTOR AND AMBIENT AIR

Rthl := Ri + Rj + Rsd + Rw + Rwa thermal resistance between the conductor and outside ambient air, thermal ft-ft (C-ft/watt)

Thermal Resistance Between Conductor and Air

	No. of cables / Conduit Size								
	1	2	3	5	8	3 "	4"	5 "	6"
Rthl =	10.1	11.5	13.9	16.8	20.9	10.1	10.1	10.1	11.5
	11	12.6	15.2	18.3	22.9	11	11	12.6	15.2
	12.3	14.1	17.1	20.6	25.8	12.3	12.3	14.1	20.9
	9.8	11.3	13.9	16.9	21.3	9.8	9.8	11.3	11.3
	11.2	13.1	16.1	19.7	24.9	11.2	11.2	13.1	19.9
	12.4	14.6	17.9	22	27.9	12.4	14.6	17.9	22
	14.6	17.6	21.7	26.8	34.3	17.6	26.9	28.6	35.8
	16.4	19.9	24.7	30.6	39.2	24.7	30.6	39.2	48.7
	14.6	17.6	21.7	26.8	34.3	14.6	17.6	26.9	28.6
	16.4	19.9	24.7	30.6	39.2	19.9	24.7	30.6	39.2
	20.2	25.2	31.3	39.2	50.6	38.8	47.8	60	76.5
	21.5	26.3	32.3	39.9	51	32.3	42.7	54.9	71.6
	23.3	28.6	35.1	43.5	55.7	43	55.7	71.7	93.9
	26.3	33.1	40.8	50.9	65.8	62	85.5	118.5	145.2
	29.5	37.8	46.7	58.6	76.1	90.7	132.1	175.7	218.7
	33.3	43.6	54	68.2	89.1	147.5	209.5	279.2	347.7
	14	17	20.8	25.6	32.7	20.8	25.6	34.2	41.8
	16.7	20.7	25.4	31.5	40.4	33.8	43.6	60.7	71.5
	18.6	23.4	28.8	35.9	46.3	46.3	65.8	82.9	107.6
	20.8	26.6	32.0	41.1	53.3	69.6	97.2	129.7	162.8
	23.3	30.5	37.6	47.5	62	108.9	158.4	207.6	259.9

$RRdc25_{i,j} := Rdc25_i$ $\quad YYc_{i,j} := Yc_i$ Converts vector into matrix.

Tc := 90 conductor temperature, deg. C (see DBD-EE-52)

Ta := 50 ambient temperature, deg. C (see DBD-EE-52)

Cable ampacity of Thermolag 330-660 Wrapped Cable in Free Air

$$IampN_{i,j} := \sqrt{(Tc - Ta) \cdot \frac{234.5 + 25}{\left[Rthl_{i,j} \cdot RRdc25_{i,j} \cdot \left[1 + YYc_{i,j}\right]\right] \cdot (234.5 + Tc)}}$$

Source: Reference 3 (Nahr-McGrath, equation 9, with Rthl = Rca', delta TD = 0, Rdc expressed at temperature Tc).

Cable Ampacity of Wrapped Cable in Free Air

IampN =

No. of cables / Conduit Size									
1	2	3	5	8	3"	4"	5"	6"	
367	344	312	285	255	367	367	367	344	1/C-500,8 KV
297	278	252	230	206	297	297	278	252	1/C-350,8 KV
222	207	188	171	153	222	222	207	170	1/C-4/0,8 KV
441	411	371	336	299	441	441	411	411	1/C-750,600 V
348	322	290	263	234	348	348	322	261	1/C-500
280	258	233	210	187	280	258	233	210	1/C-350
203	185	167	150	133	185	150	145	130	1/C-4/0
152	138	124	111	98	124	111	98	88	1/C-2/0
203	185	167	150	133	203	185	150	145	TRI-4/0
152	138	124	111	98	138	124	111	98	TRI-2/0
97	87	78	70	61	70	63	56	50	TRI-2AWG
74	67	61	55	48	61	53	47	41	3/C-4AWG
57	51	46	42	37	42	37	32	26	3/C-6AWG
42	38	34	30	27	28	23	20	18	3/C-8AWG
32	28	25	22	20	18	15	13	12	3/C-10AWG
24	21	19	17	14	11	9	8	7	3/C-12AWG
116	106	95	86	76	95	86	74	67	2/C-2AWG
67	60	54	49	43	47	41	35	32	2/C-6AWG
50	45	40	36	32	32	27	24	21	2/C-8AWG
38	33	30	27	24	21	17	15	13	2/C-10AWG
28	25	22	20	17	13	11	9	8	2/C-12AWG

Iampn expressed to one decimal place

$$IampN = \begin{bmatrix} 366.6 & 344.2 & 312.3 & 284.8 & 254.9 & 366.6 & 366.6 & 366.6 & 344.2 \\ 297 & 278.1 & 252.4 & 230 & 205.7 & 297 & 297 & 278.1 & 252.4 \\ 221.7 & 206.8 & 187.8 & 171 & 152.9 & 221.7 & 221.7 & 206.8 & 170 \\ 440.8 & 411 & 370.7 & 336.2 & 299.3 & 440.8 & 440.8 & 411 & 411 \\ 348 & 322.3 & 290.4 & 262.8 & 233.5 & 348 & 348 & 322.3 & 261.2 \\ 279.9 & 258.2 & 232.6 & 210.2 & 186.5 & 279.9 & 258.2 & 232.6 & 210.2 \\ 203 & 185.3 & 166.6 & 150 & 132.6 & 185.3 & 149.8 & 145.2 & 129.8 \\ 151.9 & 137.9 & 124 & 111.4 & 98.4 & 124 & 111.4 & 98.4 & 88.3 \\ 203 & 185.3 & 166.6 & 150 & 132.6 & 203 & 185.3 & 149.8 & 145.2 \\ 151.9 & 137.9 & 124 & 111.4 & 98.4 & 137.9 & 124 & 111.4 & 98.4 \\ 96.7 & 86.7 & 77.7 & 69.5 & 61.1 & 69.8 & 62.9 & 56.2 & 49.7 \\ 74.4 & 67.3 & 60.7 & 54.6 & 48.3 & 60.7 & 52.8 & 46.5 & 40.8 \\ 56.8 & 51.2 & 46.2 & 41.5 & 36.7 & 41.7 & 36.7 & 32.3 & 28.2 \\ 42.3 & 37.7 & 34 & 30.4 & 26.8 & 27.6 & 23.5 & 19.9 & 18 \\ 31.7 & 28 & 25.2 & 22.5 & 19.7 & 18.1 & 15 & 13 & 11.6 \\ 23.6 & 20.7 & 18.6 & 16.5 & 14.4 & 11.2 & 9.4 & 8.2 & 7.3 \\ 116.3 & 105.5 & 95.4 & 86 & 76.1 & 95.4 & 86 & 74.4 & 67.3 \\ 66.9 & 60.1 & 54.3 & 48.8 & 43 & 47.1 & 41.4 & 35.1 & 32.4 \\ 50.3 & 44.8 & 40.6 & 36.2 & 31.9 & 31.9 & 26.8 & 23.8 & 20.9 \\ 37.7 & 33.4 & 30.1 & 26.8 & 23.6 & 20.6 & 17.5 & 15.1 & 13.5 \\ 28.3 & 24.7 & 22.2 & 19.8 & 17.3 & 13.1 & 10.8 & 9.5 & 8.5 \end{bmatrix}$$

The following produces a rounded up/down set of cable ampacity to the nearest whole number for cable ampacity comparison purposes.

$$CI_{i,j} := ceil\left[IampN_{i,j}\right]$$

$$FI_{i,j} := floor\left[IampN_{i,j}\right]$$

$$IampNRd_{i,j} := if\left[IampN_{i,j} - FI_{i,j} < 0.5, FI_{i,j}, CI_{i,j}\right]$$

Cable ampacity of thermolagged cable-3/8 inch product in Free Air: template 2"

$$IampNRd = \begin{bmatrix} 367 & 344 & 312 & 285 & 255 & 367 & 367 & 367 & 344 \\ 297 & 278 & 252 & 230 & 206 & 297 & 297 & 278 & 252 \\ 222 & 207 & 188 & 171 & 153 & 222 & 222 & 207 & 170 \\ 441 & 411 & 371 & 336 & 299 & 441 & 441 & 411 & 411 \\ 348 & 322 & 290 & 263 & 234 & 348 & 348 & 322 & 261 \\ 280 & 258 & 233 & 210 & 187 & 280 & 258 & 233 & 210 \\ 203 & 185 & 167 & 150 & 133 & 135 & 150 & 145 & 130 \\ 152 & 138 & 124 & 111 & 98 & 124 & 111 & 98 & 88 \\ 203 & 185 & 167 & 150 & 133 & 203 & 185 & 150 & 145 \\ 152 & 138 & 124 & 111 & 98 & 138 & 124 & 111 & 98 \\ 97 & 87 & 78 & 70 & 61 & 70 & 63 & 56 & 50 \\ 74 & 67 & 61 & 55 & 48 & 61 & 53 & 47 & 41 \\ 57 & 51 & 46 & 42 & 37 & 42 & 37 & 32 & 28 \\ 42 & 38 & 34 & 30 & 27 & 28 & 23 & 20 & 18 \\ 32 & 28 & 25 & 22 & 20 & 18 & 15 & 13 & 12 \\ 24 & 21 & 19 & 17 & 14 & 11 & 9 & 8 & 7 \\ 116 & 106 & 95 & 86 & 76 & 95 & 86 & 74 & 67 \\ 67 & 60 & 54 & 49 & 43 & 47 & 41 & 35 & 32 \\ 50 & 45 & 40 & 36 & 32 & 32 & 27 & 24 & 21 \\ 38 & 33 & 30 & 27 & 24 & 21 & 17 & 15 & 13 \\ 28 & 25 & 22 & 20 & 17 & 13 & 11 & 9 & 8 \end{bmatrix}$$

WRITEPRN(iampn prn) := IampN This saves Iamp in an ASCII file for use in template Attachment G3

WRITEPRN(iampnrd prn) := IampNRd

This templates compares the ampacity of thermolagged cables in free air with those of thermolagged raceway: maintained spaced tray, ranmod filled tray, Thermolag 330-1 enclosed conduit (both box and shell design)

I. CABLE INPUT DATA

PRNPRECISION := 8

Iamp := READPRN(iampNRd)

N := READPRN(N) nn' := READPRN(NN)

The above files were produced by template Attachment G1 : N and nn'; Attachment G2: Iamp.

ORIGIN = 1 defines the upper corner of a matrix as 1,1

j := 1 ..9 i := 1 ..21

Cable Ampacity of Wrapped Cable in Free Air

No. of Cables / Conduit Size									
1	2	3	5	8	3"	4"	5"	6"	
367	344	312	285	255	367	367	357	344	1/C-500,8 KV
297	278	252	230	206	297	297	278	252	1/C-350,8 KV
222	207	188	171	153	222	222	207	170	1/C-4/0,8 KV
441	411	371	336	299	441	441	411	411	1/C-750,600 V
348	322	290	263	234	348	348	322	261	1/C-500
280	258	233	210	187	280	258	233	210	1/C-350
203	185	167	150	133	185	150	145	130	1/C-4/0
152	138	124	111	98	124	111	98	88	1/C-2/0
203	185	167	150	133	203	185	150	145	TRI-4/0
152	138	124	111	98	138	124	111	98	TRI-2/0
97	87	78	70	61	70	63	56	50	TRI-2AWG
74	67	61	55	48	61	53	47	41	3/C-4AWG
57	51	46	42	37	42	37	32	28	3/C-6AWG
42	38	34	30	27	28	23	20	18	3/C-8AWG
32	28	25	22	20	18	15	13	12	3/C-10AWG
24	21	19	17	14	11	9	8	7	3/C-12AWG
116	106	95	86	76	95	86	74	67	2/C-2AWG
67	60	54	49	43	47	41	35	32	2/C-6AWG
50	45	40	36	32	32	27	24	21	2/C-8AWG
38	33	30	27	24	21	17	15	13	2/C-10AWG
28	25	22	20	17	13	11	9	8	2/C-12AWG

Iamp =

Number of Cables in a Bundle

No. of Cables / Conduit Size								
1	2	3	5	8	3	4"	5"	6"	
1	2	3	5	8	1	1	1	2	1/C-500,8 KV
1	2	3	5	8	1	1	2	3	1/C-350,8 KV
1	2	3	5	8	1	1	2	4	1/C-4/0,8 KV
1	2	3	5	8	1	1	2	2	1/C-750,600 V
1	2	3	5	8	1	1	2	4	1/C-500
1	2	3	5	8	1	2	3	5	1/C-350
1	2	3	5	8	2	4	6	9	1/C-4/0
1	2	3	5	8	3	5	8	12	1/C-2/0
1	2	3	5	8	1	2	4	6	TRI-4/0
1	2	3	5	8	2	3	5	8	TRI-2/0
1	2	3	5	8	4	7	11	16	TRI-2AWG
1	2	3	5	8	3	6	10	15	3/C-4AWG
1	2	3	5	8	4	8	13	19	3/C-6AWG
1	2	3	5	8	7	13	21	30	3/C-8AWG
1	2	3	5	8	11	20	32	46	3/C-10AWG
1	2	3	5	8	18	32	51	72	3/C-12AWG
1	2	3	5	8	3	5	9	13	2/C-2AWG
1	2	3	5	8	6	10	16	23	2/C-6AWG
1	2	3	5	8	8	15	23	34	2/C-8AWG
1	2	3	5	8	13	22	35	51	2/C-10AWG
1	2	3	5	8	20	36	56	81	2/C-12AWG

N =

Note: 1/C cable are bundled in groups of three. Therefore, if N=3 then the actual number of cables for 1/C is 3 x 3 = 9

'Ampacity Comparison Between Free Air Thermoslagged Cables (3/8inch product in Free Air: template 2"

Number of Conductors in a Bundle

No. of Cables /					Conduit Size				
1	2	3	5	8	3	4"	5"	6"	
3	6	9	15	24	3	3	3	6	1/C-500,8 KV
3	6	9	15	24	3	3	6	9	1/C-350,8 KV
3	6	9	15	24	3	3	6	12	1/C-4/0,8 KV
3	6	9	15	24	3	3	6	6	1/C-750,600 V
3	6	9	15	24	3	3	6	12	1/C-500
3	6	9	15	24	3	6	9	15	1/C-350
3	6	9	15	24	6	12	18	27	1/C-4/0
3	6	9	15	24	9	15	24	36	1/C-2/0
3	6	9	15	24	3	6	12	18	TRI-4/0
3	6	9	15	24	6	9	15	24	TRI-2/0
3	6	9	15	24	12	21	33	48	TRI-2AWG
3	6	9	15	24	9	18	30	45	3/C-4AWG
3	6	9	15	24	12	24	39	57	3/C-6AWG
3	6	9	15	24	21	39	63	90	3/C-8AWG
3	6	9	15	24	33	60	96	138	3/C-10AWG
3	6	9	15	24	54	96	153	219	3/C-12AWG
2	4	6	10	16	6	10	18	26	2/C-2AWG
2	4	6	10	16	12	20	32	46	2/C-6AWG
2	4	6	10	16	16	30	46	68	2/C-8AWG
2	4	6	10	16	26	44	70	102	2/C-10AWG
2	4	6	10	16	40	72	112	162	2/C-12AWG

nn' =

Ampacities of Thermolagged Maintained Spaced Tray

Ampacity of thermolag covered 600 V cable with maintained spacing in a 50 C ambient see Reference 1 (DBD-EE-052) and Reference 18.

Development of Thermolagged Tray ampacities for 8 kV cable:

$$It := \begin{bmatrix} 515 \\ 386 \\ 265 \end{bmatrix}$$ 1/C-500, 8KV; 1/C-350, 8KV; 1/C-4/0, 8KV

Values obtained from Reference 18, Table 33 where depth > diameter.

$IthMS8kv := 0.90 \cdot 0.69 \cdot It$ where: 0.90 is multiplier for correcting ambient temperature from 40 C to 50 C (Ref. 18, page i).
0.69 is thermolag derating factor (Ref. 1).

$$IthMS8kv = \begin{bmatrix} 319.8 \\ 239.7 \\ 164.6 \end{bmatrix}$$

$$IthMS := \begin{bmatrix} 320 \\ 240 \\ 165 \\ 391 \\ 270 \\ 199 \\ 148 \\ 100 \\ 148 \\ 100 \\ 50 \\ 999 \\ 999 \\ 999 \\ 999 \\ 999 \\ 69 \\ 999 \\ 999 \\ 999 \\ 999 \end{bmatrix}$$

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-3/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

These ampacities were input from: 8 Kv Cable - calculated results of IthMS8kv shown above; 600 V cables - from DBD-EE-052. A value of 999 is entered when no ampacities are appropriate because the cables would not be installed in maintained spaced trays

$$IIthMS_{i,j} := IthMS_{i}$$

$$AMPCHK_{i,j} := if\left[IIthMS_{i,j} \le Iamp_{i,j}, 1, 0\right]$$

CHECK OF CABLE AMPACITY ADEQUACY
WITH MAINTAINED SPACING IN TRAY

Ampacity Comparison with MS Tray

AMPCHK

No of Cables /					Conduit Size				
1	2	3	5	8	3"	4"	5"	6"	
1	1	0	0	0	1	1	1	1	1/C-500,8 KV
1	1	1	0	0	1	1	1	1	1/C-350,8 KV
1	1	1	1	0	1	1	1	1	1/C-4/0,8 KV
1	1	0	0	0	1	1	1	1	1/C-750,600 V
1	1	1	0	0	1	1	1	0	1/C-500
_	1	1	1	0	1	1	1	1	1/C-350
1	1	1	1	0	1	1	0	0	1/C-4/0
1	1	1	1	0	1	1	0	0	1/C-2/0
1	1	1	1	0	1	1	1	0	TRI-4/0
1	1	1	1	0	1	1	1	0	TRI-2/0
1	1	1	1	1	1	1	1	1	TRI-2AWG
0	0	0	0	0	0	0	0	0	3/C-4AWG
0	0	0	0	0	0	0	0	0	3/C-6AWG
0	0	0	0	0	0	0	0	0	3/C-8AWG
0	0	0	0	0	0	0	0	0	3/C-10AWG
0	0	0	0	0	0	0	0	0	3/C-12AWG
1	1	1	1	1	1	1	1	0	2/C-2AWG
0	0	0	0	0	0	0	0	0	2/C-6AWG
0	0	0	0	0	0	0	0	0	2/C-8AWG
0	0	0	0	0	0	0	0	0	2/C-10AWG
0	0	0	0	0	0	0	0	0	2/C-12AWG

NOTE:
1 - Adequate cable ampacity
0 - Inadequate cable ampacity

$$CaLimit_{i,j} := if\left[AMPCHK_{i,j} \approx 1, \left[N_{i,j}\right], 0\right]$$

$$CaLimit_{i,j} := if\left[Iamp_{i,j} \approx 999, 0, CaLimit_{i,j}\right]$$

Limit of Number of Cable in Bundle:
Not to Exceed Ampacity of Cable in
MS Thermolagged Tray

CaLimit =

No. of Cables / Conduit Size								
1	2	3	5	8	3"	4"	5"	6"	
1	2	0	0	0	1	1	1	2	1/C-500,8 KV
1	2	3	0	0	1	1	2	3	1/C-350,8 KV
1	2	3	5	0	1	1	2	4	1/C-4/0,8 KV
1	2	0	0	0	1	1	2	2	1/C-750,600 V
1	2	3	0	0	1	1	2	0	1/C-500
1	2	3	5	0	1	2	3	5	1/C-350
1	2	3	5	0	2	4	0	0	1/C-4/0
1	2	3	5	0	3	5	0	0	1/C-2/0
1	2	3	5	0	1	2	4	0	TRI-4/0
1	2	3	5	0	2	3	5	0	TRI-2/0
1	2	3	5	8	4	7	11	16	TRI-2AWG
0	0	0	0	0	0	0	0	0	3/C-4AWG
0	0	0	0	0	0	0	0	0	3/C-6AWG
0	0	0	0	0	0	0	0	0	3/C-8AWG
0	0	0	0	0	0	0	0	0	3/C-10AWG
0	0	0	0	0	0	0	0	0	3/C-12AWG
1	2	3	5	8	3	5	9	0	2/C-2AWG
0	0	0	0	0	0	0	0	0	2/C-6AWG
0	0	0	0	0	0	0	0	0	2/C-8AWG
0	0	0	0	0	0	0	0	0	2/C-10AWG
0	0	0	0	0	0	0	0	0	2/C-12AWG

The limit to the number of cables under a wrap, use maximum number in a given row. Three 1/C cables are considered as one (1) 3/C cable.

Ampacities of Thermolagged Random Lay Tray

IthRS :=	999	1/C-500,8 KV	Ampacity of thermolag covered cable with random lay (no maintained spacing), see Reference 1 (DBD-EE-052)
	999	1/C-350,8 KV	
	999	1/C-4/0,8 KV	
	420	1/C-750,600 V	
	290	1/C-500	
	215	1/C-350	
	130	1/C-4/0	
	88	1/C-2/0	
	157	TRI-4/0	
	106	TRI-2/0	
	54	TRI-2AWG	
	44	3/C-4AWG	
	32	3/C-6AWG	
	20	3/C-8AWG	
	12	3/C-10AWG	
	8	3/C-12AWG	
	75	2/C-2AWG	
	36	2/C-6AWG	
	24	2/C-8AWG	
	15	2/C-10AWG	
	9	2/C-12AWG	

$$IIthRS_{i,j} := IthRS_{i}$$

$$AMPCHK_{i,j} := if\left[IIthRS_{i,j} \le Iamp_{i,j}, 1, 0\right]$$

Ampacity Comparison with Random TH-Tray

$$AMPCHK = \begin{array}{c} \begin{array}{ccccccccc} \multicolumn{5}{c}{\text{No. of Cables}} & \multicolumn{4}{c}{\text{Conduit Size}} & \\ 1 & 2 & 3 & 5 & 8 & 3" & 4" & 5" & 6" & \end{array} \\ \left[\begin{array}{ccccccccc} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \end{array}\right] \end{array} \begin{array}{l} \text{1/C-500,8 KV} \\ \text{1/C-350,8 KV} \\ \text{1/C-4/0,8 KV} \\ \text{1/C-750,600 V} \\ \text{1/C-500} \\ \text{1/C-350} \\ \text{1/C-4/0} \\ \text{1/C-2/0} \\ \text{TRI-4/0} \\ \text{TRI-2/0} \\ \text{TRI-2AWG} \\ \text{3/C-4AWG} \\ \text{3/C-6AWG} \\ \text{3/C-8AWG} \\ \text{3/C-10AWG} \\ \text{3/C-12AWG} \\ \text{2/C-2AWG} \\ \text{2/C-6AWG} \\ \text{2/C-8AWG} \\ \text{2/C-10AWG} \\ \text{2/C-12AWG} \end{array}$$

NOTE:
1 - Adequate cable ampacity
0 - Inadequate cable ampacity

$$CaLimit_{i,j} := if\left[AMPCHK_{i,j} = 1, \left[\left[N_{i,j}\right]\right], 0\right]$$

$$CaLimit_{i,j} := if\left[Iamp_{i,j} = 999, 0, CaLimit_{i,j}\right]$$

Limit of Number of Cable in Bundle:
Not to Exceed Ampacity of Cable in
Random Lay Thermolagged Tray

CaLimit =

No. of Cables / Conduit Size								
1	2	3	5	8	3"	4"	5"	6"	
0	0	0	0	0	0	0	0	0	1/C-500,8 KV
0	0	0	0	0	0	0	0	0	1/C-350,8 KV
0	0	0	0	0	0	0	0	0	1/C-4/0,8 KV
1	0	0	0	0	1	1	0	0	1/C-750,600 V
1	2	3	0	0	1	1	2	0	1/C-500
1	2	3	0	0	1	2	3	0	1/C-350
1	2	3	5	8	2	4	6	9	1/C-4/0
1	2	3	5	8	3	5	8	12	1/C-2/0
1	2	3	0	0	1	2	0	0	TRI-4/0
1	2	3	5	0	2	3	5	0	TRI-2/0
1	2	3	5	8	4	7	11	0	TRI-2AWG
1	2	3	5	8	3	6	10	0	3/C-4AWG
1	2	3	5	8	4	8	13	0	3/C-6AWG
1	2	3	5	8	7	13	21	0	3/C-8AWG
1	2	3	5	8	11	20	32	46	3/C-10AWG
1	2	3	5	8	18	32	51	0	3/C-12AWG
1	2	3	5	8	3	5	0	0	2/C-2AWG
1	2	3	5	8	6	10	0	0	2/C-6AWG
1	2	3	5	8	8	15	23	0	2/C-8AWG
1	2	3	5	8	13	22	35	0	2/C-10AWG
1	2	3	5	8	20	36	56	0	2/C-12AWG

The limit to the number of cables under a wrap, use maximum number in a given row. Three 1/C cables are considered as one (1) 3/C cable.

The following equations produce multipying factors for multiple cables in a conduit

$CDamp_{i,j} := 0$

$CDamp_{i,j} := if\left[nn'_{i,j} < 3.01, 1, CDamp_{i,j}\right]$

$CDamp_{i,j} := if\left[nn'_{i,j} > 3.01, 0.8, CDamp_{i,j}\right]$

$CDamp_{i,j} := if\left[nn'_{i,j} > 6.01, 0.7, CDamp_{i,j}\right]$

$CDamp_{i,j} := if\left[nn'_{i,j} > 24.01, 0.6, CDamp_{i,j}\right]$

$CDamp_{i,j} := if\left[nn'_{i,j} > 42.1, 0.5, CDamp_{i,j}\right]$

Conduit Ampacity Multiplying Factors
For More than 3 conductors in a Conduit

$CDamp =$

No. of Cables / Conduit Size									NEC multi-plying factor for multiple conductors in conduit
1	2	3	5	8	3"	4"	5"	6"	
1	0.8	0.7	0.7	0.7	1	1	1	0.8	1/C-500,8 KV
1	0.8	0.7	0.7	0.7	1	1	0.8	0.7	1/C-350,8 KV
1	0.8	0.7	0.7	0.7	1	1	0.8	0.7	1/C-4/0,8 KV
1	0.8	0.7	0.7	0.7	1	1	0.8	0.8	1/C-750,600 V
1	0.8	0.7	0.7	0.7	1	1	0.8	0.7	1/C-500
1	0.8	0.7	0.7	0.7	1	0.8	0.7	0.7	1/C-350
1	0.8	0.7	0.7	0.7	0.8	0.7	0.7	0.6	1/C-4/0
1	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.6	1/C-2/0
1	0.8	0.7	0.7	0.7	1	0.8	0.7	0.7	TRI-4/0
1	0.8	0.7	0.7	0.7	0.8	0.7	0.7	0.7	TRI-2/0
1	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.5	TRI-2AWG
1	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.5	3/C-4AWG
1	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.5	3/C-6AWG
1	0.8	0.7	0.7	0.7	0.7	0.6	0.5	0.5	3/C-8AWG
1	0.8	0.7	0.7	0.7	0.6	0.5	0.5	0.5	3/C-10AWG
1	0.8	0.7	0.7	0.7	0.5	0.5	0.5	0.5	3/C-12AWG
1	0.8	0.8	0.7	0.7	0.8	0.7	0.7	0.6	2/C-2AWG
1	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.5	2/C-6AWG
1	0.8	0.8	0.7	0.7	0.7	0.6	0.5	0.5	2/C-8AWG
1	0.8	0.8	0.7	0.7	0.6	0.5	0.5	0.5	2/C-10AWG
1	0.8	0.8	0.7	0.7	0.6	0.5	0.5	0.5	2/C-12AWG

Ampacities of Cable in Themolagged Conduit(Box Design)

Reference 1 (DBD-EE-052)
ampacity for three conductors
in conduit, enclosed in
Thermolag 330-660, Box Design

IthCD :=	338	1/C-500,8 KV
	277	1/C-350,8 KV
	205	1/C-4/0,8 KV
	428	1/C-750,600 V
	341	1/C-500
	275	1/C-350
	199	1/C-4/0
	146	1/C-2/0
	199	TRI-4/0
	146	TRI-2/0
	93	TRI-2AWG
	65	3/C-4AWG
	49	3/C-6AWG
	37	3/C-8AWG
	26	3/C-10AWG
	20	3/C-12AWG
	88	2/C-2AWG
	49	2/C-6AWG
	37	2/C-8AWG
	26	2/C-10AWG
	20	2/C-12AWG

$$IIthCD_{i,j} := CDamp_{i,j} \cdot IthCD_{i}$$

Thermolagged Ampacities in Conduit(Box Design)

No. of Cables / Conduit Size									
1	2	3	5	8	3"	4"	5"	6"	
338	270	237	237	237	338	338	338	270	1/C-500,8 KV
277	222	194	194	194	277	277	222	194	1/C-350,8 KV
205	164	144	144	144	205	205	164	144	1/C-4/0,8 KV
428	342	300	300	300	428	428	342	342	1/C-750,600 V
341	273	239	239	239	341	341	273	239	1/C-500
275	220	193	193	193	275	220	193	193	1/C-350
199	159	139	139	139	159	139	139	119	1/C-4/0
146	117	102	102	102	102	102	102	88	1/C-2/0
199	159	139	139	139	199	159	139	139	TRI-4/0
146	117	102	102	102	117	102	102	102	TRI-2/0
93	74	65	65	65	65	65	56	47	TRI-2*KG
65	52	46	46	46	46	46	39	33	3/C-4AWG
49	39	34	34	34	34	34	29	25	3/C-6AWG
37	30	26	26	26	26	22	19	19	3/C-8AWG
26	21	18	18	18	16	13	13	13	3/C-10AWG
20	16	14	14	14	10	10	10	10	3/C-12AWG
88	70	70	62	62	70	62	62	53	2/C-2AWG
49	39	39	34	34	34	34	29	25	2/C-6AWG
37	30	30	26	26	26	22	19	19	2/C-8AWG
26	21	21	18	18	16	13	13	13	2/C-10AWG
20	16	16	14	14	12	10	10	10	2/C-12AWG

$$AMPCHK_{i,j} := if\left[IIthCD_{i,j} \le Iamp_{i,j}, 1, 0\right]$$

Ampacity comparison equation

Ampacity Comparison with Thermolagged Conduit (Box Design)

AMPCHK :=

No. of Cables / Conduit Size									
1	2	3	5	3	8	4"	5"	6"	
1	1	1	1	1	1	1	1	1	1/C-500,8 KV
1	1	1	1	1	1	1	1	1	1/C-350,8 KV
1	1	1	1	1	1	1	1	1	1/C-4/0,8 KV
1	1	1	1	0	1	1	1	1	1/C-750,600 V
1	1	1	1	0	1	1	1	1	1/C-500
1	1	1	1	0	1	1	1	1	1/C-350
1	1	1	1	0	1	1	1	1	1/C-4/0
1	1	1	1	0	1	1	0	1	1/C-2/0
1	1	1	1	0	1	1	1	1	TRI-4/0
1	1	1	1	0	1	1	1	0	TRI-2/0
1	1	1	1	0	1	0	1	1	TRI-2AWG
1	1	1	1	1	1	1	1	1	3/C-4AWG
1	1	1	1	1	1	1	1	1	3/C-6AWG
1	1	1	1	1	1	1	1	0	3/C-8AWG
1	1	1	1	1	1	1	1	0	3/C-10AWG
1	1	1	1	1	1	0	0	0	3/C-12AWG
1	1	1	1	1	1	1	1	1	2/C-2AWG
1	1	1	1	1	1	1	1	1	2/C-6AWG
1	1	1	1	1	1	1	1	1	2/C-8AWG
1	1	1	1	1	1	1	1	1	2/C-10AWG
1	1	1	1	1	1	1	0	0	2/C-12AWG

NOTE:
1 - Adequate cable ampacity
0 - Inadequate cable ampacity

$$CaLimit_{i,j} := if\left[AMPCHK_{i,j} \approx 1, \left[N_{i,j}\right], 0\right]$$

$$CaLimit_{i,j} := if\left[Iamp_{i,j} \approx 999, 0, CaLimit_{i,j}\right]$$

Limit of Number of Cable in Bundle:
Not to Exceed Ampacity of Cable in
Thermolagged Conduit (Box Design)

No. of Cables / Conduit Size									
1	2	3	5	8	3"	4"	5"	6"	
1	2	3	5	8	1	1	1	2	1/C-500,8 KV
1	2	3	5	8	1	1	2	3	1/C-350,8 KV
1	2	3	5	8	1	1	2	4	1/C-4/0,8 KV
1	2	3	5	0	1	1	2	2	1/C-750,600 V
1	2	3	5	0	1	1	2	4	1/C-500
1	2	3	5	0	1	2	3	5	1/C-350
1	2	3	5	0	2	4	6	9	1/C-4/0
1	2	3	5	0	3	5	0	12	1/C-2/0
1	2	3	5	0	1	2	4	6	TRI-4/0
1	2	3	5	0	2	3	5	0	TRI-2/0
1	2	3	5	0	4	0	11	16	TRI-2AWG
1	2	3	5	8	3	6	10	15	3/C-4AWG
1	2	3	5	8	4	8	13	19	3/C-6AWG
1	2	3	5	8	7	13	21	0	3/C-8AWG
1	2	3	5	8	11	20	32	0	3/C-10AWG
1	2	3	5	8	18	0	0	0	3/C-12AWG
1	2	3	5	8	3	5	9	13	2/C-2AWG
1	2	3	5	8	6	10	16	23	2/C-6AWG
1	2	3	5	8	8	15	23	34	2/C-8AWG
1	2	3	5	8	13	22	35	51	2/C-10AWG
1	2	3	5	8	20	35	0	0	2/C-12AWG

CaLimit =

The limit to the number of cables under a wrap, use maximum number in a given row. Three 1/C cables are considered as one (1) 3/C cable.

Ampacities of Cable in Thermolagged Conduit (Shell Design)

$$IIthCDshell := \frac{0.925}{0.8} \cdot IIthCD$$

Reference 1 (DBD-EE-052, Rev 3 page 22,Section 4.1.2.6 g.) provides relative factors for shell vs box design.

Thermolagged Ampacities in Conduit (Shell Design)

IIthCDshell =

No. of Cables / Conduit Size									
1	2	3	5	8	3"	4"	5"	6"	
391	313	274	274	274	391	391	391	313	1/C-500,8 KV
320	256	224	224	224	320	320	256	224	1/C-350,8 KV
237	190	166	166	166	237	237	190	166	1/C-4/0,8 KV
495	396	346	346	346	495	495	396	396	1/C-750,600 V
394	315	276	276	276	394	394	315	276	1/C-500
318	254	223	223	223	318	254	223	223	1/C-350
230	184	161	161	161	184	161	161	138	1/C-4/0
169	135	118	118	118	118	118	118	101	1/C-2/0
230	184	161	161	161	230	184	161	161	TRI-4/0
169	135	118	118	118	135	118	118	118	TRI-2/0
108	86	75	75	75	75	75	65	54	TRI-2AWG
75	60	53	53	53	53	53	45	38	3/C-4AWG
57	45	40	40	40	40	40	34	28	3/C-6AWG
43	34	30	30	30	30	26	21	21	3/C-8AWG
30	24	21	21	21	18	15	15	15	3/C-10AWG
23	19	16	16	16	12	12	12	12	3/C-12AWG
102	81	81	71	71	81	71	71	61	2/C-2AWG
57	45	45	40	40	40	40	34	28	2/C-6AWG
43	34	34	30	30	30	26	21	21	2/C-8AWG
30	24	24	21	21	18	15	15	15	2/C-10AWG
23	19	19	16	16	14	12	12	12	2/C-12AWG

$$AMPCHK_{i,j} := if\left[IIthCDshell_{i,j} \le Iamp_{i,j}, 1, 0\right]$$

Ampacity Comparison with Thermolagged Conduit (Shell Design)

No. of Cables / Conduit Size									
1	2	3	5	8	3"	4"	5"	6"	
0	1	1	1	0	0	0	0	1	1/C-500,8 KV
0	1	1	1	0	0	0	1	1	1/C-350,8 KV
0	1	1	1	0	0	0	1	1	1/C-4/0,8 KV
0	1	1	0	0	0	0	1	1	1/C-750,600 V
0	1	1	0	0	0	0	1	0	1/C-500
0	1	1	0	0	0	1	1	0	1/C-350
0	1	1	0	0	1	0	0	0	1/C-4/0
0	1	1	0	0	1	0	0	0	1/C-2/0
0	1	1	0	0	0	1	0	0	TRI-4/0
0	1	1	0	0	1	1	0	0	TRI-2/0
0	1	1	0	0	0	0	0	0	TRI-2AWG
0	1	1	1	0	1	1	1	1	3/C-4AWG
1	1	1	1	0	1	0	0	0	3/C-6AWG
0	1	1	1	0	0	0	0	0	3/C-8AWG
1	1	1	1	0	0	0	0	0	3/C-10AWG
1	1	1	1	0	0	0	0	0	3/C-12AWG
1	1	1	1	1	1	1	1	1	2/C-2AWG
1	1	1	1	1	1	1	1	1	2/C-6AWG
1	1	1	1	1	1	1	1	0	2/C-8AWG
1	1	1	1	1	1	1	0	0	2/C-10AWG
1	1	1	1	1	0	0	0	0	2/C-12AWG

NOTE:
1 - Adequate cable ampacity
0 - Inadequate cable ampacity

$$CaLimit_{i,j} := if\left[AMPCHK_{i,j} \approx 1, \left[N_{i,j}\right], 0\right]$$

$$CaLimit_{i,j} := if\left[Iamp_{i,j} \approx 999, 0, CaLimit_{i,j}\right]$$

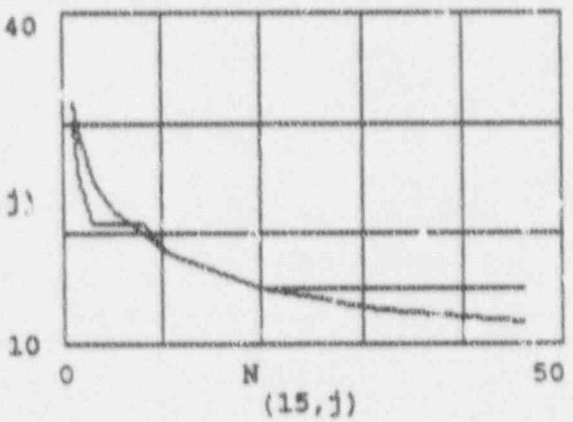
Limit of Number of Cable in Bundle:
Not to Exceed Ampacity of Cable in
Thermolagged Conduit (Shell Design)

CaLimit =

No. of Cables / Conduit Size								
1	2	3	5	8	3	4"	5"	6"	
0	2	3	5	0	0	0	0	2	1/C-500,8 KV
0	2	3	5	0	0	0	2	3	1/C-350,8 KV
0	2	3	5	0	0	0	2	4	1/C-4/0,8 KV
0	2	3	0	0	0	0	2	2	1/C-750,600 V
0	2	3	0	0	0	0	2	0	1/C-500
0	2	3	0	0	0	2	3	0	1/C-350
0	2	3	0	0	2	0	0	0	1/C-4/0
0	2	3	0	0	3	0	0	0	1/C-2/0
0	2	3	0	0	0	2	0	0	TRI-4/0
0	2	3	0	0	2	3	0	0	TRI-2/0
0	2	3	0	0	0	0	0	0	TRI-2AWG
0	2	3	5	0	3	6	10	15	3/C-4AWG
1	2	3	5	0	4	0	0	0	3/C-6AWG
0	2	3	5	0	0	0	0	0	3/C-8AWG
1	2	3	5	0	0	0	0	0	3/C-10AWG
1	2	3	5	0	0	0	0	0	3/C-12AWG
1	2	3	5	8	3	5	9	13	2/C-2AWG
1	2	3	5	8	6	10	16	23	2/C-6AWG
1	2	3	5	8	8	15	23	0	2/C-8AWG
1	2	3	5	8	13	22	0	0	2/C-10AWG
1	2	3	5	8	0	0	0	0	2/C-12AWG

The limit to the number of cables under a wrap. use maximum number in a given row. Three 1/C cables are considered as one (1) 3/C cable.

IIthCDshell(15,j) , Iamp(15,j)



PRNPRECISION := 8

IampN := READPRN(IampN_prn) Developed in Attachment G2

Iamp := READPRN(Iamp_prn) Developed in Attachment B2

Cable ampacity from Attachment B2
5/16 inch product

Iamp =

1	2	3	5	3"	4"	5"	6"
369.35	348.2	316.24	288.84	369.35	369.35	369.35	348.2
299.07	281.15	255.4	233.13	299.07	299.07	281.15	255.4
223	208.89	189.85	173.18	223	223	208.89	191.92
444.2	416	375.43	341.06	444.2	444.2	416	416
350.32	325.87	293.8	266.3	350.32	350.32	325.87	264.28
281.59	260.76	235.04	212.77	281.59	260.76	235.04	212.77
203.9	186.87	168.1	151.58	186.87	151.12	146.83	131.45
152.51	138.96	124.97	112.49	124.97	112.49	99.48	89.38
203.9	186.87	168.1	151.58	203.9	186.87	151.12	146.83
152.51	138.96	124.97	112.49	138.96	124.97	112.49	99.48
96.98	87.14	78.2	70.05	70.28	63.45	56.75	50.31
74.63	67.64	61.08	55.02	61.08	53.22	47.01	41.21
56.9	51.4	46.43	41.79	41.96	36.96	32.64	28.55
42.43	37.89	34.13	30.58	27.74	23.68	20.14	18.21
31.74	28.1	25.28	22.58	18.19	15.1	13.11	11.77
23.66	20.71	18.61	16.57	11.3	9.5	8.24	7.4
116.68	106.15	95.99	86.62	95.99	86.62	75.1	68.03
67.03	60.37	54.54	49.06	47.41	41.78	35.48	32.75
50.35	44.99	40.6	36.41	32.1	26.98	24.08	21.16
37.8	33.46	30.15	26.96	20.77	17.6	15.26	13.64
28.3	24.77	22.28	19.85	13.15	10.93	9.56	8.55

Cable ampacity from Attachment G2
3/8 inch product

	1	2	3	5	8	3"	4"	5"	6"
IampN =	366.6	344.2	312.3	284.8	254.9	366.6	366.6	366.6	344.2
	297	278.1	252.4	230	205.7	297	297	278.1	252.4
	221.7	206.8	187.8	171	152.9	221.7	221.7	206.8	170
	440.8	411	370.7	336.2	299.3	440.8	440.8	411	411
	348	322.3	290.4	262.8	233.5	348	348	322.3	261.2
	279.9	258.2	232.6	210.2	186.5	279.9	258.2	232.6	210.2
	203	185.3	166.6	150	132.6	185.3	149.8	145.2	129.8
	151.9	137.9	124	111.4	98.4	124	111.4	98.4	80.3
	203	185.3	166.6	150	132.6	203	185.3	149.8	145.2
	151.9	137.9	124	111.4	98.4	137.9	124	111.4	98.4
	96.7	86.7	77.7	69.5	61.1	69.8	62.9	56.2	49.7
	74.4	67.3	60.7	54.6	48.3	60.7	52.8	46.5	40.8
	56.8	51.2	46.2	41.5	36.7	41.7	36.7	32.3	28.2
	42.3	37.7	34	30.4	26.8	27.6	23.5	19.9	18
	31.7	28	25.2	22.5	19.7	18.1	15	13	11.6
	23.6	20.7	18.6	16.5	14.4	11.2	9.4	8.2	7.3
	116.3	105.5	95.4	86	76.1	95.4	86	74.4	67.3
	66.9	60.1	54.3	48.8	43	47.1	41.4	35.1	32.4
	50.3	44.8	40.4	36.2	31.9	31.9	26.8	23.8	20.9
	37.7	33.4	30.1	26.8	23.6	20.6	17.5	15.1	13.5
	28.3	24.7	22.2	19.8	17.3	13.1	10.8	9.5	8.5

Note: that the above matrix has an extra column, i.e data on 8 cables in a bundle. This column will be removed for comparison purposes.

$IampN'^{\langle 1\rangle} := IampN^{\langle 1\rangle}$ $IampN'^{\langle 2\rangle} := IampN^{\langle 2\rangle}$ $IampN'^{\langle 3\rangle} := IampN^{\langle 3\rangle}$

$IampN'^{\langle 1\rangle} := IampN^{\langle 4\rangle}$ $IampN'^{\langle 5\rangle} := IampN^{\langle 6\rangle}$ $IampN'^{\langle 6\rangle} := IampN^{\langle 7\rangle}$

$IampN'^{\langle 7\rangle} := IampN^{\langle 8\rangle}$ $IampN'^{\langle 8\rangle} := IampN^{\langle 9\rangle}$

"Comparison of Ampacities for 5/16" vs 3/8" Thermolag product"

	1	2	3	5	3"	4"	5"	6"
IampN' =	366.6	344.2	312.3	284.8	366.6	366.6	366.6	344.2
	297	278.1	252.4	230	297	297	278.1	252.4
	221.7	206.8	187.8	171	221.7	221.7	206.8	170
	440.8	411	370.7	336.2	440.8	440.8	411	411
	348	322.3	290.4	262.8	348	348	322.3	261.2
	279.9	258.2	232.6	210.2	279.9	258.2	232.6	210.2
	203	185.3	166.6	150	185.3	149.8	145.2	129.8
	151.9	137.9	124	111.4	124	111.4	98.4	88.3
	203	185.3	166.6	150	203	185.3	149.8	145.2
	151.9	137.9	124	111.4	137.9	124	111.4	98.4
	96.7	86.7	77.7	69.5	69.8	62.9	56.2	49.7
	74.4	67.3	60.7	54.6	60.7	52.8	46.5	40.8
	56.8	51.2	46.2	41.5	41.7	36.7	32.3	28.2
	42.3	37.7	34	30.4	27.6	23.5	19.9	18
	31.7	28	25.2	22.5	18.1	15	13	11.6
	23.6	20.7	18.6	16.5	11.7	9.4	8.2	7.3
	116.3	105.5	95.4	86	95.4	86	74.4	67.2
	66.9	60.1	54.3	48.8	47.1	41.4	35.1	32.4
	50.3	44.8	40.4	36.2	31.9	26.8	23.8	20.9
	37.7	33.4	30.1	26.8	20.6	17.5	15.1	13.5
	28.3	24.7	22.2	19.8	13.1	10.8	9.5	8.5

ORIGIN ≡ 1

J := 1 ..8 I := 1 ..21

$$DIFF\%_{I,J} := \frac{Iamp_{I,J} - IampN'_{I,J}}{Iamp_{I,J}} \cdot 100$$

Ampacity - in % - Reduction for Use of 3/8 inch Thermolag vs 5/16 inch Thermolag

	No. of Cables / Conduit Size								
	1	2	3	5	3"	4"	5"	6"	
DIFF% =	0.74	1.16	1.23	1.39	0.74	0.74	0.74	1.16	1/C-500, 8kV
	0.68	1.09	1.16	1.32	0.68	0.68	1.09	1.16	1/C-350, 8kV
	0.6	1	1.07	1.24	0.6	0.6	1	1.1	1/C-4/O, 8 kV
	0.76	1.2	1.26	1.41	0.76	0.76	1.2	1.2	1/C-750, 600 V
	0.66	1.09	1.14	1.3	0.66	0.66	1.09	1.15	1/C-500
	0.58	1	1.06	1.22	0.58	1	1.06	1.22	1/C-350
	0.47	0.85	0.9	1.05	0.85	0.9	1.13	1.26	1/C-4/O
	0.4	0.74	0.8	0.95	0.8	0.95	1.09	1.24	1/C-2/O
	0.47	0.85	0.9	1.05	0.47	0.85	0.9	1.13	TRI-4/0
	0.4	0.74	0.8	0.95	0.74	0.8	0.95	1.09	TRI-2/O
	0.29	0.57	0.61	0.74	0.61	0.81	1	1.11	TRI-2 AWG
	0.27	0.55	0.6	0.73	0.6	0.8	0.99	1.11	3/C-4 AWG
	0.24	0.49	0.54	0.66	0.54	0.79	0.98	1.08	3/C-6
	0.19	0.4	0.44	0.55	0.61	0.84	0.97	1.1	3/C-8
	0.16	0.33	0.36	0.45	0.66	0.84	0.99	1.11	3/C-10
	0.12	0.26	0.29	0.36	0.66	0.84	1	1.11	3/C-12
	0.29	0.57	0.62	0.76	0.62	0.76	0.96	1.09	2/C-2
	0.21	0.44	0.48	0.6	0.66	0.84	0.96	1.13	2/C-6
	0.18	0.37	0.41	0.51	0.62	0.84	1	1.11	2/C-8
	0.14	0.3	0.33	0.43	0.68	0.83	0.98	1.11	2/C-10
	0.11	0.24	0.27	0.34	0.67	0.84	0.98	1.11	2/C-12

min(DIFF%) = 0.115 MINIMUM % DIFFERENCE

max(DIFF%) = 1.414 MAXIMUM % DIFFERENCE

For Reviewer's ability to check the above difference calculation, the two ampacity matrix's 8th columns are shown below to 3 significant digits

$$IampN'^{\langle 8 \rangle} = \begin{bmatrix} 344.163 \\ 252.429 \\ 170.039 \\ 411.014 \\ 261.239 \\ 210.181 \\ 129.794 \\ 88.269 \\ 145.176 \\ 98.403 \\ 49.747 \\ 40.757 \\ 28.246 \\ 18.011 \\ 11.637 \\ 7.314 \\ 67.284 \\ 32.38 \\ 20.923 \\ 13.487 \\ 8.459 \end{bmatrix} \qquad Iamp^{\langle 8 \rangle} = \begin{bmatrix} 348.199 \\ 255.4 \\ 171.922 \\ 415.999 \\ 264.283 \\ 212.766 \\ 131.448 \\ 89.38 \\ 146.83 \\ 99.485 \\ 50.306 \\ 41.212 \\ 28.553 \\ 18.211 \\ 11.768 \\ 7.396 \\ 68.028 \\ 32.748 \\ 21.159 \\ 13.638 \\ 8.553 \end{bmatrix}$$

RUBIN FELDMAN, P.E.
President

17 November 1989

Mr. John Wawrzeniak
Impell Corporation
FM Road 56
5 Miles Northwest of Glen Rose
Glen Rose, Texas 76043

ACCEPTABLE MARGINAL QUALITY
INIT AJR DATE 12/2/92

Reference: Texas Utilities Purchase Order No. 665-71871

Dear Mr. Wawrzeniak:

The following is the information requested regarding certain properties of the THERMO-LAG 330-660 Flexi-Blanket Thermal Barrier Material being supplied to Texas Utilities under the above referenced Purchase Order.

1. Maximum Specific Weight When Delivered
   2.1 Lbs/Ft2

2. A Weight Reduction at equilibrium of at least 7% is expected.

3. Minimum Weight based on 0.250" thickness
   1.4 lbs/Ft2

4. Maximum Average Thickness
   3/8"

5. Maximum Individual Thickness not to exceed 2% of the total surface area
   7/16"

6. Minimum Individual Thickness not to exceed 1% of the total surface area
   0.230"

If you have any additional questions, do not hesitate to contact me.

Yours truly,

Rubin Feldman
President

RF/meg

ATTACHMENT 982

CABLE AMPACITY OF THERMOLAGGED CABLE IN FREE AIR: TEMPLATE 2
(FOR THREE LAYERS OF THERMOLAG ON BUNDLES LESS THAN THREE INCHES)

ATTACHMENT BB2
CABLE AMPACITY OF THERMOLAGGED CABLE IN FREE AIR: TEMPLATE 2 (FOR THREE LAYERS OF THERMOLAG ON BUNDLES LESS THAN THREE INCHES)

This templates calculates the thermal resistance terms and cable ampacity. The cable ampacity is input to template Attachment BB3 for comparison with ampacity of the cable in adjacent raceways sections.

I. CABLE INPUT DATA

PRNPRECISION := 8

CABLE := READPRN("cable.prn") File: cable.prn was produced by template- Attaqchment A and is documented separately.

ORIGIN = 1 defines the upper corner of a matrix as 1,1

$j := 1..7$ $i := 1..21$ $n'_{i,j} := 0$ $Cdiam_{i,j} := 0$

Matrix CABLE is comprised of the following indicated columns.

Rdc25 := CABLE<1> Yc := CABLE<2> Dc := CABLE<3> Ac := CABLE<4>

n' := CABLE<1> It := CABLE<5> Jt := CABLE<6> ρi := CABLE<7> ρj := CABLE<8>

Diam1C := CABLE<9> Cdiam := CABLE<10> CABLE<11>

Where:

Rdc25	Conductor dc resistance at 25 deg C, Ω/ft
Yc	Conductor proximity/skin effect
Dc	Conductor diameter, in.
Ac	Conductor cross-sectional area, sq mm
n'	Number of conductors in cable
It	Insulation thickness, mils
Jt	Overall jacket thickness, mils
ρi	Insulation thermal resistivity, C-cm/W
ρj	Jacket thermal resistivity, C-cm/W
Diam1C	Diameter of 1/c cable or 1 cable of multi-conductor cable, in.
Cdiam	Overall diameter of cable, in.

CABLE PHYSICAL PROPERTIES

CABLE =

Rdc 25 Ω/ft	Yc	Dc in.	Ac mm2	n'	It mil	Jt mil	ρi	ρj	DiamIC inch	Cdiam inch
$2.22 \cdot 10^{-5}$	0.06	0.813	253.4	1	280	0	500	500	1.373	2.95195
$3.2 \cdot 10^{-5}$	0.03	0.681	177.3	1	280	0	500	500	1.241	2.66815
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	1	280	0	500	500	1.088	2.3392
$1.48 \cdot 10^{-5}$	0.13	0.998	380	1	145	0	500	500	1.288	2.7692
$2.22 \cdot 10^{-5}$	0.06	0.813	253.4	1	130	0	500	500	1.073	2.30695
$3.2 \cdot 10^{-5}$	0.03	0.681	177.3	1	130	0	500	500	0.941	2.02315
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	1	100	0	500	500	0.728	1.5652
$8.43 \cdot 10^{-5}$	0	0.418	67.43	1	100	0	500	500	0.618	1.3287
$5.25 \cdot 10^{-5}$	0.01	0.528	107.2	3	100	0	500	500	0.728	1.5652
$8.43 \cdot 10^{-5}$	0	0.418	67.43	3	100	0	500	500	0.618	1.3287
$1.69 \cdot 10^{-4}$	0	0.292	33.62	3	75	0	500	500	0.442	0.9503
$2.69 \cdot 10^{-4}$	0	0.232	21.15	3	75	80	500	500	0.382	0.9813
$4.27 \cdot 10^{-4}$	0	0.184	13.3	3	75	80	500	500	0.334	0.8781
$6.79 \cdot 10^{-4}$	0	0.146	8.37	3	60	60	500	500	0.266	0.6919
0.00108	0	0.116	5.26	3	45	60	500	500	0.206	0.5629
0.00172	0	0.092	3.31	3	30	60	500	500	0.152	0.4468
$1.69 \cdot 10^{-4}$	0	0.292	33.62	2	75	80	500	500	0.442	1.044
$4.27 \cdot 10^{-4}$	0	0.184	13.3	2	75	60	500	500	0.334	0.788
$6.79 \cdot 10^{-4}$	0	0.146	8.37	2	60	60	500	500	0.266	0.632
0.00108	0	0.116	5.26	2	45	60	500	500	0.206	0.532
0.00172	0	0.092	3.31	2	30	60	500	500	0.152	0.424

The above matrix is manually compared with the matrix CABLE of Attachment A to demonstrate successful data transfer.

N, nnn', and CCdiam were developed in template- Attachment B1

N := READPRN(N prn) nnn' := READPRN(NNN prn)

CCdiam := READPRN(CCdiam prn)

No. of cables in a Bundle

No. of cables				Conduit Size			
1	2	3	5	3 "	4 "	5 "	6"

N =

1	2	3	5	1	1	1	2
1	2	3	5	1	1	2	3
1	2	3	5	1	1	2	4
1	2	3	5	1	1	2	2
1	2	3	5	1	1	2	4
1	2	3	5	1	2	3	5
1	2	3	5	2	4	6	9
1	2	3	5	3	5	8	12
1	2	3	5	1	2	4	6
1	2	3	5	2	3	5	8
1	2	3	5	4	7	11	16
1	2	3	5	3	6	10	15
1	2	3	5	4	8	13	19
1	2	3	5	7	13	21	30
1	2	3	5	11	20	32	46
1	2	3	5	18	32	51	73
1	2	3	5	3	5	9	13
1	2	3	5	6	10	16	23
1	2	3	5	8	15	23	34
1	2	3	5	13	22	35	51
1	2	3	5	20	36	56	81

Equivalent No. of conductors in a Bundle

No. of cables				Conduit Size			
1	2	3	5	3 "	4"	5 "	6"
3	6	7.92	11.76	3	3	3	6
3	6	7.92	11.76	3	3	6	7.92
3	6	7.92	11.76	3	3	6	9.84
3	6	7.92	11.76	3	3	6	6
3	6	7.92	11.76	3	3	6	9.84
3	6	7.92	11.76	3	6	7.92	11.76
3	6	7.92	11.76	6	9.84	13.68	20.06
3	6	7.92	11.76	7.92	11.76	17.83	26.75
3	6	7.92	11.76	3	6	9.84	13.68
3	6	7.92	11.76	6	7.92	11.76	17.83
3	6	7.92	11.76	9.84	15.6	24.52	35.66
3	6	7.92	11.76	7.92	13.68	22.29	33.44
3	6	7.92	11.76	9.84	17.83	28.98	42.35
3	6	7.92	11.76	15.6	28.98	46.81	66.87
3	6	7.92	11.76	24.52	44.58	71.33	102.53
3	6	7.92	11.76	40.12	71.33	113.68	162.72
2	4	5.28	7.84	5.28	7.84	13.37	19.32
2	4	5.28	7.84	9.12	14.86	23.78	34.18
2	4	5.28	7.84	11.68	22.29	34.18	50.52
2	4	5.28	7.84	19.32	32.69	52.01	75.79
2	4	5.28	7.84	29.72	53.5	83.22	120.37

nnn' =

Diameter of Cable Bundle

No. of cables				Conduit Size			
1	2	3	5	3 "	4"	5 "	6"
2.95	5.9	5.35	7.97	2.95	2.95	2.95	5.9
2.67	5.34	5.74	7.2	2.67	2.67	5.34	5.74
2.34	4.68	5.01	6.32	2.34	2.34	4.68	5.01
2.77	5.54	5.95	7.48	2.77	2.77	5.54	5.54
2.31	4.61	4.96	6.23	2.31	2.31	4.61	4.94
2.02	4.05	4.35	5.46	2.02	4.05	4.35	5.46
1.57	3.13	3.37	4.23	3.13	3.35	4.7	5.67
1.33	2.66	2.86	3.59	2.86	3.59	4.4	5.51
1.57	3.13	3.37	4.23	1.57	3.13	3.35	4.7
1.33	2.66	2.86	3.59	2.66	2.86	3.59	4.4
0.95	1.9	2.04	2.57	2.03	2.85	3.8	4.47
0.98	1.96	2.11	2.65	2.11	2.94	3.93	4.61
0.88	1.76	1.89	2.37	1.88	2.91	3.87	4.39
0.69	1.38	1.49	1.87	2.08	3.05	3.67	4.44
0.56	1.13	1.21	1.52	2.25	2.99	3.77	4.5
0.45	0.89	0.96	1.21	2.23	2.99	3.76	4.47
1.04	2.09	2.24	2.82	2.24	2.82	3.78	4.6
0.79	1.58	1.69	2.13	2.36	3.15	3.7	4.73
0.65	1.3	1.4	1.76	2.16	3.06	3.91	4.56
0.53	1.06	1.14	1.44	2.35	2.99	3.72	4.47
0.42	0.85	0.91	1.14	2.25	2.97	3.69	4.41

CCdiam =

III. Calculation of thermal resistance terms

$j := 1 \ldots 8$

$$Ri_{i,j} := 0.012 \cdot \rho_i \cdot \log\left[\frac{Diam1C_i}{Dc_i}\right]$$

thermal resistance of insulation
C-ft/watt
Source: Reference 3 (Nehr-McGrath), equation 38.

Thermal Resistance of Insulation

No. of cables / Conduit Size								
1	2	3	5	3 "	4"	5 "	6"	
1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1/C-500,8 KV
1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1/C-350,8 KV
1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1/C-4/0,8 KV
0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1/C-750,600 V
0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1/C-500
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1/C-350
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1/C-4/0
1	1	1	1	1	1	1	1	1/C-2/0
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	TRI-4/0
1	1	1	1	1	1	1	1	TRI-2/0
1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	TRI-2AWG
1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	3/C-4AWG
1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3/C-6AWG
1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3/C-8AWG
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	3/C-10AWG
1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	3/C-12AWG
1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	2/C-2AWG
1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2/C-6AWG
1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	2/C-8AWG
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2/C-10AWG
1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	2/C-12AWG

$Ri =$

Thermal Resistance of the Jacket on 2/C and 3/C cable

$$Rj_{i,j} := \left[Jt_i > 0\right] \cdot \left[0.012 \cdot n'_{i,1} \cdot \rho j_i \cdot \log\left[\frac{Cdiam_{i,1}}{Cdiam_{i,1} - 2 \cdot Jt_i \cdot 10^{-3}}\right]\right]$$

Thermal resistance of jacket, C-ft/watt Source: Derived from equation 38 in Reference 3 (Nehr-McGrath) This first part of the expression is a logical statement to only calculate Rj if a jacket exists.

Thermal Resistance of Jacket

Rj =

No. of cables / Conduit Size							
1	2	3	5	3"	4"	5"	6"
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39
1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57
1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49
1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87
2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73

$A' := 4.5$ $B' := 0.27$ factors used in Rsd, developed constants in Table VII of Reference 3 (Nehr-McGrath). See Methodology 8

$$Rsd_{i,j} := nnn'_{i,j} \frac{A'}{CCdiam_{i,j} + B'}$$

thermal resistance between cable and 330-660, C-ft/watt this assumes an airgap between the two surfaces. Equation 41A from Reference 3, (Nehr-McGrath).

$$Rsd = \begin{bmatrix} 4.2 & 4.4 & 5.4 & 6.4 & 4.2 & 4.2 & 4.2 & 4.4 \\ 4.6 & 4.8 & 5.9 & 7.1 & 4.6 & 4.6 & 4.8 & 5.9 \\ 5.2 & 5.5 & 6.7 & 8 & 5.2 & 5.2 & 5.5 & 8.4 \\ 4.4 & 4.6 & 5.7 & 6.8 & 4.4 & 4.4 & 4.6 & 4.6 \\ 5.2 & 5.5 & 6.8 & 8.1 & 5.2 & 5.2 & 5.5 & 8.5 \\ 5.9 & 6.3 & 7.7 & 9.2 & 5.9 & 6.3 & 7.7 & 9.2 \\ 7.4 & 7.9 & 9.8 & 11.8 & 7.9 & 12.2 & 12.4 & 15.2 \\ 8.4 & 9.2 & 11.4 & 13.7 & 11.4 & 13.7 & 17.2 & 20.8 \\ 7.4 & 7.9 & 9.8 & 11.8 & 7.4 & 7.9 & 12.2 & 12.4 \\ 8.4 & 9.2 & 11.4 & 13.7 & 9.2 & 11.4 & 13.7 & 17.2 \\ 11.1 & 12.4 & 15.4 & 18.7 & 19.2 & 22.5 & 27.1 & 33.9 \\ 10.8 & 12.1 & 15 & 18.1 & 15 & 19.2 & 23.9 & 30.8 \\ 11.8 & 13.3 & 16.5 & 20 & 20.6 & 25.3 & 31.5 & 40.9 \\ 14 & 16.3 & 20.3 & 24.8 & 29.9 & 39.3 & 53.4 & 64 \\ 16.2 & 19.3 & 24.1 & 29.6 & 43.8 & 61.6 & 79.4 & 96.7 \\ 18.8 & 23.2 & 29 & 35.8 & 72.1 & 98.4 & 127 & 154.5 \\ 6.8 & 7.6 & 9.4 & 11.4 & 9.4 & 11.4 & 14.9 & 17.8 \\ 8.5 & 9.8 & 12.1 & 14.7 & 15.6 & 19.5 & 26.9 & 30.8 \\ 9.8 & 11.4 & 14.2 & 17.4 & 22 & 30.1 & 36.8 & 47 \\ 11.2 & 13.5 & 16.8 & 20.7 & 33.2 & 45.1 & 58.6 & 71.9 \\ 13 & 16.1 & 20.1 & 24.9 & 53 & 74.3 & 94.6 & 115.6 \end{bmatrix}$$

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-2/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

THERMAL RESISTANCE OF THERMOLAG 330-660 WRAP

Btu/hr = B B := .2931 watts Ft := 30.4785 cm

$F := \frac{5}{9}$ This is to convert degree F to degrees C

$K := (0.249)\cdot\frac{B}{Ft}\cdot\frac{1}{F}$ See Attachment D (conductivity)

$\rho w := \frac{1}{K}$

$\rho w = 232.01$ thermal resistivity of 330-660 wrap,C-Cm/watt

$Twrap1_{i,j} := if\left[CCdiam_{i,j} < 3,6\cdot\frac{3}{8},4\cdot\frac{3}{8}\right]$ Thickness of wrap (bundles of less than 3 inches have a maximum of 6 layers of Thermolag)

$Twrap_{i,j} := if\left[j > 4,4\cdot\frac{3}{8},Twrap1_{i,j}\right]$ Conduit of 3 inches or greater will have a maximum of 4 layers of Thermolag

Thickness of Wrap

No. of cables / Conduit Size								
1	2	3	5	3 "	4"	5 "	6"	
2.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1/C-500,8 KV
2.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1/C-350,8 KV
2.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1/C-4/0,8 KV
2.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1/C-750,600 V
2.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1/C-500
2.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1/C-350
2.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1/C-4/0
2.25	2.25	2.25	1.5	1.5	1.5	1.5	1.5	1/C-2/0
2.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	TRI-4/0
2.25	2.25	2.25	1.5	1.5	1.5	1.5	1.5	TRI-2/0
2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5	TRI-2AWG
2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5	3/C-4AWG
2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5	3/C-6AWG
2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5	3/C-8AWG
2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5	3/C-10AWG
2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5	3/C-12AWG
2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5	2/C-2AWG
2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5	2/C-6AWG
2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5	2/C-8AWG
2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5	2/C-10AWG
2.25	2.25	2.25	2.25	1.5	1.5	1.5	1.5	2/C-12AWG

Twrap =

$$Rw_{i,j} := 0.012 \cdot nnn'_{i,j} \cdot \rho w \cdot \log\left[\frac{CCdiam_{i,j} + 2 \cdot Twrap_{i,j}}{CCdiam_{i,j}}\right]$$

Thermal resistance of Thermolag wrap, Thermal Ω/ft. Source: Reference 2 equation 6

Thermal Resistance of Wrap

No. of cables / Conduit Size								
1	2	3	5	3 "	4"	5 "	6"	
3.4	3	3.7	4.5	2.5	2.5	2.5	3	1/C-500,8 KV
3.6	3.2	4	5	2.7	2.7	3.2	4	1/C-350,8 KV
3.9	3.6	4.5	5.5	3	3	3.6	5.6	1/C-4/0,8 KV
3.5	3.1	3.9	4.8	2.7	2.7	3.1	3.1	1/C-750,600 V
3.9	3.6	4.5	5.6	3	3	3.6	5.6	1/C-500
4.2	4	5	6.2	3.3	4	5	6.2	1/C-350
4.9	4.9	6.1	7.6	4.9	7.6	8.2	10.3	1/C-4/0
5.4	7.2	9.1	8.6	6.9	8.6	11.2	14	1/C-2/0
4.9	4.9	6.1	7.6	3.9	4.9	7.6	8.2	TRI-4/0
5.4	7.2	9.1	8.6	5.5	6.9	8.6	11.2	TRI-2/0
6.3	8.8	11.1	14.4	10.8	13.6	17.2	22.2	TRI-2AWG
6.2	8.6	10.9	14.1	8.5	11.6	15.3	20.3	3/C-4AWG
6.6	9.2	11.7	15.1	11.4	15.3	20.1	26.7	3/C-6AWG
7.3	10.5	13.3	17.4	16.9	24	33.8	41.8	3/C-8AWG
8	11.7	14.9	19.6	25.1	37.5	50.5	63.3	3/C-10AWG
8.7	13	16.6	22.1	41.3	59.9	30.7	101.1	3/C-12AWG
4	5.6	7	9	5.4	6.9	9.4	11.7	2/C-2AWG
4.6	6.5	8.3	10.8	9	12	17.1	20.3	2/C-6AWG
5	7.2	9.2	12	12.5	18.4	23.5	30.9	2/C-8AWG
5.4	8	10.2	13.5	19.2	27.5	37.2	47	2/C-10AWG
5.9	8.9	11.4	15.1	30.4	45.2	59.9	75.5	2/C-12AWG

THERMAL RESISTANCE BETWEEN THE THERMOLAG AND AMBIENT AIR

$Dwrap_{i,j} := 2\ Twrap_{i,j} + CCdiam_{i,j}$ Overall diameter of wrap, in.

Diameter Over the Wrap

Dwrap =

No. of cables / Conduit Size								
1	2	3	5	3	4"	5 "	6"	
7.5	8.9	9.3	11	6	6	6	8.9	1/C-500,8 KV
7.2	8.3	8.7	10.2	5.7	5.7	8.3	8.7	1/C-350,8 KV
6.8	7.7	8	9.3	5.3	5.3	7.7	8	1/C-4/0,8 KV
7.3	8.5	9	10.5	5.8	5.8	8.5	8.5	1/C-750,600 V
6.8	7.6	8	9.2	5.3	5.3	7.6	7.9	1/C-500
6.5	7	7.3	8.5	5	7	7.3	8.5	1/C-350
6.1	6.1	6.4	7.2	6.1	6.3	7.7	8.7	1/C-4/0
5.8	7.2	7.4	6.6	5.9	6.6	7.4	8.5	1/C-2/0
6.1	6.1	6.4	7.2	4.6	6.1	6.3	7.7	TRI-4/0
5.8	7.2	7.4	6.6	5.7	5.9	6.6	7.4	TRI-2/0
5.5	6.4	6.5	7.1	5	5.9	6.8	7.5	TRI-2AWG
5.5	6.5	6.6	7.1	5.1	5.9	6.9	7.6	3/C-4AWG
5.4	6.3	6.4	6.9	4.9	5.9	6.9	7.4	3/C-6AWG
5.2	5.9	6	6.4	5.1	6.1	6.7	7.4	3/C-8AWG
5.1	5.6	5.7	6	5.3	6	6.8	7.5	3/C-10AWG
4.9	5.4	5.5	5.7	5.2	6	6.8	7.5	3/C-12AWG
5.5	6.6	6.7	7.3	5.2	5.8	6.8	7.6	2/C-2AWG
5.3	6.1	6.2	6.6	5.4	6.2	6.7	7.7	2/C-6AWG
5.2	5.8	5.9	6.3	5.2	6.1	6.9	7.6	2/C-8AWG
5	5.6	5.6	5.9	5.3	6	6.7	7.5	2/C-10AWG
4.9	5.3	5.4	5.6	5.3	6	6.7	7.4	2/C-12AWG

$\epsilon := 0.89$ emissivity of Thermolag 330-660 (see Attachment D)

$$Rwa_{i,j} := \frac{9.5 \cdot nnn'_{i,j}}{1 + 1.7 \cdot Dwrap_{i,j} \cdot (\epsilon + 0.41)}$$

Thermal resistance between wrap and ambient air, thermal ft-ft (C-ft/watt)
Source: Reference 3 (Nahr-McGrath, equation 42A)

Thermal Resistance of Wrap to Air

	No. of cables / Conduit Size							
	1	2	3	5	3 "	4"	5 "	6"	
Rwa =	1.6	2.8	3.5	4.4	2	2	2	2.8	1/C-500,8 KV
	1.7	2.9	3.7	4.7	2.1	2.1	2.9	3.7	1/C-350,8 KV
	1.8	3.2	4	5.2	2.2	2.2	3.2	5	1/C-4/0,8 KV
	1.7	2.9	3.6	4.6	2.1	2.1	2.9	2.9	1/C-750,600 V
	1.8	3.2	4	5.2	2.2	2.2	3.2	5	1/C-500
	1.8	3.4	4.4	5.7	2.4	3.4	4.4	5.7	1/C-350
	2	3.9	5	6.6	3.9	6.2	7.2	9.5	1/C-4/0
	2.1	3.4	4.4	7.2	5.4	7.2	9.8	12.8	1/C-2/0
	2	3.9	5	6.6	2.6	3.9	6.2	7.2	TRI-4/0
	2.1	3.4	4.4	7.2	4.2	5.4	7.2	9.8	TRI-2/0
	2.2	3.8	4.9	6.7	7.7	10.6	14.6	19.4	TRI-2AWG
	2.2	3.7	4.8	6.6	6.1	9.2	13	17.8	3/C-4AWG
	2.2	3.8	5	6.9	7.9	12.1	17	23.2	3/C-6AWG
	2.3	4.1	5.3	7.4	12.1	19.2	28.2	36.4	3/C-8AWG
	2.3	4.2	5.5	7.8	18.5	29.7	42.4	55.4	3/C-10AWG
	2.4	4.4	5.8	8.2	30.3	47.6	67.8	88.3	3/C-12AWG
	1.4	2.4	3.2	4.3	4	5.4	7.9	10.3	2/C-2AWG
	1.5	2.6	3.4	4.8	6.7	9.7	14.3	18	2/C-6AWG
	1.5	2.7	3.6	5	9.1	14.7	19.9	27.1	2/C-8AWG
	1.6	2.9	3.7	5.3	14.3	21.8	31.2	41.1	2/C-10AWG
	1.6	3	3.9	5.5	22.4	35.8	50.1	65.8	2/C-12AWG

THERMAL RESISTANCE BETWEEN CONDUCTOR AND AMBIENT AIR

Rth1 := Ri + Rj + Rsd + Rw + Rwa thermal resistance between the conductor and outside ambient air, thermal Ω-ft (C-ft/watt)

Thermal Resistance Between Conductor and Air

Rth1 =

No. of cables / Conduit Size								
1	2	3	5	3 "	4"	5 "	6"	
10.5	11.5	13.9	16.8	10.1	10.1	10.1	11.5	1/C-500,8 KV
11.4	12.6	15.2	18.3	11	11	12.6	15.2	1/C-350,8 KV
12.7	14.1	17.1	20.6	12.3	12.3	14.1	20.9	1/C-4/0,8 KV
10.3	11.3	13.9	16.9	9.8	9.8	11.3	11.3	1/C-750,600 V
11.7	13.1	16.1	19.7	11.2	11.2	13.1	19.9	1/C-500
12.8	14.6	17.9	22	12.4	14.6	17.9	22	1/C-350
15.1	17.6	21.7	26.8	17.6	26.9	28.6	35.8	1/C-4/0
16.9	20.8	25.8	30.6	24.7	30.6	39.2	48.7	1/C-2/0
15.1	17.6	21.7	26.8	14.6	17.6	26.9	28.6	TRI-4/0
16.9	20.8	25.8	30.6	19.9	24.7	30.6	39.2	TRI-2/0
20.7	26.1	32.5	40.9	38.8	47.8	60	76.5	TRI-2AWG
21.9	27.2	33.4	41.6	32.3	42.7	54.9	71.6	3/C-4AWG
23.7	29.5	36.3	45.2	43	55.7	71.7	93.9	3/C-6AWG
26.7	33.9	42	52.7	62	85.5	118.5	145.2	3/C-8AWG
29.9	38.6	47.8	60.3	90.7	132.1	175.7	218.7	3/C-10AWG
33.7	44.4	55.1	69.9	147.5	209.5	279.2	347.7	3/C-12AWG
14.3	17.6	21.6	26.8	20.8	25.6	34.2	41.8	2/C-2AWG
17	21.3	26.2	32.7	33.8	43.6	60.7	71.5	2/C-6AWG
18.9	24	29.6	37	46.3	65.8	82.9	107.6	2/C-8AWG
21.1	27.2	33.5	42.2	69.6	97.2	129.7	162.8	2/C-10AWG
23.5	31	38.4	48.6	108.9	158.4	207.6	259.9	2/C-12AWG

$RRdc25_{i,j} := Rdc25_i$ $\quad YYc_{i,j} := Yc_i$ Converts vector into matrix.

Tc := 90 conductor temperature, deg. C (see DBD-EE-52)

Ta := 50 ambient temperature, deg. C (see DBD-EE-52)

Cable ampacity of Thermolag 330-660 Wrapped Cable in Free Air

$$Iamp_{i,j} := \sqrt{(Tc - Ta)\frac{234.5 + 25}{\left[Rth1_{i,j}\ RRdc25_{i,j}\left[1 + YYc_{i,j}\right]\right](234.5 + Tc)}}$$

Source: Reference 3 (Nehr-McGrath, equation 9, with Rth1 = Rca', delta TD = 0, Rdc expressed at temperature Tc).

WRITEPRN(iamp_prn) := Iamp This saves Iamp in an ASCII file for use in template Attachment BB3

Cable Ampacity of Wrapped Cable in Free Air

No. of cables / Conduit Size								
1	2	3	5	3"	4"	5"	6"	
359	344	312	285	367	367	367	344	1/C-500,8 KV
291	278	252	230	297	297	278	252	1/C-350,8 KV
218	207	188	171	222	222	207	170	1/C-4/0,8 KV
431	411	371	336	441	441	411	411	1/C-750,600 V
341	322	290	263	348	348	322	261	1/C-500
275	258	233	210	280	258	233	210	1/C-350
200	185	167	150	185	150	145	130	1/C-4/0
150	135	121	111	124	111	98	88	1/C-2/0
200	185	167	150	203	185	150	145	TRI-4/0
150	135	121	111	138	124	111	98	TRI-2/0
96	85	76	68	70	63	56	50	TRI-2AWG
74	66	60	53	61	53	47	41	3/C-4AWG
56	50	45	41	42	37	32	28	3/C-6AWG
42	37	34	30	28	23	20	18	3/C-8AWG
31	28	25	22	18	15	13	12	3/C-10AWG
23	20	18	16	11	9	8	7	3/C-12AWG
115	104	94	84	95	86	74	67	2/C-2AWG
66	59	53	48	47	41	35	32	2/C-6AWG
50	44	40	36	32	27	24	21	2/C-8AWG
38	33	30	26	21	17	15	13	2/C-10AWG
28	24	22	20	13	11	9	8	2/C-12AWG

Iamp =

ATTACHMENT BB3

COMPARISON BETWEEN FREE AIR THERMOLAGGED CABLES AND CABLES IN THERMOLAGGED RACEWAYS (FOR THREE LAYERS OF THERMOLAG ON BUNDLES LESS THAN THREE INCHES) AND CABLES IN THERMOLAGGED RACEWAY.

ATTACHMENT BB3

Comparison between free air Thermolagged cables (for three layers of Thermolag on bundles less than three inches and cables in Thermolagged raceway

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This templates compares the ampacity of thermolagged cables in free air with those of thermolagged raceway: maintained spaced tray, ransod filled tray, Thermolag 330-1 enclosed conduit (both box and shell design)

I. CABLE INPUT DATA

PRNPRECISION := 8

Iamp := READPRN(iamp)

N := READPRN(N) nn' := READPRN(NN)

The above files were produced by template Attachment B1 : N and nn'; Attachment BB2: Iamp.

ORIGIN ≡ 1 defines the upper corner of a matrix as 1,1

j := 1 ..8 i := 1 ..21

Cable Ampacity of Wrapped Cable in Free Air

Iamp =

No. of Cables				Conduit Size				
1	2	3	5	3"	4"	5"	6"	
359	344	312	285	367	367	367	344	1/C-500,8 KV
291	278	252	230	297	297	278	252	1/C-350,8 KV
218	207	188	171	222	222	207	170	1/C-4/0,8 KV
431	411	371	336	441	441	411	411	1/C-750,600 V
341	322	290	263	348	348	322	261	1/C-500
275	258	233	210	280	258	233	210	1/C-350
200	185	167	150	185	150	145	130	1/C-4/0
150	135	121	111	124	111	98	88	1/C-2/0
200	185	167	150	203	185	150	145	TRI-4/0
150	135	121	111	138	124	111	98	TRI-2/0
96	85	76	68	70	63	56	50	TRI-2AWG
74	66	60	53	61	53	47	41	3/C-4AWG
56	50	45	41	42	37	32	28	3/C-6AWG
42	37	34	30	28	23	20	18	3/C-8AWG
31	28	25	22	18	15	13	12	3/C-10AWG
23	20	18	16	11	9	8	7	3/C-12AWG
115	104	94	84	95	86	74	67	2/C-2AWG
66	59	53	48	47	41	35	32	2/C-6AWG
50	44	40	36	32	27	24	21	2/C-8AWG
38	33	30	26	21	17	15	13	2/C-10AWG
28	24	22	20	13	11	9	8	2/C-12AWG

Number of Cables in a Bundle

N =

No. of Cables				Conduit Size				
1	2	3	5	3	4"	5"	6"	
1	2	3	5	1	1	1	2	1/C-500,8 KV
1	2	3	5	1	1	2	3	1/C-350,8 KV
1	2	3	5	1	1	2	4	1/C-4/0,8 KV
1	2	3	5	1	1	2	2	1/C-750,600 V
1	2	3	5	1	1	2	4	1/C-500
1	2	3	5	1	2	3	5	1/C-350
1	2	3	5	2	4	6	9	1/C-4/0
1	2	3	5	3	5	8	12	1/C-2/0
1	2	3	5	1	2	4	6	TRI-4/0
1	2	3	5	2	3	5	8	TRI-2/0
1	2	3	5	4	7	11	16	TRI-2AWG
1	2	3	5	3	6	10	15	3/C-4AWG
1	2	3	5	4	8	13	19	3/C-6AWG
1	2	3	5	7	13	21	30	3/C-8AWG
1	2	3	5	11	20	32	46	3/C-10AWG
1	2	3	5	18	32	51	73	3/C-12AWG
1	2	3	5	3	5	9	13	2/C-2AWG
1	2	3	5	6	10	16	23	2/C-6AWG
1	2	3	5	8	15	23	34	2/C-8AWG
1	2	3	5	13	22	35	51	2/C-10AWG
1	2	3	5	20	36	56	81	2/C-12AWG

Note: 1/C cable are bundled in groups of three. Therefore, if N=3 then the actual number of cables for 1/C is 3 x 3 = 9

Number of Conductors in a Bundle

No. of Cables /				Conduit Size				
1	2	3	5	3	4"	5"	6"	
3	6	9	15	3	3	3	6	1/C-500,8 KV
3	6	9	15	3	3	6	9	1/C-350,8 KV
3	6	9	15	3	3	6	12	1/C-4/0,8 KV
3	6	9	15	3	3	6	6	1/C-750,600 V
3	6	9	15	3	3	6	12	1/C-500
3	6	9	15	3	6	9	15	1/C-350
3	6	9	15	6	12	18	27	1/C-4/0
3	6	9	15	9	15	24	36	1/C-2/0
3	6	9	15	3	6	12	18	TRI-4/0
3	6	9	15	6	9	15	24	TRI-2/0
3	6	9	15	12	21	33	48	TRI-2AWG
3	6	9	15	9	18	30	45	3/C-4AWG
3	6	9	15	12	24	39	57	3/C-6AWG
3	6	9	15	21	39	63	90	3/C-8AWG
3	6	9	15	33	60	96	138	3/C-10AWG
3	6	9	15	54	96	153	219	3/C-12AWG
2	4	6	10	6	10	18	26	2/C-2AWG
2	4	6	10	12	20	32	46	2/C-6AWG
2	4	6	10	16	30	46	68	2/C-8AWG
2	4	6	10	26	44	70	102	2/C-10AWG
2	4	6	10	40	72	112	162	2/C-12AWG

$nn' =$

Ampacities of Thermolagged Maintained Spaced Tray

Ampacity of thermolag covered 600 V cable with maintained spacing in a 50 C ambient see Reference 1 (DBD-EE-052) and Reference 18.

Development of Thermolagged Tray ampacities for 8 kV cable:

$$It := \begin{bmatrix} 515 \\ 386 \\ 265 \end{bmatrix}$$

1/C-500, 8KV
1/C-350, 8KV
1/C-4/0, 8KV

Values obtained from Reference 18, Table 33 where depth > diameter.

$IthMS8kv := 0.90 \cdot 0.60 \cdot It$ where: 0.90 is multiplier for correcting ambient temperature from 40 C to 50 C (Ref. 18, page i).
0.60 is thermolag derating factor (Ref. 1).

$$IthMS8kv = \begin{bmatrix} 278.1 \\ 208.4 \\ 143.1 \end{bmatrix}$$

$$IthMS := \begin{bmatrix} 278 \\ 208 \\ 143 \\ 340 \\ 235 \\ 173 \\ 129 \\ 87 \\ 129 \\ 87 \\ 43 \\ 999 \\ 999 \\ 999 \\ 999 \\ 999 \\ 60 \\ 999 \\ 999 \\ 999 \\ 999 \end{bmatrix}$$

1/C-500,8 KV
1/C-350,8 KV
1/C-4/0,8 KV
1/C-750,600 V
1/C-500
1/C-350
1/C-4/0
1/C-2/0
TRI-4/0
TRI-2/0
TRI-2AWG
3/C-4AWG
3/C-6AWG
3/C-8AWG
3/C-10AWG
3/C-12AWG
2/C-2AWG
2/C-6AWG
2/C-8AWG
2/C-10AWG
2/C-12AWG

These ampacities were input from: 8 Kv Cable - calculated results of IthMS8kv shown above; 600 V cables - from DBD-EE-052. A value of 999 is entered when no ampacities are appropriate because the cables would not be installed in maintained spaced trays

$$IIthMS_{i,j} := IthMS_{i}$$

$$AMPCHK_{i,j} := if\left[IIthMS_{i,j} < Iamp_{i,j}, 1, 0\right]$$

CHECK OF CABLE AMPACITY ADEQUACY
WITH MAINTAINED SPACING IN TRAY

Ampacity Comparison with MS Tray

No. of Cables / Conduit Size

1	2	3	5	3	4"	5"	6"	
1	1	1	1	1	1	1	1	1/C-500,8 KV
1	1	1	1	1	1	1	1	1/C-350,8 KV
1	1	1	1	1	1	1	1	1/C-4/0,8 KV
1	1	1	0	1	1	1	1	1/C-750,600 V
1	1	1	1	1	1	1	1	1/C-500
1	1	1	1	1	1	1	1	1/C-350
1	1	1	1	1	1	1	1	1/C-4/0
1	1	1	1	1	1	1	1	1/C-2/0
1	1	1	1	1	1	1	1	TRI-4/0
1	1	1	1	1	1	1	1	TRI-2/0
1	1	1	1	1	1	1	1	TRI-2AWG
0	0	0	0	0	0	0	0	3/C-4AWG
0	0	0	0	0	0	0	0	3/C-6AWG
0	0	0	0	0	0	0	0	3/C-8AWG
0	0	0	0	0	0	0	0	3/C-10AWG
0	0	0	0	0	0	0	0	3/C-12AWG
1	1	1	1	1	1	1	1	2/C-2AWG
0	0	0	0	0	0	0	0	2/C-6AWG
0	0	0	0	0	0	0	0	2/C-8AWG
0	0	0	0	0	0	0	0	2/C-10AWG
0	0	0	0	0	0	0	0	2/C-12AWG

$AMPCHK =$

NOTE:
1 - Adequate cable ampacity
0 - Inadequate cable ampacity

$$CaLimit_{i,j} := if\left[AMPCHK_{i,j} \approx 1, \left[N_{i,j}\right], 0\right]$$

$$CaLimit_{i,j} := if\left[Iamp_{i,j} \approx 999, 0, CaLimit_{i,j}\right]$$

Limit of Number of Cable in Bundle:
Not to Exceed Ampacity of Cable in
MS Thermolagged Tray

CaLimit =

No. of Cables / Conduit Size							
1	2	3	5	3	4"	5"	6"	
1	2	3	5	1	1	1	2	1/C-500,8 KV
1	2	3	5	1	1	2	3	1/C-350,8 KV
1	2	3	5	1	1	2	4	1/C-4/0,8 KV
1	2	3	0	1	1	2	2	1/C-750,600 V
1	2	3	5	1	1	2	4	1/C-500
1	2	3	5	1	2	3	5	1/C-350
1	2	3	5	2	4	6	9	1/C-4/0
1	2	3	5	3	5	8	12	1/C-2/0
1	2	3	5	1	2	4	6	TRI-4/0
1	2	3	5	2	3	5	8	TRI-2/0
1	2	3	5	4	7	11	16	TRI-2AWG
0	0	0	0	0	0	0	0	3/C-4AWG
0	0	0	0	0	0	0	0	3/C-6AWG
0	0	0	0	0	0	0	0	3/C-8AWG
0	0	0	0	0	0	0	0	3/C-10AWG
0	0	0	0	0	0	0	0	3/C-12AWG
1	2	3	5	3	5	9	13	2/C-2AWG
0	0	0	0	0	0	0	0	2/C-6AWG
0	0	0	0	0	0	0	0	2/C-8AWG
0	0	0	0	0	0	0	0	2/C-10AWG
0	0	0	0	0	0	0	0	2/C-12AWG

The limit to the number of cables under a wrap, use maximum number in a given row. Three 1/C cables are considered as one (1) 3/C cable.

Ampacities of Thermolagged Random Lay Tray

IthRS :=	999	1/C-500,8 KV
	999	1/C-350,8 KV
	999	1/C-4/0,8 KV
	365	1/C-750,600 V
	252	1/C-500
	187	1/C-350
	113	1/C-4/0
	76	1/C-2/0
	136	TRI-4/0
	92	TRI-2/0
	47	TRI-2AWG
	38	3/C-4AWG
	28	3/C-6AWG
	17	3/C-8AWG
	11	3/C-10AWG
	7	3/C-12AWG
	65	2/C-2AWG
	31	2/C-6AWG
	21	2/C-8AWG
	13	2/C-10AWG
	8	2/C-12AWG

Ampacity of thermolag covered cable with random lay (no maintained spacing), see Reference 1 (DBD-EE-052)

$$IIthRS_{i,j} := IthRS_{i}$$

$$AMPCHK_{i,j} := if\left[IIthRS_{i,j} < Iamp_{i,j}, 1, 0\right]$$

Ampacity Comparison with Random TH-Tray

	No. of Cables / Conduit Size 1	2	3	4	3	4"	5"	6"	
	0	0	0	0	0	0	0	0	1/C-500,8 KV
	0	0	0	0	0	0	0	0	1/C-350,8 KV
	0	0	0	0	0	0	0	0	1/C-4/0,8 KV
	1	1	1	0	1	1	1	1	1/C-750,600 V
	1	1	1	1	1	1	1	1	1/C-500
AMPCHK =	1	1	1	1	1	1	1	1	1/C-350
	1	1	1	1	1	1	1	1	1/C-4/0
	1	1	1	1	1	1	1	1	1/C-2/0
	1	1	1	1	1	1	1	1	TRI-4/0
	1	1	1	1	1	1	1	1	TRI-2/0
	1	1	1	1	1	1	1	1	TRI-2AWG
	1	1	1	1	1	1	1	1	3/C-4AWG
	1	1	1	1	1	1	1	1	3/C-6AWG
	1	1	1	1	1	1	1	1	3/C-8AWG
	1	1	1	1	1	1	1	1	3/C-10AWG
	1	1	1	1	1	1	1	1	3/C-12AWG
	1	1	1	1	1	1	1	1	2/C-2AWG
	1	1	1	1	1	1	1	1	2/C-6AWG
	1	1	1	1	1	1	1	0	2/C-8AWG
	1	1	1	1	1	1	1	1	2/C-10AWG
	1	1	1	1	1	1	1	1	2/C-12AWG

NOTE:
1 - Adequate cable ampacity
0 - Inadequate cable ampacity

$$CaLimit_{i,j} := if\left[AMPCHK_{i,j} \approx 1, \left[\left[N_{i,j}\right]\right], 0\right]$$

$$CaLimit_{i,j} := if\left[Iamp_{i,j} \approx 999, 0, CaLimit_{i,j}\right]$$

Limit of Number of Cable in Bundle:
Not to Exceed Ampacity of Cable in
Random Lay Thermolagged Tray

CaLimit =

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
0	0	0	0	0	0	0	0	1/C-500,8 KV
0	0	0	0	0	0	0	0	1/C-350,8 KV
0	0	0	0	0	0	0	0	1/C-4/0,6 KV
1	2	3	0	1	1	2	2	1/C-750,600 V
1	2	3	5	1	1	2	4	1/C-500
1	2	3	5	1	2	3	5	1/C-350
1	2	3	5	2	4	6	9	1/C-4/0
1	2	3	5	3	5	8	12	1/C-2/0
1	2	3	5	1	2	4	6	TRI-4/0
1	2	3	5	2	3	5	8	TRI-2/0
1	2	3	5	4	7	11	16	TRI-2AWG
1	2	3	5	3	6	10	15	3/C-4AWG
1	2	3	5	4	8	13	19	3/C-6AWG
1	2	3	5	7	13	21	30	3/C-8AWG
1	2	3	5	11	20	32	46	3/C-10AWG
1	2	3	5	18	32	51	70	3/C-12AWG
1	2	3	5	3	5	9	13	2/C-2AWG
1	2	3	5	6	10	16	23	2/C-6AWG
1	2	3	5	8	15	23	0	2/C-8AWG
1	2	3	5	13	22	35	51	2/C-10AWG
1	2	3	5	20	36	56	81	2/C-12AWG

The limit to the number of cables under a wrap, use maximum number in a given row. Three 1/C cables are considered as one (1) 3/C cable.

Ampacities of Cable in Themolagged Conduit(Box Design)

Reference 1 (DBD-EE-052) ampacity for three conductors in conduit, enclosed in Thermolag 330-660, Box Design

IthCD :=	338	1/C-500,8 KV
	277	1/C-350,8 KV
	205	1/C-4/0,8 KV
	428	1/C-750,600 V
	341	1/C-500
	275	1/C-350
	199	1/C-4/0
	146	1/C-2/0
	199	TRI-4/0
	146	TRI-2/0
	93	TRI-2AWG
	65	3/C-4AWG
	49	3/C-6AWG
	37	3/C-8AWG
	26	3/C-10AWG
	20	3/C-12AWG
	88	2/C-2AWG
	49	2/C-6AWG
	37	2/C-8AWG
	26	2/C-10AWG
	20	2/C-12AWG

The following equations produce multipying factors for multiple cables in a conduit

$CDamp_{i,j} := 0$

$CDamp_{i,j} := if\left[nn'_{i,j} < 3.01, 1, CDamp_{i,j}\right]$

$CDamp_{i,j} := if\left[nn'_{i,j} > 3.01, 0.8, CDamp_{i,j}\right]$

$CDamp_{i,j} := if\left[nn'_{i,j} > 6.01, 0.7, CDamp_{i,j}\right]$

$CDamp_{i,j} := if\left[nn'_{i,j} > 24.01, 0.6, CDamp_{i,j}\right]$

$CDamp_{i,j} := if\left[nn'_{i,j} > 42.1, 0.5, CDamp_{i,j}\right]$

Conduit Ampacity Multiplying Factors
For More than 3 conductors in a Conduit

$CDamp =$

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
1	0.8	0.7	0.7	1	1	1	0.8	1/C-500,8 KV
1	0.8	0.7	0.7	1	1	0.8	0.7	1/C-350,8 KV
1	0.8	0.7	0.7	1	1	0.8	0.7	1/C-4/0,8 KV
1	0.8	0.7	0.7	1	1	0.8	0.8	1/C-750,600 V
1	0.8	0.7	0.7	1	1	0.8	0.7	1/C-500
1	0.8	0.7	0.7	1	0.8	0.7	0.7	1/C-350
1	0.8	0.7	0.7	0.8	0.7	0.7	0.6	1/C-4/0
1	0.8	0.7	0.7	0.7	0.7	0.7	0.6	1/C-2/0
1	0.8	0.7	0.7	1	0.8	0.7	0.7	TRI-4/0
1	0.8	0.7	0.7	0.8	0.7	0.7	0.7	TRI-2/0
1	0.8	0.7	0.7	0.7	0.7	0.6	0.5	TRI-2AWG
1	0.8	0.7	0.7	0.7	0.7	0.6	0.5	3/C-4AWG
1	0.8	0.7	0.7	0.7	0.7	0.6	0.5	3/C-6AWG
1	0.8	0.7	0.7	0.7	0.6	0.5	0.5	3/C-8AWG
1	0.8	0.7	0.7	0.6	0.5	0.5	0.5	3/C-10AWG
1	0.8	0.7	0.7	0.5	0.5	0.5	0.5	3/C-12AWG
1	0.8	0.8	0.7	0.8	0.7	0.7	0.6	2/C-2AWG
1	0.8	0.8	0.7	0.7	0.7	0.6	0.5	2/C-6AWG
1	0.8	0.8	0.7	0.7	0.6	0.5	0.5	2/C-8AWG
1	0.8	0.8	0.7	0.6	0.5	0.5	0.5	2/C-10AWG
1	0.8	0.8	0.7	0.6	0.5	0.5	0.5	2/C-12AWG

NEC multiplying factor for multiple conductors in conduit

$$IIthCD_{i,j} := CDamp_{i,j} \cdot IthCD_{i}$$

Thermolagged Ampacities in Conduit(Box Design)

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
338	270	237	237	338	338	338	270	1/C-500,8 KV
277	222	194	194	277	277	222	194	1/C-350,8 KV
205	164	144	144	205	205	164	144	1/C-4/0,8 KV
428	342	300	300	428	428	342	342	1/C-750,600 V
341	273	239	239	341	341	273	239	1/C-500
275	220	193	193	275	220	193	193	1/C-350
199	159	139	139	159	139	139	119	1/C-4/0
146	117	102	102	102	102	102	88	1/C-2/0
199	159	139	139	199	159	139	139	TRI-4/0
146	117	102	102	117	102	102	102	TRI-2/0
93	74	65	65	65	65	56	47	TRI-2AWG
65	52	46	46	46	46	39	33	3/C-4AWG
49	39	34	34	34	34	29	25	3/C-6AWG
37	30	26	26	26	22	19	19	3/C-8AWG
26	21	18	18	16	13	13	13	3/C-10AWG
20	16	14	14	10	10	10	10	3/C-12AWG
88	70	70	62	70	62	62	53	2/C-2AWG
49	39	39	34	34	34	29	25	2/C-6AWG
37	30	30	26	26	22	19	19	2/C-8AWG
26	21	21	18	16	13	13	13	2/C-10AWG
20	16	16	14	12	10	10	10	2/C-12AWG

$IIthCD = $

$$AMPCHK_{i,j} := if\left[IIthCD_{i,j} < Iamp_{i,j}, 1, 0\right]$$

Ampacity Comparison equation

Ampacity Comparison with Thermolagged Conduit (Box Design)

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
1	1	1	1	1	1	1	1	1/C-500,8 KV
1	1	1	1	1	1	1	1	1/C-350,8 KV
1	1	1	1	1	1	1	1	1/C-4/0,8 KV
1	1	1	1	1	1	1	1	1/C-750,600 V
1	1	1	1	1	1	1	1	1/C-500
1	1	1	1	1	1	1	1	1/C-350
1	1	1	1	1	1	1	1	1/C-4/0
1	1	1	1	1	1	0	1	1/C-2/0
1	1	1	1	1	1	1	1	TRI-4/0
1	1	1	1	1	1	1	0	TRI-2/0
1	1	1	1	1	0	1	1	TRI-2AWG
1	1	1	1	1	1	1	1	3/C-4AWG
1	1	1	1	1	1	1	1	3/C-6AWG
1	1	1	1	1	1	1	0	3/C-8AWG
1	1	1	1	1	1	0	0	3/C-10AWG
1	1	1	1	1	0	0	0	3/C-12AWG
1	1	1	1	1	1	1	1	2/C-2AWG
1	1	1	1	1	1	1	1	2/C-6AWG
1	1	1	1	1	1	1	1	2/C-8AWG
1	1	1	1	1	1	1	1	2/C-10AWG
1	1	1	1	1	1	0	0	2/C-12AWG

AMPCHK =

NOTE:
1 - Adequate cable ampacity
0 - Inadequate cable ampacity

$$CaLimit_{i,j} := if\left[AMPCHK_{i,j} \approx 1, \left[N_{i,j}\right], 0\right]$$

$$CaLimit_{i,j} := if\left[Iamp_{i,j} \approx 999, 0, CaLimit_{i,j}\right]$$

Limit of Number of Cable in Bundle:
Not to Exceed Ampacity of Cable in
Thermolagged Conduit (Box Design)

CaLimit =

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
1	2	3	5	1	1	1	2	1/C-500,8 KV
1	2	3	5	1	1	2	3	1/C-350,6 KV
1	2	3	5	1	1	2	4	1/C-4/0,8 KV
1	2	3	5	1	1	2	2	1/C-750,600 V
1	2	3	5	1	1	2	4	1/C-500
1	2	3	5	1	2	3	5	1/C-350
1	2	3	5	2	4	6	9	1/C-4/0
1	2	3	5	3	5	0	12	1/C-2/0
1	2	3	5	1	2	4	6	TRI-4/0
1	2	3	5	2	3	5	0	TRI-2/0
1	2	3	5	4	0	11	16	TRI-2AWG
1	2	3	5	3	6	10	15	3/C-4AWG
1	2	3	5	4	8	13	19	3/C-6AWG
1	2	3	5	7	13	21	0	3/C-8AWG
1	2	3	5	11	20	0	0	3/C-10AWG
1	2	3	5	18	0	0	0	3/C-12AWG
1	2	3	5	3	5	9	13	2/C-2AWG
1	2	3	5	6	10	16	23	2/C-6AWG
1	2	3	5	8	15	23	34	2/C-8AWG
1	2	3	5	13	22	35	51	2/C-10AWG
1	2	3	5	20	36	0	0	2/C-12AWG

The limit to the number of cables under a wrap, use maximum number in a given row. Three 1/C cables are considered as one (1) 3/C cable.

Ampacities of Cable in Themolagged Conduit (Shell Design)

CCdiam := READPRN(CCDIAM_prn)

$$IIthCDshell1_{i,j} := if\left[CCdiam_{i,j} < 3, \frac{0.65}{0.8} IIthCD_{i,j}, \frac{0.925}{0.8} IIthCD_{i,j}\right]$$

$$IIthCDshell_{i,j} := if\left[j > 4, \frac{0.925}{0.8} IIthCD_{i,j}, IIthCDshell1_{i,j}\right]$$

Thermolagged Ampacities in Conduit (Shell Design)

IIthCDshell =

No. of Cables / Conduit Size								
1	2	3	5	3"	4"	5"	6"	
275	313	274	274	391	391	391	313	1/C-500,8 KV
225	256	224	224	320	320	256	224	1/C-350,8 KV
167	190	166	166	237	237	190	166	1/C-4/0,8 KV
348	396	346	346	495	495	396	396	1/C-750,600 V
277	315	276	276	394	394	315	276	1/C-500
223	254	223	223	318	254	223	223	1/C-350
162	184	161	161	184	161	161	138	1/C-4/0
119	95	83	118	118	118	118	101	1/C-2/0
162	184	161	161	230	184	161	161	TRI-4/0
119	95	83	118	135	118	118	118	TRI-2/0
76	60	53	53	75	75	65	54	TRI-2AWG
53	42	37	37	53	53	45	38	3/C-4AWG
40	32	28	28	40	40	34	28	3/C-6AWG
30	24	21	21	30	26	21	21	3/C-8AWG
21	17	15	15	18	15	15	15	3/C-10AWG
16	13	11	11	12	12	12	12	3/C-12AWG
72	57	57	50	81	71	71	61	2/C-2AWG
40	32	32	28	40	40	34	28	2/C-6AWG
30	24	24	21	30	26	21	21	2/C-8AWG
22	17	17	15	18	15	15	15	2/C-10AWG
16	13	13	11	14	12	12	12	2/C-12AWG

$$AMPCHK_{i,j} := if\left[IIthCDshell_{i,j} < Iamp_{i,j}, 1, 0\right]$$

Ampacity Comparison with Thermolagged Conduit (Shell Design)

No. of Cables / Conduit Size								
1	2	3	5	3	4"	5"	6"	
1	1	1	1	0	0	0	1	1/C-500,8 KV
1	1	1	1	0	0	1	1	1/C-350,8 KV
1	1	1	1	0	0	1	1	1/C-4/0,8 KV
1	1	1	0	0	0	1	1	1/C-750,600 V
1	1	1	0	0	0	1	0	1/C-500
1	1	1	0	0	1	1	0	1/C-350
1	1	1	0	1	0	0	0	1/C-4/0
1	1	1	0	1	0	0	0	1/C-2/0
1	1	1	0	0	1	0	0	TRI-4/0
1	1	1	0	1	1	0	0	TRI-2/0
1	1	1	1	0	0	0	0	TRI-2AWG
1	1	1	1	1	1	1	1	3/C-4AWG
1	1	1	1	1	0	0	0	3/C-6AWG
1	1	1	1	0	0	0	0	3/C-8AWG
1	1	1	1	1	0	0	0	3/C-10AWG
1	1	1	1	0	0	0	0	3/C-12AWG
1	1	1	1	1	1	1	1	2/C-2AWG
1	1	1	1	1	1	1	1	2/C-6AWG
1	1	1	1	1	1	1	0	2/C-8AWG
1	1	1	1	1	1	1	0	2/C-10AWG
1	1	1	1	0	0	0	0	2/C-12AWG

NOTE:
1 - Adequate cable ampacity
0 - Inadequate cable ampacity

$$CaLimit_{i,j} := if\left[AMPCHK_{i,j} \approx 1, \left[N_{i,j}\right], 0\right]$$

$$CaLimit_{i,j} := if\left[Iamp_{i,j} \approx 999, 0, CaLimit_{i,j}\right]$$

Limit of Number of Cable in Bundle:
Not to Exceed Ampacity of Cable in
Thermolagged Conduit (Shell Design)

CaLimit =

No. of Cables / Conduit				Size				
1	2	3	5	3	4"	5"	6"	
1	2	3	5	0	0	0	2	1/C-500,8 KV
1	2	3	5	0	0	2	3	1/C-350,8 KV
1	2	3	5	0	0	2	4	1/C-4/0,8 KV
1	2	3	0	0	0	2	2	1/C-750,600 V
1	2	3	0	0	0	2	0	1/C-500
1	2	3	0	0	2	3	0	1/C-350
1	2	3	0	2	0	0	0	1/C-4/0
1	2	3	0	3	0	0	0	1/C-2/0
1	2	3	0	0	2	0	0	TRI-4/0
1	2	3	0	2	3	0	0	TRI-2/0
1	2	3	5	0	0	0	0	TRI-2AWG
1	2	3	5	3	6	10	15	3/C-4AWG
1	2	3	5	4	0	0	0	3/C-6AWG
1	2	3	5	0	0	0	0	3/C-8AWG
1	2	3	5	11	0	0	0	3/C-10AWG
1	2	3	5	0	0	0	0	3/C-12AWG
1	2	3	5	3	5	9	13	2/C-2AWG
1	2	3	5	6	10	16	23	2/C-6AWG
1	2	3	5	8	15	23	0	2/C-8AWG
1	2	3	5	13	22	35	0	2/C-10AWG
1	2	3	5	0	0	0	0	2/C-12AWG

The limit to the number of cables under a wrap, use maximum number in a given row. Three 1/C cables are considered as one (1) 3/C cable.

$IIthCDshell_{(15,j)}$, $Iamp_{(15,j)}$