Total number of pages: 302

CY MP1 MP2 MP3 SB

AMPACITY DERATING OF CABLES DUE TO THERMO-LAG

TITLE

96-ENG-01528E2	00	
CALCULATION #	**REV #**	**Vendor Calc#**

System MSC/2391 **Structure** N/A **Component** CABLES

Executive Summary

This calculation addresses the cables in cable trays and conduit encased in Thermo-Lag fire wrap at MP2. For cable tray, a model was developed using standard heat transfer equations. The validity of this model was verified by comparing the calculated surface temperature of the wrap and its associated ACF (ampacity correction factor) produced by the model to actual test results on wrapped cable tray tested by Texas Utilities. The model was then used to determine an ACF for the various cable tray installations at MP2, the worse case value determined was then utilized. For the conduit installations a model using the same heat transfer type equations was employed and its associated ACF determined.

The ampacity allowed of cables in tray were determined by the simultaneous solution of the heat transfer equations (Stolpe equations). For cables in conduit, the IPCEA values were taken directly from Standard P54-426 and derated based upon directions provided in the standard to adjust for temperature and the number of conductors contained within the conduit. The resultant ampacities were then multiplied by the ACF factor and an Imax ampacity determined. This value was finally compared to the load current on the cable (appropriate multiplication factor used to ensure conservatism).and evaluated against the acceptance criteria of the calculation .

Does this calculation:		
1.	Support a DCR, MMOD, an independent review method for a DCR ,or confirm test results for an installed DCR? If yes, indicate the DCR, MMOD number and/or Test Procedure number.	Yes ☐ No ☒
2.	Support independent analysis? If yes, indicate the procedure, work control or other reference it supports.	Yes ☐ No ☒
3.	Revise, supersede, or void existing calculations? If yes, indicate the calculation number and revisions.	Yes ☐ No ☒
4.	Involve QA or QA-related systems, components or structures?	Yes ☒ No ☐
5.	Impact the Unit licensing basis, including technical specifications, FSAR, procedures or licensing commitments? If yes, identify appropriate change documents.	Yes ☐ No ☒

Approvals (Print/Signature)	
Preparer Dan Hundley / D R Hundley	Date: 12/13/96
Independent Reviewer MICHAEL H. CHAMPAGNE / Michael H Champagne	Date: 12-13-96
Supervisor RG Ewing R G Ewing	Date: 12-13-96

(This calculation originally prepared 11/29/96 under incorrect calculation No. 96-ENG-01288E2) RGE 12/13/96

NUC DCM FORM 5-1A
Rev. 03

9612200086 961213
PDR ADOCK 05000336
P PDR

CTP DATA BASE INPUTS [CT Unit Only]

Calculation Number: 96 (prefix) ENG (sequence number) 01528E2 (suffix) Revision 00 Date 12/13/96

Vendor Calculation Number/Other: __________

CCN# ______ Superseded By: ______ QA ☒ Yes ☐ No Supercedes Calc: ______

Unit	EWR Number	Component Id	Computer Code	Rev. #/Level
2	N/A	N/A	N/A	00

PMMS CODES					
Structure	System	Component	Reference Calculation	Reference Drawings	Sheet
N/A	MSC/2391	N/A	N/A	N/A	

Comments:

TABLE OF CONTENTS

1.0 Purpose

The objective of this calculation is to determine if the cables covered with Thermo-Lag fire barrier material at Millstone Nuclear Power Station Unit 2 are within their ampacity design limitations. This will be accomplished by determining the load on each affected conductor and comparing this value to the maximum allowed derated current due to the presence of Thermo-Lag.

Acceptance Criteria: The maximum derated ampacity (Imax) must be greater than the actual (load) current in each conductor.

2.0 Summary of Results

4160 Volts

The 4160 volt cables used to backfeed from Unit 1 between the Z5 bus and the Z1 and Z2 diesel buses were found to be of insufficient size to carry 3MVA as allowed by OP - 2343 (Ref. 3.1.11).

CABLE	DESCRIPTION
Z5A501A/A	Z5 SAFETY BUS TIE
Z5A505A/B	Z5 SAFTEY BUS TIE

Cable tray Z52FA10 was wrapped with conduit 5T540 for approximately an eight foot (8) section. This was beyond the model's limits. From the 120/125v section that follows, it is obvious that no appreciable heat is contributed by the cables in the conduit. Cable Z5A505A/B after reducing its ampacity by the derate specified by the model still has a 75 amp spare capacity and when powering the Z5 (24E) bus would by inspection be acceptable. This cable, if used as a backfeed from Unit 1 as identified above, is not capable of picking up the load of a diesel and has been identified as failing.

2.0 Summary of Results Continued:

480 Volt Continued:

480 Volts

The cables tabulated and identified below could not meet ampacity requirements

CABLE	DESCRIPTION
Z1B5103/A	Charging Pump MP18A (No. 1)
Z1B5105/A	Charging Pump MP18B (No. 2)
Z2B6102/H	Charging Pump MP18C (No. 3)
Z2B6105/F	Charging Pump MP18B (No.2)

120/125 Volt

All the 120/125 volt cables passed with an acceptable margin.

Conduit 5T540 which contains a 3/C #6 cable (5A602/C) has been boxed in with cable tray Z52FA10 and is considered beyond the model's limits. The continuous load on this cable is less than 1 amp. After using the projected model derate, the cable still has a capacity of 47 amps. By inspection this installation is acceptable.

An ACR has been generated (ACR M2-96-0757)(Ref. 3.1.84) to identify the cables that did not pass the calculations acceptance criteria.

3.0 References/Design Inputs:

3.1 References:

3.1.1 Standard Handbook for Electrical Engineers, Tenth Edition.

3.1.2 Drawing 25203-32020, Sheet 49, Revision 5.

3.1.3 Drawing 25203-34077, Sheet 15, Revision 3.

3.1.4 The National Electric Code Handbook, 1993 edition.

3.1.5 IPCEA P46-426, Power Cable Ampacities, AIEE S-135-1-62 Volume 1 Copper Conductors and S-135-2-62 Volume II Aluminum conductors.

3.1.6 Millstone Nuclear Power Site - Unit 2, Final Safety Analysis Report (MNPS-2 FSAR), Section 8.0.

3.1.7 Drawing 25203-34077, Sheet 13, Revision 3

3.1.8 Tray Schedule Millstone Unit 2 -Volume 1 Pages 1-1045 dated March 27, 1996 and Volume II pages 1046-2011 dated March 27, 1996 (note both volumes contain work in progress to date).

3.1.9 Drawing 25203-30022 Sheet 3HA, Revision 1.

3.1.10 3M Letter, dated June 17, 1986.

3.1.11 Operating Procedure 2343, Revision 17.

3.1.12 TU Electric Ampacity Derating Test Report No. 12340-94583-95166, 95246, dated March 19, 1993.

3.1.13 Thermo-Lag PDCR 2-57-86.

3.1.14 OPAL Load Management System Program, SP-EE-344.

3.1.15 Drawing 25203-30011 Sheet 41, Revision 18 .

3.1.16 Okonite Cable Technical Data Catalog, 1984.

3.1.17 Calculation #95-ENG-01327-E2, Revision 0, Millstone Unit 2 -600-1000 volt cable Ampacity review tray Section Z15NA40.

3.0 **References/Design Inputs continued:**

Referenced continued:

3.1.18 Bechtel Calculation #E-204-3, dated February 21, 1972.

3.1.19 Drawing 25203-32009 Sheet 43A, Revision 3.

3.1.20 Drawing 25203-30001, Revision 11.

3.1.21 Bechtel Calculation E-209-1, dated April 5, 1976.

3.1.22 Drawing 25203-32021 Sheet 15, Revision 5.

3.1.23 Foxboro Catalog cut MI-2A0-130, dated May 1978.

3.1.24 Drawing 25203-30011 Sheet 21, Revision 15.

3.1.25 Drawing 25203-32009 Sheet 42A, Revision 1.

3.1.26 MP2 TSO2 Cable Raceway Schedule (Computerized) 11/23/96

3.1.27 ICEA P-54-440, Ampacities Cables in Open-top Cable Trays, Revision 2, 1979 and Revision 3, 1986.

3.1.28 Drawing 25203-30011 Sheet 34, Revision 12.

3.1.29 Drawing 25203-30022 Sheet 28, Revision 3.

3.1.30 Drawing 25203-32020 Sheet 49A, Revision 2.

3.1.31 Drawing 25203-39360 Sheet 1, Revision 3.

3.1.32 Drawing 25203-32009 Sheet 40, Revision 15.

3.1.33 Drawing 25203-32009 Sheet 42, Revision 9.

3.1.34 Drawing 252003-34001 Sheet 11, Revision 5.

3.1.35 Drawing 25203-30022 Sheet 3 Revision 10.

3.1.36 Drawing 25203-32009 Sheet 43, Revision 14.

3.0 **References/Design Inputs continued:**
References continued:

3.1.37 Drawing 25203-30022 Sheet 10, Revision 2.

3.1.38 Drawing 25203-30011 Sheet 40, Revision 21.

3.1.39 Drawing 25203-30011 Sheet 39, Revision 16.

3.1.40 Drawing 25203-30022 Sheet 12, Revision 23.

3.1.41 Drawing 25203-30012 Sheet 12, Revision 4.

3.1.42 Kerite Engineering Memorandum No. 178A, May 1, 1979.

3.1.43 Cable Description Report, Dated April 9, 1996 (computer generated)

3.1.44 EPRI Volume 4.

3.1.45 EWR M2-96-024

3.1.46 Drawing 25203-32021 Sheet 12, Revision 5.

3.1.47 Drawing 25203-32009 Sheet 46, Revision 5.

3.1.48 Drawing 25203-32031 Sheet 41, Revision 1.

3.1.49 Drawing 25203-32009 Sheet 38, Revision 8.

3.1.50 Drawing 25203-32009 Sheet 35, Revision 4.

3.1.51 Drawing 25203-32009 Sheet 37, Revision 5.

3.1.52 Drawing 25203-32031 Sheet 40, Revision 3.

3.1.53 Drawing 25203-32012 Sheet 22, Revision 10.

3.1.54 Drawing 25203-32009 Sheet 54, Revision 6.

3.1.55 Drawing 25203-30011 Sheet 42, Revision 21.

3.1.56 Drawing 25203-32033 Sheet 9, Revision 3.

3.0 **References/Design Inputs continued:**

References continued:

3.1.57 Drawing 25203-32033 Sheet 13, Revision 7.

3.1.58 Drawing 25203-32009 Sheet 6, Revision 11.

3.1.59 Drawing 25203-32009 Sheet 53, Revision 6.

3.1.60 Drawing 25203-32009 Sheet 39, Revision 6.

3.1.61 Drawing Specification 7604-E-15, "5&8 Kv Power Cable".

3.1.62 Conduit Schedule Millstone Unit 2- pages 1-600 dated March 27, 1996. (note volume contains work in progress to date).

3.1.63 Drawing 25203-32007 Sheet 56, Revision 1.

3.1.64 ASCO Catalog No. NP-1.

3.1.65 Drawing 25203-32020 Sheet 42, Revision 10.

3.1.66 Drawing 25203-30011 Sheet 43, Revision 17

3.1.67 Drawing 25203- 32009 Sheet 44, Revision 4.

3.1.68 Drawing 25203-28500 Sheet 604B, Revision 4.

3.1.69 Drawing 25203-32025 Sheet 33, Revision 6.

3.1.70 Drawing 25203-32025 Sheet 32, Revision 6.

3.1.71 Drawing 25203-32009 Sheet 7, Revision 9.

3.1.72 Drawing 25203-32009 Sheet 60, Revision 3.

3.1.73 Drawing 25203-28500 Sheet 1100, Revision 2.

3.1.74 Drawing 25203-39282, Revision 2.

3.1.75 Drawing 25203-39284, Revision 2.

3.0 **References/Design Inputs continued:**

References continued:

3.1.76 Drawing 25203-34077, Sheet 2, Revision 3.

3.1.77 Drawing 25203-34077, Sheet 25, Revision 3.

3.1.78 Drawing 25203-34077, Sheet 24, Revision 3.

3.1.79 Drawing 25203-34077, Sheet 20, Revision 3.

3.1.80 Drawing 25203-34077, Sheet 16, Revision 4.

3.1.81 Drawing 25203-34077, Sheet 14, Revision 3.

3.1.82 J.H. Neher, M. H. McGrath "Power Apparatus Systems", October 1967.

3.1.83 Drawing 25203-30022, Sheet 1WH, Revision 1.

3.1.84 ACR M2-96-0757.

3.1.85 Drawing 25203-30011, Sheet 29, Revision 17.

3.1.86 Drawing 25203-30011, Sheet 24, Revision 35.

3.1.87 Specification 7604-E-15A, "5Kv Power Cable".

3.1.88 Specification 7604-E-17, "Low Voltage Power Cable".

3.1.89 Specification 7604-E-18, "Multiconductor Control Cable".

3.1.90 Drawing 25203-30022 Sheet 12DC, Revision 1.

3.1.91 Drawing 25203-32021 Sheet 14, Revision 5.

3.1.92 Drawing 25203-32021 Sheet 13, Revision 5.

3.1.93 Bechtel Calculation E-200-2 dated February 15, 1971.

3.1.94 Drawing 25203-30044 Sheet 10, Revision 7.

References/Design Inputs continued:

References continued:

3.1.95 G.E. Heat Transfer and Fluid Flow Data Book, 1971.

3.1.96 NUSCO Calculation 96-ENG-1559E1, Rev. 00.

3.1.97 EEQ Walk down Attachemnt B page B1, dated 8/29/90

3.2 **Design Inputs:**

3.2.1 Allowable ampacities for cables in conduit and cables in air were taken from IPCEA Power Cable Ampacities P-46-426 copy right 1962. Maintained spacing ampacities were taken from Bechtel Calculation E-204-3 (Ref. 3.1.18) unless otherwise noted.

3.2.2 Allowable ampacities for cable in cable tray (random fill) were developed in Attachment 2 or taken from NEC Table 310-68 (Ref. 3.1.4) unless otherwise noted.

3.2.3 Texas Utilities Thermo-Lag Test ampacity derate values for various sizes of cables covered with Thermo-Lag (Ref. 3.1.12).

3.2.4 Ambient Temperature is provide by the FSAR as 50° C (Ref. 3.1.6)

3.2.5 The power cable installed at MP2 is rated 90°C (Ref.3.1.6). The control cable installed at MP2 is rated 90°C. (Ref.3.1.42).

3.2.6 The copper and aluminum wire properties are taken from Okonite Cable (Ref. 3.1.16)

3.2.7 The Unit 2 cables covered by Thermo-Lag are identified in Attachment C. The cables were identified from field walk down . The input was cross verified by using the PDCR that installed the Thermo-Lag (Ref. 3.1.13) and the cable raceway schedule (Ref. 3.1.8) [see Attachment 7].

3.2.8 The loading on cables listed in tables in Section 6.0 were obtained from the one lines and motor data obtained from References 3.1.20, 3.1.15, 3.1.38, 3.1.39 3.1.25, 3.1.28, 3.1.29, 3.1.30, 3.1.31, 3.1.32 and 3.1.33 or as specified in various sections of this calculation. In addition the trays and conduits which are fire wrapped are shown on the 25203-34077 series drawings. (Ref. 3.1.76, 3.1.7, 3.1.81, 3.1.3, 3.1.80, 3.1.79, 3.1.78, 3.1.77)

3.0 **References/Design Inputs continued:**
Design Inputs continued:

3.2.9 **Thermo-Lag Thickness Conversion**

To convert from the Thermo-Lag thickness values used by TU to the 1" Thermo-Lag thickness used by NU see Attachment A.

3.2.10 **Ambient Temperature Conversion**

The ampacity of cables taken from various sources are not all based upon an ambient of 50°C. To adjust to 50°C the following formula can be used:

$$I_2 = I_1 \sqrt{\frac{TC - TA_2 - \Delta TD}{TC - TA_1 - \Delta TD}}$$

where:
I_1 is the current at the existing ambient (A_1)
I_2 is the current at the desired new ambient (A_2)
TC is the conductor temperature in°C
ΔTD is the dielectric loss temperature rise.(see Assumption 4.5)

3.2.11 **Load Conversions (3 phase)**

Knowing either horse power (HP), Kilowatts (KW) or Kilovolt-amps (KVA) the following formula can be used to determine load ampacity for 3 phase systems.

Where HP is known:

$$I = \frac{HP \times 746}{\sqrt{3} \times E \times \%eff \times pf}$$

Where KW is known:

$$I = \frac{KW \times 1000}{\sqrt{3} \times E \times pf}$$

Where KVA is known:

$$I = \frac{KVA \times 1000}{\sqrt{3} \times E}$$

3.0 **References/Design Inputs continued:**

Design Inputs continued:

3.2.12 **Depth of fill (heat Intensity) to Ampacity**

Knowing the depth of fill, the heat intensity can be determined, with the diameter of the conductor, number of conductors and resistance per foot the allowed ampacity for a cable can be determined utilizing the formula below (Attachment D):

$$I = \frac{D}{2}\sqrt{\frac{Q\pi}{nR}}$$

See Attachment B for solutions for Q for various cable trays and for specific cables.

3.1.13 All unincorporated design changes against the referenced drawings have been reviewed to ensure that the latest design was reviewed for impact.

4.0 Assumptions:

4.1 All loads are considered balanced, each phase carrying the same current. Justification - Loading of distribution panels, power panels, lighting panels, etc, employ standard engineering practices that optimize phase loading.

4.2 Feeder cables load will be determined based upon 1.25 times the largest load with the remaining loads added directly to this value. Justification - National Electric Code Article 430-24 allows development of feeder cable loads employing this method (Ref. 3.1.4)

4.3 Motor operated valves do not contribute any appreciable heat to the raceways. Justification -cables must be energized continuously to reach their equilibrium temperature. Motor operated valve cables only carry loads for minutes and are off the majority of the time. The cables are not energized long enough to contribute appreciable heat to a raceway.

4.4. Spare cables act as heat sinks and will reduce the overall temperature of a raceway. This will be ignored, unless specifically identified within the calculation, and the spare cables included in the depth calculation and ampacity ratings of the raceway (Ref. 3.1.44).

4.0 **Assumptions continued:**

4.5 The dielectric temperature loss on a cable is very small and will have a negligible impact upon ampacity calculations since it is subtracted from both the numerator and denominator of the Temperature adjustment equation. Justification - as an example using a typical value for ΔTD of 0.19 and a temperature difference of 40 ° C to 50° C ambient the differences are:

$$\sqrt{\frac{90 - 50 - 0.19}{90 - 40 - 0.19}} \text{ vs } \sqrt{\frac{90 - 50}{90 - 40}} \text{ or}$$

0.894000616 vs 0.894427191 or less than .048%

This assumption is valid for lower voltage cables and only becomes of interest at voltages above 15KV (Ref. 3.1.44).

4.6 Cables that are wrapped using conduit wrap (not in conduit) in cable tray will have the cables ampacity determined based upon cable fill. The derate ACF for the cable will use the worse case (tray or conduit ACF) to ensure that the cables are evaluated conservatively. The conduit wrap around cables without the conduit by inspection is bounded by the conduit model (one conduit barrier is eliminated) thus the conduit model ACF will be utilized as it is more conservative than the free air wrapped cable(s) .

4.7 The 4160 volt cables installed in cable tray were installed using uniform spacing. Justification - Standard installation practices employed at MP2 required higher voltage cables to be installed using maintained spacing. (Ref. 3.1.34, Note 17). Random spacing will be used unless cables are specifically identified as being installed with uniform spacing.

4.8 Junction Boxes will use the same ampacity as used for conduit. Justification, the box is fully enclosed as is a conduit but has a larger surface area to dissipate heat.

4.0 **Assumptions continued:**

4.9 For 460 volt motors the power factor and efficiency are assumed to be 0.85 and 0.88 respectively. Justification- values are taken from OPAL which is conservative (Ref. 3.1.14).

4.10 Cable diameters were taken from Reference 3.1.8 and 3.1.43. For ampacity calculations, a -10% value will be used. Justification - the smaller diameter will ensure conservatism.

4.11 Load Multipliers will be used to adjust for potential voltage fluctuations. For motors 1.25 will be used, 1.2 for transformers and for all other loads a 1.1 multiplier will be used. Justification -Ref. 3.1.44.

4.12 All conduits, unless field verified will be assumed to be in a 6 x 6 grouping and a multiplier of 0.68 will be used against the ampacity. Justification - this is a worse case conservative approach based upon IPCEA Table IX (Ref. 3.1.5).

4.13 Electronic cards mounted components utilizing transistors and intergrated circuits are limited by heat (5Watts) by design limitations. For transistor and integrated circuits this value will be used. Justification - very conservative assumption.

4.14 MOV's by their nature are intermittent loads and do not contribute to the steady state temperature of the tray other than by providing diversity. MOV cables will be evaluated under transient conditions. For example, from Referenace 3.1.97, MOV for 2-CH-501 has a rise of 7.5 ° C for a 15 minute duty cycle.

Tc(f) = 50 + 7.5 = 57.5 ° C.

For other similar valves, the final temperature, the temperature at any time (t) can be determined using the following equation:

$$T_c(t) = T_c(0) + [T_c(f) - T_c(0)](1 - e^{\frac{-t}{k}})$$ (Ref. 3.1.44)

This confirms that the MOV's do not contribute appreciable heat and actually contribute diversity.

5.0 Method of Calculation:

This calculation will identify all cables in MP2 where Thermo-Lag has been installed. For ease of organization the cables will be grouped by voltage class (4160, 480, 120-125 and instrumentation).

The physical installation of the cable will be determined, i.e. whether it is in tray, conduit, free air, or wire-way and the allowable ampacity determined (Ref. 3.1.76 through 3.1.81).

Conduit:

For cables in conduit , the ampacity will be derated based upon the number of conductors in the conduit (Ref. 3.1.44), the grouping factor (assumption 4.12) and then multiplied by the Thermo-Lag derating factor from Attachment 1. The cable load will be determined and adjusted to reflect voltage fluctuations. These values then will be compared and the cable's installation will be considered acceptable if the load current is below the derated maximum value (Imax).

Tray:

For cables in tray the process is slightly more complicated than conduit installations. The allowed ampacity will differ based upon the possible field installation variations.

Uniform Spacing

For cables that have been identified as installed utilizing uniform spacing the allowable ampacity will be determined directly from the ampacity tables in Calculation E204-3 (Ref. 3.1.18). The Thermo-Lag derating from Attachment 1 will be applied to this ampacity and the maximum allowable current (Imax) obtained. This value is then compared to the cable's load current to determine if the installation is acceptable.

Random Fill

Determination of the maximum ampacity a cable can withstand and not exceed its jacket rating when installed in cable tray is dependent upon the cable tray dimensions and depth of fill.

The ampacities of the cables will be determined based upon the ampacities developed using the Stolpe equations and constants provided in the ICEA publication 54-440 (Ref. 3.1.27).

5.0 **Method of Calculation:**

Random Fill continued:

After the maximum permissible ampacity is identified (conductor temperature cannot exceed 90° C), the load ampacity on the cable is determined. Load values that are below the maximum allowable (Imax) will be deemed acceptable.

Free Air Cable

The maximum allowable ampacity for free air cables as required will be obtained from IPCEA (Ref. 3.1.5) or the National Electrical Code (Ref. 3.1.4) for smaller cables not included in IPECA. This value will be multiplied by the appropriate Thermo-Lag derating value from Attachment 1. The cable load current will be compared to the maximum allowable ampacity (Imax) and if it is more than the load current the cable will be considered acceptable as installed.

Load Ampacities:

The loads used for cables will be determined utilizing a conservative sequence approach. This will ensure the calculation is conservative and will reduce the need for excessive load research. The search may be halted once an ampacity is determined not to exceed the maximum allowably ampacity. Should the cable still have an ampacity too high after using all five approaches, depicted below, additional more detailed evaluations will be conducted using other means of evaluation as specified later in this methodology. The order of determining the appropriate value of load is :

1. 80% of breaker rating
2. 100% fuse rating
3. calculation E-209-1
4. OPAL
5. Drawing/vendor documentation review

To adjust for voltage fluctuations, efficiencies and other conditions which may affect ampacity, a multiplication factor (EPRI recommended, Ref. 3.1.44) will be used to ensure conservatism. Motors -1.25, Transformers- 1.2, other loads - 1.1.

For feeder cables, the load will be determined by multiplying the largest motor load by a 1.25 multiplier. The remaining loads will then be summed with this value (Ref. 3.1.4, Section 430-24).

5.0 Method of Calculation:

Additional Evaluations :

Load ampacities for trays that are not overfilled will be evaluated at its existing fill and the increased ampacity used to evaluate the loads.

It is important to note that a great deal of conservatism is also included in this method since every cable is assumed to be fully loaded and at 90°C. Should the maximum value as determined by the above method still be insufficient to allow acceptance of the installation, specific cable ampacities will be utilized and diversity will be taken into consideration.

6.0 Body of Calculation

6.1 4160 Volt Cables

A total of four (4) 4160 volt cable trays were identified in the plant that are covered with Thermo-Lag. The cables associated with these trays are tabulated in Table 6.1. From the tray schedule (Ref. 3.1.8) the cables are either aluminum triplexed 750 MCM cable or triplexed 350 MCM aluminum. (Note that maintained spacing ampacity values were not used for these cables).

Tray Z52EA10

This tray is 38% full (Ref. 3.1.8) which equates to a depth of

$$\text{Depth} = \frac{\%\text{fill x Depth of Tray}}{100\pi/4} = .38 \times 4 \times 4 \div \pi = 1.935''.$$

From Attachment B, Appendix B1, the value (I_1) for 750 MCM at an ambient of 40° C and a depth of 1.935" is 609.38 amps.

To adjust to 50° C, the plant ambient (Ref. 3.2.10), the formula provided in Section 310-15 of Reference 3.1.4. [shown below] is used (Note that ΔTD is very small and negligible(Assumption 4.5).

$$I_2 = I_1\sqrt{\frac{TC - TA_2 - \Delta TD}{TC - TA_1 - \Delta TD}}$$

$$750\text{MCM} - 609.38\sqrt{\frac{90 - 50}{90 - 40}} = 609.38 \times 0.89 = 542.35\,amps$$

The cable is limited to 80% of the free air value or 418.66 amps.

Derating for the Thermo-Lag installed on the cable tray (Attachment A) provides the maximum ampacity the cable can carry and not go above its 90°C rating.

750MCM - Imax = 418.66 x 0.60 = 251.2 amps

6.0 **Body of Calculation continued:**

6.1 4160 Volt Cables continued:

Tray 52BA10

This tray is also at 38% fill. The allowed ampacity for 750MCM will be the same as for the tray above, Imax = 251.2 amps.

Tray Z52FA10

This tray is also at 38% fill. The allowed ampacity for 750 MCM will be the same as for the tray above, Imax = 251.2 amps.

Tray Z22EA10

This tray is at 23% fill. From Attachment B, Appendix B2, 350 MCM at an ambient of 40° C at a 1.1714" depth is 508.46 amps.

To adjust to 50° C, the plant ambient (Ref. 3.2.10), the formula provided in Section 310-15 of Reference 3.1.4. [shown below] is used (Note that ΔTD is very small and negligible Assumption 4.5).

$$I_2 = I_1 \sqrt{\frac{TC - TA_2 - \Delta TD}{TC - TA_1 - \Delta TD}}$$

$$= 508.46 \sqrt{\frac{90 - 50}{90 - 40}} = 508.46 \times 0.89 = 452.53\, amps$$

The cable is limited to 80% of the free air value or 262.02 amps.

Derating for the Thermo-Lag installed on the cable tray (Attachment 1) provides the maximum ampacity the cable can carry and not go above its 90°C rating.

350MCM - Imax = 262.02 x 0.60 = 157.21 amps

The four trays and their associated cables are tabulated on the following page along with the Imax determined using the above method. In addition the table includes the cable's load values determined as follows:

6.1 4160 Volt Cables continued:

TABLE 6.1

Tray	Cable	Code	Type	I_{50C}	Imax	Load	P/F
Z52EA10	Z5A501A/A	A14	1-3/C750	418.66	251.2*	174.64	P
38%	**Backfeed**			418.66	251.2*	416.36	F
52BA10	5A505/A	A14	1-3/C750	418.66	251.2*	87.32	P
38%	5A505/P	A14	1-3/C750	418.66	251.2*	87.32	P
	Backfeed			418.66	251.2*	208.18	P
Z52FA10	Z5A505A/B	A14	1-3/C750	418.66	251.2*	174.64	P
38%	**Backfeed**			418.66	251.2*	416.36	F
Z22EA10	Z2A407/A	A16	1-3/C350	262.02	157.21	76.5	P
23%							

* Unit 1 calculation (Ref. 3.1.96) must also be reviewed for worst case Imax value.

Load Determination

Cable Z5A501A/A is the Z5 (24E) swing bus feed from Bus 24C. The load on the Z5 consists of the following (Ref. 3.1.20 , 3.1.62, 3.1.93 and 3.1.94):

DEVICE	RATING	FLA	VOLT	MULT	LOAD
P5B	450HP	61.2	4000	1.25	76.5
P11B	350HP	45	4000	1.00	45
P41B	400HP	52.5	4000	1.00	52.5
XFMS	KVA/Ø		4160	1.00	0.64
TOTAL					174.64

(Note that the Unit 1 inter-tie is considered open for this analysis.)

The HP (horse power), E (voltage, motor nameplate), FLA values for the motors identified (P5B, P11B and P41B) are available in the Bechtel Calculation (Ref. 3.1.93) . Ampacity for the transformers was calculated from a 5 ohm load at 120v or 600va related to 4160v = 0.144 amps + .5 amp PT = 0.64 amps (Ref. 3.1.94). In accordance with Reference 3.1.4 the largest load on a feeder cable uses a 1.25 load multiplier, all other loads are summed directly to the total.

6.0 **B~dy of Calculation continued:**
t. 4160 Volt Cables continued:

Cable Z5A505A/B is a feed to swing bus Z5 from bus 24D and will see the same load identified for cable Z5A501A/A (174.64 amps) (Ref. 3.1.20).

Cables 5A505/A and 5A505/P (parallel feeds from Unit 1) for Unit 2 would carry the Z5 (24E) bus load identified above, 174.64/2 or 87.32 amps) (Ref. 3.1.20).

OP-2343 (Ref. 3.1.11) specifies a load of 3MVA be provided via Unit 1.

$$I = \frac{3,000,000}{4160 \times \sqrt{3}} = 416.36\,amps$$

Resolution of the 3MVA backfeed capability will be addressed via ACR M2-96-0757 (Ref. 3.1.84)

Cable Z2A407/A is the power feed to Service Water Pump P5C (Ref.3.1.93). Load current is obtained by multiplying the full load amps (Ref. 3.1.14) by 1.25.

61.2 x 1.25 = 76.5 amps.

6.0 **Body of Calculation continued:**

6.2 480 Volt Cables

A total of ten (10) cable trays were identified in the plant that were covered with Thermo-Lag and six (6) conduits. The cables associated with these trays are tabulated on the following pages. From the cable schedule (Ref. 3.1.26) the cables can be identified as power cables. The cables in the tray were installed in accordance with Reference 3.1.18, meeting the requirements of random fill. Note, conduits listed identify all voltage class cables to allow determination of the total number of conductors and any appropriate derating factor.

Imax Evaluations:

The following is an example of how the loads were determined for the cables listed in Table 6.2: For tray Z23HA10 at 10% full, the allowed ampacity for 500MCM triplexed at 50° C ambient is calculated in Attachment B, I_1 = 412.96 amps. Imax is obtained by using the Thermo-Lag derating, 412.96 x 0.6 = 247.78 amps.

TABLE 6.2 **key follows**

Raceway	Cable	Code	Type	I_{50C}	Made	Imax	Load	P/F
Z23HA10	Z2B0610/A	B14	3-1/C500	412.96	TPLX	247.78	198.69	P
10%	Z2B0610/B	B14	3-1/C500	412.96	TPLX	247.78	198.69	P
Z23HB10	Z2B0610/A	B14	3-1/C500	412.96	TPLX	247.78	198.69	P
19%	Z2B0610/B	B14	3-1/C500	412.96	TPLX	247.78	198.69	P
Z23GE10	Z2B0610/A	B14	3-1/C500	412.96	TPLX	247.78	198.69	P
22%	Z2B0610/B	B14	3-1/C500	412.96	TPLX	247.78	198.69	P
	Z2B0607/A	B10	3-1/C250	230.55	TPLX	138.33	102.3 NOTE 1	P
	Z2B0606/A	B14	3-1/C500	412.96	TPLX	247.78	225.4	P
	Z2B0606/B	B14	3-1/C500	412.96	TPLX	247.78	225.4	P
Z23FA30	Z2B0607/A	B10	3-1/C250	213.06	TPLX	127.84	102.3 NOTE 1	P
25%								
Z23FA25	Z2B0607/A	B10	3-1/C250	202.54	TPLX	121.52	102.3 NOTE 1	P
27%								

Raceway	Cable	Code	Type	I_{50C}	Made	Imax	Load	P/F
Z14FM20	Z1B5103/A	B09	3-1/C4/0	238.52	TPLX	143.1	147.5	F
9%	Z1B5105/A	B09	3-1/C4/0	238.52	TPLX	143.1	147.5	F
	Z1B5145/A	B01	3/C#12	22.78		13.67	MOV	P
	1B5158/A	B01	3/C#12	22.78		13.67	MOV	P
Z24FL20	Z2B6105/A	B09	3-1/C4/0		TPLX		SPARE	P
8%	Z2B6102/H	B29	1/C4/0	166.34		99.80	147.5	F
	Z2B6105/F	B29	1/C4/0	166.34		99.80	147.5	F
Z25BG20	Z2B6105/A	B09	3-1/C4/0		TPLX		SPARE	P
10%	2B41A16/A	B03	3/C#8	43.85		26.31	23.5	P
	Z2HT007/H	B03	3/C#8				SPARE	P
	Z2B6102/A	B09	3-1/C4/0		TPLX		SPARE	P
	Z2HT032/H	B03	3/C#8				SPARE	P
	2B41A55/A	B01	3/C#12				SPARE	P
Z14FM10	Z1B5103/A	B09	3-1/C4/0	238.52	TPLX	143.11	147.5	F
12%	Z1B5105/A	B09	3-1/C4/0	238.52	TPLX	143.11	147.5	F
	Z1B5145/A	B01	3/C#12	19.34		11.6	MOV	P
	1B5158/A	B01	3/C#12	19.34		11.6	MOV	P
	1B3238/C	B01	3/C#12	19.34		11.6	1.57	P
	1B31A08/A	B02	3/C#10				SPARE	P
	1B31A08/G	B03	3/C#8	46.54		27.92	23.6	P
Z1A636	Z1B5103/A	B09	3-1/C4/0	247	TPLX	90.53	147.5	F
35%	Z1MCV02/B	C02	2/C #14	20.05	1KV	7.51	0.55	P
	Z1VA1010/A	C62	2/C#10	32.8	1KV	12.02	1.82	P
Z2A209	Z2B6102/H	(3)B29	1/C4/0	227		118.86	147.5	P
21%								
Z2A201	Z2B6105/F	(3)B29	1/C4/0	227		83.2	147.5	F
30%	Z2B6105/G	C86	7/C #14	20.5		7.51	3.52	P
	Z2B6105/K	C86	7/C #14	20.5		7.51	3.52	P
Z2A1074	Z2B6105/F	(3)B29	1/C4/0	227		83.2	147.5	F
53%	Z2B6102/H	(3)B29	1/C4/0	227		83.2	147.5	F
	Z2MCV04/J	C85	3/C #14	20.5		7.51	0.55	P
	Z2B6105/G	C86	7/C #14	20.5		7.51	3.52	P

Raceway	Cable	Code	Type	I_{50c}	Make	Imax	Load	P/F
Z2A1074	Z2B6105/K	C86	7/C #14	20.5		7.51	3.52	P
Z24FL10	Z2B6102/H	B29	1/C4/0	241.90		145.14	147.5	F
4%	Z2B6105/F	B29	1/C4/0	241.90		145.14	147.5	F
Z2A1070	2B6168/A	B01	3/C#12	24.6		9.47*	7.84	P
33%	2B6169/A	B01	3/C#12	24.6		6.44	2.35	P
	Z2HV5279/T	C81	2/C #16	14.76		3.86	0.044	P
	Z2B6102/K	C86	7/C #14	20.5		5.37	3.52	P
	Z2B6105/J	C85	3/C #14	20.5		5.37	3.52	P
	Z2B6117/F	C86	7/C #14	20.5		5.37	4.95	P
	2B6168/C	C07	7/C #14	20.5		5.37	0.66	P
	2B6169/F	C07	7/C #14	20.5		5.37	0.66	P
	Z2CH517/F	C86	7/C #14	20.5		5.37	0.309	P
	Z2CH519/F	C86	7/C #14	20.5		5.37	0.153	P
	Z2HV2525/F	C87	9/C #14	20.5		5.37	0.153	P
	2K01160/B	C85	3/C #14	20.5		5.37	0.04	P
	2K04028/B	C85	3/C #14	20.5		5.37	0.04	P
	Z2NF09/G	C86	7/C #14	20.5		5.37	1.76	P
	2QR006B/H	C85	3/C #14	20.5		5.37	0.093	P
Z2A1073	Z2B6102/H	B29	1/C4/0	227		71.3	147.5	F
38%	Z2B6105/F	B29	1/C4/0	227		71.3	147.5	F
	Z2B6102/J	C87	9/C #14	20.5		6.44	3.52	P
	Z2B6105/G	C86	7/C #14	20.5		6.44	3.52	P
	Z2B6105/H	C87	9/C #14	20.5		6.44	3.52	P
	Z2B6117/D	C86	7/C #14	20.5		6.44	4.95	P
	Z2B6117/E	C85	3/C #14	20.5		6.44	4.95	P

Key for Table 6.2

NOTE 1 -Load is taken from OPAL, 81.5 KVA or 102.3 amps.

I for tray is obtained through calculation (solving the simultaneous Stolpe equations in Attachment D). This is the method employed by ICEA in the development of the ampacity tables in Publication P-54-440.
For conduits include all voltage classes of cable to ensure of proper derate for the number of conductors.
IPCEA P46-426 is used if possible, NEC is used for wire smaller than #8 AWG.
* group factor of 1.0 from field inspection

6.0 **Body of Calculation continued:**
6.2 480 Volts continued:

Imax Evaluations :

Tray Z23HB10 the 500MCM cable's allowed ampacity at 19% fill (depth = 0.968 in) is obtained from Attachment B, 412.96 amps. Derating for Thermo-Lag, 412.96 x 0.6 = 247.78 amps.

Tray Z23GE10 the 500MCM cable's allowed ampacity at 22% fill is (depth = 1.12 in) obtained from Attachment B, 412.96 amps. Derating for Thermo-Lag, 412.96 x 0.6 = 247.78 amps.

The 250MCM cable's allowed ampacity at 22% fill is also obtained from Attachment B, 230.55 amps. Derating for Thermo-Lag, 230.55 x 0.6 = 138.33 amps.

Tray Z14FM20 at 9% fill Depth = 0.458 inches

For 3/C 4/0 Triplex, free air at 40° C is 335 amps , adjusting to 50° C gives 335 x .89 = 298.15amps and 80% is equal to 238.52 amps. Derating for Thermo-Lag gives 238.52 x 0.6 = 143.1 amps.

The 3/C#12 cable's allowed ampacity at 9% fill is also obtained from Attachment B, 22.78 amps. Derating for Thermo-Lag, 22.78 x 0.6 = 13.67 amps.

Tray Z24FL20 is at 8% fill and a depth of 0.407 in.
The 4/0 Triplexed cable is limited to 80% of its free air value at 50° C. See Tray Z14FM20 for allowed ampacity. For non-triplexed 4/C see Attachment B, 166.34 amps. Derating for Thermo-Lag, 166.34 x 0.6 = 99.80 amps.

Tray Z25BG20 is at 10% fill and a depth = 0.509 inches. The 3/C #8 allowed ampacity from Attachment B is 43.85 amps. Derating for Thermo-Lag, 43.85 x 0.6 = 26.31 amps.

Tray Z14FM10 is at 12% fill and a depth = 0.611 inches.
The 80% of free air values calculated for the 4/0 triplex cables in the tray above will also be applicable for this tray, 238.52 amps. Derating for thermo-lag 238.52 x 0.6 = 143.11 amps.

For the 3/C #12, from Attachment B the ampacity is 19.34 amps. Derating for Thermo-Lag, 19.34 x 0.6 = 11.6 amps.

6.0 **Body of Calculation continued:**

6.2 480 Volts continued:

Z1A636 Conduit This conduit is 35% full, the 3-1/C4/0 TPLX from IPCEA (REF. 3.1.5) is 278 amps at 40° C. Adjusting to 50° C ambient gives 278 x .89 = 247 amps. Derating for the total number of conductors in the conduit (7), requires a 0.7 derate (Ref. 3.1.44). Or 247 x .7 = 172.9 amps, derating for grouping factor, 172.9 x .68 =117.57 amps, derating for Thermo-Lag 117.57 x 0.77 = 90.53 amps.

From Reference 3.1.4:
For #14 AWG the allowed ampacity is 25 amps at 30° C, adjusted to 50° C gives 25 x 0.82 = 20.5 amps. Adjusting for the number of conductors in the conduit, 20.5 x .7 = 14.35 amps derating for grouping factor , 14.35 x .68 = 9.76 amps and derating for Thermo-Lag 9.76 x 0.77 = 7.51 amps.

For #10 AWG the allowed ampacity is 40 amps at 30° C, adjusted to 50° C gives 40 x 0.82 = 32.8 amps. Adjusting for the number of conductors in the conduit (7), 32.8 x .7 = 22.96 amps, derating for grouping factor, 22.96 x 0.68 = 15.61 amps and derating for Thermo-Lag 15.61 x 0.77 = 12.02 amps.

Z2A209 Conduit This conduit is 21% full, the 3-1C 4/0 cable from IPCEA (Ref. 3.1.5) is 255 amps at 40° C. Adjusting to an ambient of 50° C, 255 x 0.89 = 227 amps. (The total number of current carrying conductors in the conduit is 3). Derating for grouping factor, 227 x .68 = 154.36 amps and derating for Thermo-Lag gives 154.36 x 0.77 = 118.86 amps.

Z2A201 Conduit This conduit is 30% full, the 3-1C 4/0 cable from IPCEA (Ref. 3.1.5) is 255 amps at 40° C. Adjusting to an ambient of 50° C, 255 x 0.89 = 227 amps. Adjusting for the total number of conductors in the conduit (17), requires a derate of 0.7 (Ref. 3.1.44). 227 x .7 =158.9 amps, derating for grouping factor, 158.9 x .68 = 108.05 and derating for Thermo-Lag 108.05 x 0.77 = 83.2 amps

For #14 AWG the allowed ampacity is 25 amps at 30° C, adjusted to 50° C gives 25 x 0.82 = 20.5 amps. Adjusting for the number of conductors in the conduit, 20.5 x .7 = 14.35 amps, derating for grouping factor, 14.35 x .68 = 9.76 amps and derating for Thermo-Lag 9.76 x 0.77 = 7.51 amps.

Z2A1073 Conduit This conduit is 38% full, the 3-1/C 4/0 cable from IPCEA (Ref. 3.1.5) is 255 amps at 40° C. Adjusting to an ambient of 50° C, 255 x 0.89 = 227 amps. (The total number of conductors in the conduit is 41, requiring a derate of .6). Adjusting for the number of conductors in the conduit, 227 x .6 = 136.2 amps , adjusting for group factor, 136.2 x .68 = 92.6 amps and derating for Thermo-Lag 92.6 x 0.77 = 71.3 amps.

6.0 **Body of Calculation continued:**

6.2 480 Volts continued:

Z2A1073 Conduit

The #14 AWG cable from above is rated at 20.5 amperes at 50° C , adjusting for 41 conductors, 20.5 x 0.6 = 12.3 amps adjusting for grouping factor, 12.3 x .68 = 8.36 amps. Deratng for Thermo-Lag 8.36 x 0.77 = 6.44 amps.

Tray Z24FL10 is at a 4% fill Depth = 0.2037 inches.

From Attachment B the 3-1/C 4/0 ampacity is 241.90 amps. Derating for Thermo-Lag gives 241.90 x 0.6 = 145.14 amps.

Z2A1074 Conduit This conduit is 53% full, the conduit length is 3 feet. This short distance allows the greater than 40 % fill without doing damage to the cables. The ampacity of the 3-1/C 4/0 from IPCEA (Ref. 3.1.5) is 255 amps at 40° C. Adjusting to an ambient of 50° C, 255 x 0.89 = 227 amps. The total number of conductors in the conduit is 23, derating for the conductors, 227 x 0.7 = 158.9 amps. Derating for grouping factor, 158.9 x .68 = 108.05 aamps and derating for Thermo-Lag, 108.05 x 0.77 = 83.2 amps.

The #14 AWG cable from above is rated at 20.5 amperes at 50° C , adjusting for 23 conductors, 20.5 x 0.7 = 14.35 amps. Derating for grouping factor, 14.35 x 0.68 = 9.758 amps and deleting for Thermo-Lag 9.758 x 0.77 = 7.51 amps.

Z2A1070 Conduit This conduit is 33% full, the #12 AWG cable is 30 amps at 30° C , adjusting to 50° C, 30 x 0.82 = 24.6 amps. Adjusting for 78 conductors, 24.6 x 0.5 = 12.3 amps. Derating for group factor 12.3 x 0.68 = 8.36 amps and derating for Thermo-Lag 8.36 x 0.77 = 6.44 amps.

The #14 cable is rated at 20.5 amperes at 50° C , adjusting for 78 conductors, 20.5 x 0.5 = 10.25 amps, adjusting for group factor, 10.25 x 0.68 = 6.97 amps and deleting for Thermo-Lag, 6.97 x 0.77 = 5.37 amps.

The #16 cable is rated at 18 amperes at 30° C , adjusting to 50° C 18 x .82 = 14.76 amps. The total number of conductor in the conduit is 78, 14.76 x 0.5 = 7.38 amps. Derating for grouping factor, 7.38 x .68 = 5.02 amps and derating for Thermo-Lag, 5.02 x 0.77 = 3.86 amps.

6.0 **Body of Calculation continued:**
6.2 480 Volts continued:

Load Determination:

Cables **Z2B0610/A** and **Z2B0610/B** are parallel feeder cables to MCC B61. Continuous load on MCC B61 is shown on Attachment 5 [397.38 amps].

$$397.38 \div 2 = 198.69 \text{ amps}$$

Cables **Z2B0606/A** and **Z2B0606/B** are parallel feeder cables to MCC B62. Continuous load on MCC B62 is shown on Attachment 6, [450.8 amps]

$$450.8 \div 2 = 225.4 \text{ amps}$$

Cables **Z1B5103/A, Z1B5105/A ,Z2B6102/H** and **Z2B6105/F** for Charging Pumps P18A and P18B and P18C are all 100HP motors per (Ref. 3.1.28, 3.1.39).
The nameplate full load amps is 118 amps. Adjusting for voltage fluctuations 118 x 1.25 gives 147.5 amps.

Cables Z2B6102/A, 1B31A08/A, Z2B6105/A, 2B41A55/A, Z2HT032/H and Z2HT007/H are spare (Ref. 3.1.26)

Cables Z1B5145/A and 1B5158/A are MOV feeds (see Assumption 4.14, Ref. 3.1.58 and 3.1.71).

Cable **2B41A16/A** is the degasifier Pump #2 motor is 15 HP (Ref. 3.1.85)

$$I = \frac{HP \times 746}{\sqrt{3} \times E \times eff \times pf} = 18.8 \times 1.25 = 23.5 \text{ amps}$$

Cable **1B3238/C** is RM8997, a 1 hp motor (Ref. 3.1.86)

$$I = \frac{1 \times 746}{\sqrt{3} \times 460 \times .88 \times .89} = 1.25 \times 1.25 = 1.57\,AMPS$$

Cable **2B6168A** is for a 5hp motor MP72B (Ref. 3.1.38)

$$I = \frac{5 \times 746}{\sqrt{3} \times 460 \times .88 \times .89} = 6.27 \times 1.25 = 7.84 \text{ amps}$$

6.0 **Body of Calculation continued:**

6.2 480 Volts continued:

Load Determination continued:

Cable **2B6169A** is for a 1.5 hp motor MP125 (Ref. 3.1.38)

$$I = \frac{1.5 \times 746}{\sqrt{3} \times 460 \times .88 \times .85} = 1.88\,amps \times 1.25 = 2.35 \text{ amps}$$

Cable **1B31A08/G** is for a 15 hp motor, NP16A1. (Ref. 3.1.24)

$$I = \frac{15 \times 746}{\sqrt{3} \times 460 \times .88 \times .85} = 18.88\,amps \times 1.25 = 23.6 \text{ amps}$$

Cable **Z2B0607/A**, Battery Charger 201B, per OPAL/FSAR Table 8.3-2 maximum load on diesel during LOCA from charger is 81.5KVA (Ref. 3.1.31).

$$I = \frac{81.5 \times 1000}{\sqrt{3} \times 480} = 102.3\,amps$$

Cable **Z1MCV02/B**, load is 0.5 amps (Ref. 3.1.67) x 1.1 = 0.55 amps

Cable **Z1VA1010/A,** load is 1.65 amps (Ref. 3.1.37) x 1.1 = 1.82 amps

Cable **Z2MCV04/J**, load is 0.5 amps (Ref. 3.1.47) x 1.1 =0.55 amps

Cable **Z2B6105/G**, load is 3.2 amps (Ref. 3.1.25) x 1.1 = 3.52 amps

Cable **Z2B6105/K**, load is 3.2 amps (Ref. 3.1.25). x 1.1 = 3.52 amps

6.0 **Body of Calculation continued:**
6.2 480 Volts continued:

Load Determination continued:

Cable **Z2HV5279/T**, V =±10vdc, R = 250Ω, load is 0.04 amps (Ref. 3.1.68 and 3.1.23) x 1.1 = 0.044 amps

Cable **Z2B6102/K**, load is 3.2 amps (Ref. 3.1.36) x 1.1 = 3.52 amps

Cable **Z2B6105/J**, load is 3.2 amps (Ref. 3.1.25) x 1.1 = 3.52 amps

Cable **Z2B6117/F**, load is 4.5 amps (Ref. 3.1.49) x 1.1 = 4.95 amps

Cable **2B6168/C**, load is 0.6 amps (Ref. 3.1.56) x 1.1 = 0.66 amps

Cable **2B6169/F**, load is 0.6 amps (Ref. 3.1.57) x 1.1 = 0.66 amps

Cable **Z2CH517/F**, load is 0.281 amps (Ref. 3.1.64 and 3.1.50)X 1.1 = 0.309 amps

Cable **Z2CH519/F**, load is 0.139 amps (Ref. 3.1.64 and 3.1.51) x 1.1 = 0.153 amps

Cable **Z2HV2525/F**, load is 0.139 amps (Ref. 3.1.64) x 1.1 = 0.153 amps

Cable **2K01160/B**, load is 0.04 amps (Ref. 3.1.52) x 1.1 = 0.04 amps

Cable **2K04028/B**, load is 0.04 amps (Ref. 3.1.48) x 1.1 = 0.04 amps

Cable **2QR006B/H**, load is 0.0842 amps (Ref. 3.1.63) x 1.1 = 0.0926 amps

Cable **Z2B6102/J** load is based on a 3.2 amp fuse (Ref. 3.1.19) x 1.1 = 3.52 amps.

Cable **Z2B6105/H** load is based on a 3.2 amp fuse (Ref. 3.1.25) x 1.1 = 3.52 amps.

Cable **Z2B6117/D** load is based on a 4.5 amp fuse (Ref. 3.1.49) x 1.1 = 4.95 amps.

Cable **Z2B6117/E** load is based on a 4.5 amp fuse (Ref. 3.1.49) x 1.1 = 4.95 amps.

Cable **Z2NF09/G** load is based upon a 200ohm load at 125VDC (Ref. 3.1.65)
1.6 amps x 1.1 = 1.76 amps.

6.0 **Body of Calculation continued:**

6.3 120ac/125dc Volts Power

A total of five cable trays, a wire-way, five conduit and one box were identified in the plant as covered with Thermo-Lag.

TABLE 6.3

Tray/ Conduit	Cable	Code	Type	I_{50_C}	Imax	Load	P/F
5T540	5A602/C	B04	3/C#6	61.5	32.2	1	P
10%							
Z2A1078	Z2DV2008/A	B46	2/C#10	32.8	13.74	0.91	P
	Z2VA2004/A	B46	2/C#10	32.8	13.74	1.76	P
J603	see Z25XA10						
Z25XA10	Z2DV2008/A	B46	2/C#10	32.8	12.63	0.91	P
	Z2VA2004/A	B46	2/C#10	32.8	12.63	1.76	P
	Z25V4188/K	C90	7/C#12	24.6	9.47	0.91	P
	Z2SV4188/M	C94	2/C#10	32.8	12.63	0.91	P
	Z2SV4188/L	C90	7/C#12	24.6	9.47	0.185	P
	Z2SV4188/J	C94	2/C#10	32.8	12.63	0.185	P
	Z2HV5279/P	C89	3/C#12	24.6	9.47	0.39	P
	Z2HV5279/R	C89	3/C#12	24.6	9.47	0.434	P
	Z2HV5279/T	C81	2/C#16	14.76	5.68	0.92*	P
	Z2HV5279/U	C81	2/C#16	14.76	5.68	0.55	P
	Z2B6102/J	C87	9/C#14	20.5	7.89	3.52*	P
	Z2B6102/K	C86	7/C#14	20.5	7.89	3.52*	P
	Z2B6105/H	C87	9/C#14	20.5	7.89	3.52*	P
	Z2B6105/J	C85	3/C#14	20.5	7.89	3.52	P
	Z2B6105/K	C86	7/C#14	20.5	7.89	0.13	P
	Z2B6117/D	C86	7/C#14	20.5	7.89	4.95*	P
	Z2B6117/E	C85	3/C#14	20.5	7.89	4.95*	P
	Z2B6117/F	C86	7/C#14	20.5	7.89	4.95	P
	Z2CH517/E	C86	7/C#14	20.5	7.89	0.168	P
	Z2CH517/F	C86	7/C#14	20.5	7.89	0.168	P
	Z2CH519/E	C87	9/C#14	20.5	7.89	0.168	P
	Z2CH519/F	C86	7/C#14	20.5	7.89	0.168	P

*LOAD IDENTIFIED FOR 480 V SECTION

6.0 **Body of Calculation continued:**

6.3 120ac/125dc Volts Power

Tray/ Conduit	Cable	Code	Type	I_{50}	Imax	Load	P/F
Z25XA10	Z2HV2525/F	C87	9/C#14	20.5	7.89	0.213	P
	Z2HV2525/G	C86	7/C#14	20.5	7.89	0.213	P
	Z2HV2525/H	C85	3/C#14	20.5	7.89	0.085	P
	Z2NF09/F	C86	7/C#14	20.5	7.89	1.73	P
	Z2NF09/G	C86	7/C#14	20.5	7.89	1.73	P
	2K01160/B	C85	3/C#14	20.5	7.89	0.055	P
	Z2MCV04/J	C85	3/C#14	20.5	7.89	0.55*	P
	Z2HV5279/S	C76	9/C#12	24.6	9.47	0.37	P
Z2T871	Z2SV4188/C	C91	9/C#12	24.6	9.02	0.91	P
	Z2SV4188/D	C96	4/C#10	32.8	12.02	0.91	P
	Z2NF09/F	C86	7/C #14	20.5	7.51	1.73	P
Z25BG20	Z2HT007/C	C62	2/C#10			SP	P
10%	Z2HT028/C	C62	2/C#10			SP	P
	Z2HT032/C	C62	2/C#10			SP	P
	2B6102/F	B01	3/C#12	9.984	5.99	2.3	P
	2HT007/F	C02	2/C #14			SP	P
	2HT028/F	C02	2/C #14			SP	P
	2HT032/F	C02	2/C #14			SP	P
	2K02049/B	C02	2/C #14	7.68	4.61	0.04	P
	2K02051/B	C02	2/C #14	7.68	4.61	0.04	P
	2K02053/B	C02	2/C #14	7.68	4.61	0.04	P
	2K02055/B	C02	2/C #14	7.68	4.61	0.04	P
	2CH910/B	C03	3/C #14	6.153	3.68	1.65	P
	2CH910/C	C03	3/C #14	6.153	3.68	1.65	P
	2FT9860/A	C03	3/C #14	6.153	3.68	0.04	P
	2HC2152/B	C03	3/C #14			SP	P
	Z2HT028/H	C62	2/C#10			SP	P

6.0 **Body of Calculation continued:**

6.3 120ac/125dc Volts Power

Tray / Conduit	Cable	Code	Type	I_{150c}	Imax	Load	P/F
Z24FL20	2B41A16/F	C07	7/C#14	4.96	2.97	0.334	P
	Z2B6105/G	C86	7/C#14	4.96	2.97	2.5	P
	Z2B6105/K	C86	7/C#14	4.96	2.97	0.146	P
	Z2HV8133/C	C02	2/C#14	7.68	5.10	0.153	P
Z24FL20	Z2HV8133/D	C07	7/C#14	4.96	2.97	0.301	P
	Z2HV8248/C	C02	2/C#14	7.68	4.61	0.301	P
	Z2HV8248/D	C07	7/C#14	4.96	2.97	0.301	P
	Z2MCV04/B	C02	2/C#14	7.68	4.61	0.55	P
	Z2VA2010/A	C02	2/C#14	7.68	4.61	1.82	P
	Z2MCV04/J	C85	3/C#14	6.153	3.69	0.55*	P
Z14FM10	1B5103/F	B01	3/C#12	9.984	6.3	1.01	P
12%	1B5105/C	B01	3/C#12	9.984	6.3	1.01	P
	Z1VA1010/A	C62	2/C#10	13.358	8.87	1.82*	P
	1B31A08/F	C07	7/C#14	4.96	2.97	0.34	P
	Z1B5145/C	C07	7/C#14	4.96	2.97	1.29	P
	1B5158/B	C07	7/C#14	4.96	2.97	0.66	P
	Z1CH192/B	C07	7/C#14	4.96	2.97	0.853	P
	Z1HV8247/C	C07	7/C#14	4.96	2.97	0.153	P
	Z1HV8247/D	C07	7/C#14	4.96	2.97	0.153	P
	Z1HV8249/C	C02	2/C#14	4.96	2.97	0.153	P
	Z1HV8249/D	C07	7/C#14	4.96	2.97	0.153	P
	1K96001/B	C02	2/C#14	7.68	4.61	0.04	P
	1K96002/B	C02	2/C#14	7.68	4.61	0.04	P
	Z1MCV02/B	C02	2/C#14	7.68	4.61	0.123	P
	1RM8997/D	C02	2/C#14	7.68	4.61	0.83	P
	1VAAS/E	C02	2/C#14	7.68	4.61	SP	P
	1VAAS/EE	C02	2/C#14	7.68	4.61	SP	P
	Z1CH196/B	C07	7/C#14	4.96	2.97	0.254	P

6.0 Body of Calculation continued:

6.3 120ac/125dc Volts Power continued:

TABLE 6.3

Tray / Conduit	Cable	Code	Type	I_{50C}	Imax	Load	P/F
Z14FM20	Z1VA1010/A	C62	2/C#10	13.358	8.02	1.82*	P
9%	1B5103/F	B01	3/C#12	9.984	5.99	3.2	P
	1B5105/C	B01	3/C#12	9.984	5.99	2.31	P
	Z1B5145/C	C07	7/C #14	4.96	2.97	1.29	P
	1B5158/B	C07	7/C #14	4.96	2.97	0.66	P
	Z1CH192/B	C07	7/C #14	4.96	2.97	0.854	P
	Z1HV8247/C	C02	2/C#14	7.68	4.61	0.153	P
	Z1HV8247/D	C07	7/C #14	4.96	2.97	0.153	P
	Z1HV8249/C	C02	2/C#14	7.68	4.61	0.153	P
	Z1HV8249/D	C07	7/C #14	4.96	2.97	0.153	P
	Z1MCV02/B	C02	2/C#14	7.68	4.61	0.124*	P
	Z1CH196/B	C07	7/C #14	4.96	2.97	0.28	P
Z2A201	Z2B6105/G	C86	7/C #14	20.5	7.51	2.52*	P
	Z2B6105/K	C86	7/C #14	20.5	7.51	0.134*	P
Z24FL10	Z2MCV04/J	C85	3/C #14	6.153	3.69	0.55*	P
4%	Z2B6105/G	C86	7/C #14	17.57	10.54	3.52*	P
	Z2B6105/K	C86	7/C #14	17.57	10.54	3.52*	P
Z1A636	Z1VA1010/A	C62	2/C#10	32.8	12.02	0.55*	P
	Z1MCV02/B	C02	2/C #14	20.5	7.51	1.82*	P

* load identified for 480 volt section.

6.0 Body of Calculation continued:

6.3 120ac/125dc Volts Power continued:
Imax Evaluation

5T540 Conduit, the ampacity of 5A602/C : 3/C #6 cable in conduit is 75 amps (Ref. 3.1.4) at 30° C. Adjusting to 50° C, 75 x 0.82 = 61.5 amps. This is the only cable in the conduit. Derating due to grouping factor, 61.5 x .68 = 41.82 amps and derating for Thermo-Lag, 41.82 x 0.77 = 32.20 amps.

Z2A1078 Conduit, the ampacity of #10 AWG cable in conduit is 40 amps at 30° C.(Ref.3.1.4) Adjusting for 50° C, 40 x .82 = 32.8. Derating for 4 conductors in a conduit (Ref.3.1.44), 32.8 x 0.8 = 26.24 amps. Derating for group factor, 26.24 x .68 = 17.84 amps and derating for Thermo-Lag, 17.84 x 0.77 = 13.74 amps.

Z25XA10 Wire-Way, will be treated as a conduit. For #12 AWG (Ref. 3.1.4) cable is rated 30 amps at 30° C. Adjusting for 50° C, 30 x 0.82 = 24.6. Adjusting for the number of conductors (REF. 3.1.44), 146 gives 24.6 x 0.5 = 12.3 amps. Derating for the Thermo-Lag, 12.3 x 0.77 = 9.47 amps.

For # 10 AWG (Ref. 3.1.4) cable is rated at 40 amps at 30° C, adjusting for 50° C., 40 x 0.82 = 32.8. Adjusting for the number of conductors 146, 32.8 x 0.5 = 16.4 amps. Derating for Thermo-Lag, 16.4 x 0.77 = 12.63 amps.

For # 14 (Ref. 3.1.4) is good for 25 amps at 30° C.. Adjusting to a 50°C ambient, 25 x 0.82 = 20.5 amps. Adjusting for 146 conductors, 20.5 x 0.5 = 10.25 amps. Derating for Thermo-Lag, 10.25 x 0.77 = 7.89 amps.

For #16 (Ref. 3.1.4) cable is rated at 18 amps in a 30°C ambient, adjusting for a 50°C ambient 18 x 0.82 = 14.76, adjusting for 146 conductors , 14.76 x 0.5 = 7.38 amps. Derating for Thermo-Lag, 7.38 x 0.77 = 5.68 amps.

Z25BG20 TRAY the ampacities for the control cables will use the 35% fill values for conservatism (actual 10% fill) . From Attachment 2, Appendix AD, 2/C #10 in tray can carry 13.358 amps, at 50° C. Derating for Thermo-Lag, 13.358 x 0.6 = 8.02 amps.

The 3/C #12 can be obtained from Attachment 2, Appendix AC, using the 35% fill value, provides 9.984 amps at 50° C. Derating for Thermo-Lag, 9.984 x 0.6 = 5.99 amps.

6.3 120ac/125dc Volts Power continued:
Imax Evaluation continued:

Z25BG20 TRAY continued:

The 3/C #14 at a fill of 35 % (1.78") per Attachment 2, Appendix AA provides an allowed ampacity of 6.153 amps at 50° C. Derating for Thermo-Lag, 6.153 x 0.6 = 3.69 amps.
For 2/C #14, Attachment 2, Appendix AB allowed ampacity is 7.68 amps at 50° C . Derating for Thermo-Lag 7.68 x 0.6 = 4.61 amps.

For **Tray Z14FM20** , **Z24FL20**, and **Tray Z14FM10**, the fill and the values developed for cables in Z25BG20 above are also applicable.
For 7/C #14 (C86) adjusting for the diameter difference:

$$I_2 = \frac{d_2}{d_1} I_1 = \frac{0.64}{0.52} 6.163 = 7.57 amps$$ adjusting for number of

conductor difference, I = $7.57\sqrt{\frac{3}{7}}$ = 4.96 amps Derating for Thermo-Lag, 4.96 x 0.6 = 2.97 amps.

Z2T871 Conduit. From Reference 3.1.4, 3/C #12 in conduit can carry 30 amps. at 30° C, adjusting to 50° C, 30 x .82 = 24.6. Adjusting for the number of conductors (20), 24.6x 0.7 = 17.22 amps. Derating for group factor, 17.22 x .68 = 11.71 am ps and derating for Thermo-Lag, 11.71x 0.77 = 9.02 amps.

For 4/C #10 the allowed ampacity is 40 amps (Ref. 3.1.4) at 30° C, for a 50° C ambient, 40 x .82 = 32.8. Adjusting for the number of conductors (20), 32.8 x 0.7 = 22.96 amps. Derating for grouping factor, 22.96 x 0.68 = 15.61 and derating for Thermo-Lag, 15.61 x 0.77 = 12.02 amps.

The #14 cable is rated at 20.5 amperes at 50° C (Ref. 3.1.4), adjusting for 17 conductors, 20.5 x 0.7 = 14.35 amps. Derating for grouping factor, 14.35 x .68 = 9.76 amps and deleting for Thermo-Lag, 9.76 x 0.77 = 7.51 amps.

Z2A201 Conduit. The #14 cable is rated at 20.5 amperes at 50° C (Ref. 3.1.4), adjusting for 17 conductors, 20.5 x 0.7 = 14.35 amps. Derating for grouping factor, 14.35 x .68 = 9.76 amps and deleting for Thermo-Lag, 9.76 x 0.77 = 7.51 amps.

Z24FL10 Tray From Attachment 2, Appendix X, the cable is rated at 17.57 amps at 50° C. Derating for Thermo-Lag 17.57 x .6 = 10.54 amps.

6.3 120ac/125dc Volts Power continued:

Load Determination :

Cable **5A602/C** provides 125 vdc to the 4160v switch gear from MP1 4160v switchgear bus 14H cubicle A610 Unit 105A. The breaker trip requirement is approximately 12 amps but is only momentary. The circuit breaker closing is less than 7 amps and is also only momentary. The indicating lights constitute the only continuous load and are less than 1 amp (Ref. 3.1.3 and 3.1.83).

Cable **Z2VA2004/A** powers C09 control room panel. The cable is the power supply to a Foxboro power supply (N-2ARPS 05) which transforms the 120 to 24 volts, this breaks down into two circuits one requiring 5 amps in a dc loop and one 3 amps ac. These ampacities are combined as a conservative measure and the total load is taken as 8 amps at 24 ac. The VA rating of the transformer is thus 24 x 8 = 192 va. The cable would see 192 / 120 = 1.6 amps (Ref. 3.1.90).

Cable **Z2DV2008/A** powers C10 control room panel. The cable is fed from DV20 circuit 8 which is a 30 amp 250 volt dc breaker. From DM2-5-1213-95 Sheet 6 (Ref. 3.1.35) the starting load on the panel is 17.5 amps. The normal load seen by the cable is 0.8268 amps and will be used as the load (Ref. 3.1.60, 3.1.9, 3.1.53)

Cables **Z2SV4188/K**, **Z2SV4188/M**, **Z2SV4188/C** and **Z2SV4188/D** are all associated with the controls of C10 and see part or all of the 0.8268 amps identified above. For conservatism all will use a load of 0.8268 amps (Ref. 3.1.9, 3.1.2).

Cable **2B6102/F** per Drawing 25230-32009 Sheet 43 (Ref. 3.1.36) the motor heater is 110 watts at 120, the current is 110/120 = 0.9167 amps (rounded up to 0.92).

For Tray **Z14FM20** the 1/C#12 cables (1B5103/F and 1B5105/C) feed 110 watt heaters (Ref. 3.1.32 and 3.1.33). The load is 110 watts, 110/120 = 0.9167 amps (rounded up to 0.92). Cable Z1VA1010/A is on breaker 10 of Panel VA10 (Ref . 3.1.37) and is loaded to 1.6472 amps (rounded up to 1.65)

For Tray **Z14FM10** see the above tray for common cables.

Cable **Z2MCV04/B** (Ref. 3.1.47) uses a 0.5 amp fuse in the circuit.

Cable **Z2VA2010/A** (Ref. 3.1.37) has a total load of 1.648 amps on this cable.

6.3 120ac/125dc Volts Power continued:

Load Determination continued:

Cable **Z2B6105/H** has a 3.2 amp fuse in the circuit, current value used will be the fuse value (Ref. 3.1.25 and 3.1.30).

Cable **Z2HV5279/U** (Ref. 3.1.68) has a 250 ohm resister in series with the load. Using the highest DC voltage (125 v) as its source, I =V/R or 125/250 = 0.5 amps.

Cable **1B31A08/F** (Ref. 3.1.70) has a 6 amp fuse, the worse case conductor for this cable has 4 relays (0.13 amps each). This worse case value will be used as the load (0.52 amps).

Cable **2CH910B and 2CH910C** (Ref.3.1.72) has a 1.5 amp load.

Cable **2FT9860/A** (Ref. 3.1.73) has a 0.04 amp load.

Cables starting with K after the facility indicator are connected to alarm circuitry cards which directly interface with transistors and other electronic components. A conservative 5Watts will be used (Assumption 4.13) 5w ÷ 120v = 0.04 amps.

Control circuits where multi-conductors are used have been evaluated on a conductor by conductor basis. The largest load on any conductor is used as the load for all remaining conductors. See Attachment 8 for the appropriate ampacities.

Cable **Z2SV4188/L** (Ref. 3.1.2) identifies a 0.1684 amp load.

Cable **Z2SV4188/J** (Ref. 3.1.2) identifies a 0.1684 amp load.

Cable **Z2B6105/J** (Ref. 3.1.25) identifies a 3.2 amp fuse in the circuit.

Cable **Z2B6117/F** (Ref. 3.1.49) identifies a 4.5 amp fuse in the circuit.

Cable **2HC2152/B** (Cable is not installed)

6.4 Instrumentation Cable

From Attachment 3 a total of 3 cable trays 4 conduits one wire-way and one box were identified in the plant that were covered with Thermo-Lag. Although the instrumentation cable will not be impacted by Thermo-Lag since it only carries minimal current this section is included to document all cables covered by Thermo-Lag in MP2. See Table 6.4.

6.0 Body of Calculation continued:

TABLE 6.4

Tray / Conduit	Cable	Code	Type
wire way			
Z26TA10	2P9934/B	I34	2/C#16
	2QR011/C	I34	2/C#16
	2QR011/D	I34	2/C#16
	2PT102B/D	I34	2/C#16
	2PT102B/E	I34	2/C#16
	Z2QR032/K	I34	2/C#16
	Z2QR032/L	I34	2/C#16
	Z2QR033/S	I34	2/C#16
	Z2QR033/R	I34	2/C#16
	Z2LT5282/D	I34	2/C#16
	Z2LT5282/E	I34	2/C#16
	2QR035B/D	I34	2/C#16
	Z2QR003B/BB	I34	2/C#16
	Z2QR003B/AA	I36	4/C#16
	Z2QR003B/R	I36	4/C#16
	Z2QR003B/Z	I34	2/C#16
	Z2QR003B/CC	I34	2/C#16
	2QR035B/D	I34	2/C#16
	Z2PT4224/H	I34	2/C#16
	Z2PT4224/K	I34	2/C#16
	Z2PT4224/G	I34	2/C#16
	Z2FT5278B/D	I34	2/C#16
	Z2FT5278B/E	I34	2/C#16
	2LT208/B	I34	2/C#16
	2LT208/C	I34	2/C#16
	2LT206/C	I34	2/C#16
	2LT206/B	I34	2/C#16

7.0 Reviewers Comments and Resolutions

7.1 Additional references were identified as needed to document loads.

Resolution: References were added.

7.2 Revision levels of several drawings were updated.

Resolution: Latest revisions were reviewed and confirmed that no impact resulted due to the changes implemented on the new revision.

7.3 Several 120 volt loads were revised.

Resolution: All 120 volt loads revised except 1 (one) were revised downward, one load was erroneous. All changes were evaluated and agreed to.

7.4 Two cables were identified as entered in a table under an incorrect tray.

Resolution: Cables were entered in their proper location.

7.5 Additional loads were identified on the MCC's (Attachments E and F).

Resolution: The loads were checked and entered.

7.6 Spare cables were identified that were not shown as spare in the calculation.

Resolution: Cables were confirmed as spare and identified as such in the calculation.

7.7 Tray width dimensions were identified as incorrect.

Resolution: All trays were rechecked and the appropriate dimensions on three (3) trays corrected.

7.8 Discrepancy with raceway fill was identified.

Resolution: Comment was rejected, fills were correct, wording was revised for clarity.

7.0 Reviewers Comments and Resolutions continued:

7.9 Uniformity of Ampacity (I) values in the tables for each voltage section were identified.

Resolution: Tables were made uniform to eliminate confusion.

7.10 Review of TS02 computerized raceway schedule identified two discrepancies in the schedule pertaining to fire wrap.

Resolution: The schedule was determined to be incorrect. DCN DM2-00-1439-96 was initiated to correct.

The independent reviews were completed by 6 personnel, (Bob Blodgett, Mike Champagne, Jose Gomez, Khwaja Haque, Jack Padden and Mike Relyea).

B. Blodgett: was responsible for reviewing the reference design drawings / documents and for reviewing the electrical loads on these documents. In addition, Bob also reviewed the design documents to verify that the cables that are wrapped with thermo-lag were identified, this was accomplished by review of drawings, field walk downs and review of photographs of the installations.

J. Gomez: was responsible for reviewing the cable in conduit deratings and for verifying that the applicable information was transferred into the main body of the calculation.

K. Haque: was responsible for reviewing Attachments A(excluding thermal models) and B (excluding thermal models) for data inputs, the cable in tray deratings and for verifying that the applicable information was transferred into the main body of the calculation.

M. Champagne: was responsible for reviewing the engineering references, design inputs , assumptions , Attachments E and F , the method of calculation, the thermal model was reviewed (Attachment's A and B) and the independent overall review of the calculation.

J. Padden: was responsible for reviewing the reference design drawings / documents and for reviewing the electrical loads on these documents.

Mike Relyea: was responsible for reviewing the reference design drawings / documents and for reviewing the electrical loads on these documents.

8.0 **Attachments**

INDEX

8.0 Attachments

INDEX continued:

ATTACHMENT A

This attachment provides the thermal models for the TSI covered cable tray and conduits at MP2 and the development of the ACF (ampacity correction factor) for each.

The model was developed using standard heat transfer equations.

The model developed predicts a given surface temperature for a specific material and installation. The model was then compared to existing test results performed on TSI wrap at Texas Utilities. The comparison shows that the model conservatively predicts the surface temperature [0.675 vs 0.68].

The only difference between the TU and MP2 model is the thickness of the TSI material. With only one variable changing, i.e. thickness, the model is re-run to address the maximum and minimum possibilities of TSI installation at MP2 for all wrapped tray and the worse case determined (see the following page). Note that the change in thickness of the TSI wrap has a minimal affect upon the resultant temperature. This is to be expected as the TSI has a relatively low resistance to heat transfer.

The tray model was also run increasing the dimensions of the cable tray to much larger installation [48" width]. As expected the surface are becomes the governing factor and the temperature of the surface reduces as expected [62.3° C down to 60.7 ° C]. This indicates that the model behaves as expected when the size of the installation becomes large.

The conduit model, uses the same methodology as the cable tray model and is based upon the heat transfer through a cylinder. The Ampacity Correction Factor (ACF) for the two different models is tabulated below.

ACF

Cable Tray	0.60*
Conduit	0.77

* This conservative value is utilized for ease of calculation unless noted.

ATTAC HMENT A

SUMMARY

The values in the table are a summary of the values obtained from the following pages of Attachment A and from Attachment B.

Appendix	Tray	depth	Q	Min ACF	Max ACF
A	Z23HA10	0.509	13.137	0.693	0.609
B	Z23HB10	0.968	10.157	0.735	0.623
C	Z23GE10	1.12	5.161	0.685	0.614
D	Z23GE10	1.12	5.161	0.685	0.614
E	Z14FM10	0.611	10.661	0.691	0.61
F	Z14FM20	0.458	14.747	0.694	0.609
G	Z24FL10	0.2037	35.701	0.698	0.606
H	Z14FM20	0.458	14.797	0.694	0.609
I	Z14FL20	0.407	16.88	0.694	0.608
K	Z25BG20	0.509	13.137	0.693	0.609
M	Z14FM10	0.611	10.661	0.691	0.61
N	Z14FM10	0.611	10.661	0.691	0.61
B1	Z52EA10	1.935	5.07	0.792	0.689
B2	Z22EA10	1.1741	11.313	0.864	0.689
V	Z23FA30	0.2037	4.407	0.617	0.608
W	Z23FA25	0.2037	3.983	0.615	0.607
X	Z24FL10	0.2037	35.701	0.698	0.606

For conservatism 0.6 will be used as the ACF for cable tray.

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 13.137$	Allowable heat generated for a ladder tray Z23HA10 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 4$	Surface area of tray, sqft/ft 24"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.0$	Thickness of TSI (minimum)
$e1 := 4$	Tray inner height, inches
$e2 := 24$	Tray inner width, inches

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 13.137$

$d := 0.509$ d is adjusted by pi over 4

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation of a 24"wide by d i nches deep uncoveredl tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 160.482$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 55.864$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 90.997$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.018$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\frac{1}{k \cdot 1.8 \cdot .2928}}{\left(\frac{e1}{b1} + 0.54\right) + \left(\frac{e2}{b2} + 0.54\right) + \left(\frac{e1}{b3} + 0.54\right) + \left(\frac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.326$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.308$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27 \cdot \left[\left(12 \cdot \frac{1.8}{e2 + 2 \cdot b1} \right)^{0.25} \right] \cdot \left(\frac{e2 + 2 \cdot b1}{12} \right) \cdot 0.527$$

$A1 = 0.294$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12 \cdot \left(12 \cdot \frac{1.8}{e2 + 2 \cdot b1} \right)^{0.25} \right] \cdot \frac{e2 + 2 \cdot b1}{12} \cdot 0.527$$

$A2 = 0.131$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29 \cdot \left(12 \cdot \frac{1.8}{e1 + 2 \cdot b1} \right)^{0.25} \cdot \frac{e1 + 2 \cdot b1}{(12)} \cdot 2 \cdot 0.527$$

$A3 = 0.211$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.636$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3) \cdot (Ts - Ta)^{\frac{5}{4}} + 5.3 \cdot 10^{-9} \cdot \varepsilon tsi \cdot 2 \cdot \left(\frac{e1 + e2 + b1 + b2}{12} \right) \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 66.236$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 20.716$

$$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon\cdot 2\cdot \frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -6.261$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 77.061$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.693$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 13.137$ Allowable heat generated for a ladder tray Z23HA10 (Attachment 2)

$Ta := 50$ Ampient temperature MP2)

$Tc := 90$ Conductor maximum allowed temperature

$A := 4$ Surface area of tray, sqft/ft 24"wide x 1'long x top and bottom) (Ref. 3.1.8)

$\sigma := 5.3 \cdot 10^{-9}$ Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)

$\varepsilon := 0.1$ Emissivity of galvanized steel tray cover (Ref. 3.1.1)

$ACFcov := 0.59$ Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)

$\varepsilon tsi := 0.9$ Emissivity of TSI surface (Attachment 1)

$k := 0.1$ Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)

$Ttsi := 1.5$ Thickness of TSI (maximum)

$e1 := 4$ Tray inner height, inches

$e2 := 24$ Tray inner width, inches

ATTACHMENT A

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 13.137$

$d := 0.509$ d is adjusted by pi over 4.

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation oof 24"wide and 3" deep uncovered fill tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 160.482$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 55.864$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 90.997$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.018$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) + \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.48$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.463$

ATTACHMENT A

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.303$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.135$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.236$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.674$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4 - (Ta+273.16)^4\right)$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 62.44$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 15.739$

$$Qrc := -0.53\cdot 10^{-8}\cdot\varepsilon\cdot 2\cdot\frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -4.871$

$$QTSI := \frac{90 - Ts}{Rw}$$

$QTSI = 59.578$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

ACFtsi = 0.6[illegible]

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 10.157$	Allowable heat generated for a ladder tray Z23HB10 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 2$	Surface area of tray, sqft/ft (12"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.0$	Thickness of TSI (minimum)
$e1 := 4$	Tray inner height, inches
$e2 := 12$	Tray inner width, inches

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 10.157$

$d := 0.968$ d is adjusted by pi over 4

$Quntray := Qt \cdot 12 \cdot d$ Allowed heat generation of a 24"wide by d i nches deep uncoveredl tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 117.984$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 41.07$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.24 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 100.164$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.247$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\frac{1}{k \cdot 1.8 \cdot .2928}}{\left(\frac{e1}{b1} + 0.54\right) + \left(\frac{e2}{b2} + 0.54\right) + \left(\frac{e1}{b3} + 0.54\right) + \left(\frac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.555$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.308$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27 \cdot \left[\left(12 \cdot \frac{1.8}{e2 + 2 \cdot b1} \right)^{0.25} \right] \cdot \left(\frac{e2 + 2 \cdot b1}{12} \right) \cdot 0.527$$

$A1 = 0.185$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12 \cdot \left(12 \cdot \frac{1.8}{e2 + 2 \cdot b1} \right)^{0.25} \right] \cdot \frac{e2 + 2 \cdot b1}{12} \cdot 0.527$$

$A2 = 0.082$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29 \cdot \left(12 \cdot \frac{1.8}{e1 + 2 \cdot b1} \right)^{0.25} \cdot \frac{e1 + 2 \cdot b1}{(12)} \cdot 2 \cdot 0.527$$

$A3 = 0.21$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.478$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3) \cdot (Ts - Ta)^{\frac{5}{4}} + 5.3 \cdot 10^{-9} \cdot \epsilon tsi \cdot 2 \cdot \left(\frac{e1 + e2 + b1 + b2}{12} \right) \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 70.346$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 20.645$

$$Qrc := -0.53\cdot 10^{-8}\cdot\varepsilon\cdot 2\cdot\frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -4.797$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 63.82$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.735$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 10.157$	Allowable heat generated for a ladder tray Z23HB10 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 2$	Surface area of tray, sqft/ft 12"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.5$	Thickness of TSI (maximum)
$e1 := 4$	Tray inner height, inches
$e2 := 12$	Tray inner width, inches

ATTACHMENT A

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 10.157$

$d := 0.968$ d is adjusted by pi over 4.

$Quntray := Qt \cdot 12 \cdot d$ Allowed heat generation oof 24"wide and 3" deep uncovered fill tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 117.984$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 41.07$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.24 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 100.164$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.247$ degC· ft/watts

Attachment A

Model for the TSI Encased Cable Tray

$b1 := Ttsi$	Top thickness of TSI, inches
$b2 := Ttsi$	Side thickness of TSI,inches
$b3 := Ttsi$	Bottom thickness of TSI,inches
$b4 := Ttsi$	Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k\cdot 1.8\cdot .2928}}{\left(\dfrac{e1}{b1}+0.54\right)+\left(\dfrac{e2}{b2}+0.54\right)+\left(\dfrac{e1}{b3}+0.54\right)+\left(\dfrac{e2}{b4}+0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.808$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.56$

ATTACHMENT 1

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.195$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.087$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.236$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.518$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4 - (Ta+273.16)^4\right)$$

$Ts := \text{Find}(Ts)$

$Ts = 64.362$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 14.475$

$$Qrc := -0.53\cdot 10^{-8}\cdot\varepsilon\cdot 2\cdot\frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -3.477$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 45.771$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.623$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 5.161$	Allowable heat generated for a ladder tray Z23GE10 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 4$	Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.0$	Thickness of TSI (minimum)
$e1 := 4$	Tray inner height, inches
$e2 := 24$	Tray inner width, inches

ATTACHMENT A

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 5.161$

$d := 1.12$ d is adjusted by pi over 4

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation of a 24"wide by d i nches deep uncoveredl tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 138.728$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 48.291$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 86.422$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = 0.074$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\frac{1}{k \cdot 1.8 \cdot .2928}}{\left(\frac{e1}{b1} + 0.54\right) + \left(\frac{e2}{b2} + 0.54\right) + \left(\frac{e1}{b3} + 0.54\right) + \left(\frac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.326$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.4$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.294$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.131$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.211$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.636$

Given

$$\frac{Tc-Ts}{Rws} = (A1+A2+A3)\cdot(Ts-Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4-(Ta+273.16)^4\right)$$

$Ts := \text{Find}(Ts)$

$Ts = 63.954$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$ Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 17.143$

$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon\cdot 2\cdot \frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$

$Qrc = -5.324$

$QTSI := \frac{90 - Ts}{Rws}$

$QTSI = 65.063$

Calculate Derating Factor of tray covered with TSI fire wrap

$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$

$ACFtsi = 0.685$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 5.161$	Allowable heat generated for a ladder tray Z23GE10 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 4$	Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.5$	Thickness of TSI (maximum)
$e1 := 4$	Tray inner height, inches
$e2 := 24$	Tray inner width, inches

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 5.161$

$d := 1.12$ d is adjusted by pi over 4.

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation oof 24"wide and 3" deep uncovered fill tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 138.728$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 48.291$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot ((Ts + 273.16)^4 - (Ta + 273.16)^4)$$

$Ts := Find(Ts)$

$Ts = 86.422$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = 0.074$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$	Top thickness of TSI, inches
$b2 := Ttsi$	Side thickness of TSI,inches
$b3 := Ttsi$	Bottom thickness of TSI,inches
$b4 := Ttsi$	Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) + \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref.3.1.95)

$Rk = 0.48$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.555$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref.3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.303$ Convection coefficient for the toop surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.135$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.236$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.674$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4 - (Ta+273.16)^4\right)$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 61.042$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 13.56$

$$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon\cdot 2\cdot \frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -4.296$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 52.221$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.614$

ATTACHMENT A

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 10.061$ Allowable heat generated for a ladder tray Z14FM10 (Attachment 2)

$Ta := 50$ Ampient temperature MP2)

$Tc := 90$ Conductor maximum allowed temperature

$A := 4$ Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)

$\sigma := 5.3 \cdot 10^{-9}$ Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)

$\varepsilon := 0.1$ Emissivity of galvanized steel tray cover (Ref. 3.1.1)

$ACFcov := 0.59$ Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)

$\varepsilon tsi := 0.9$ Emissivity of TSI surface (Attachment 1)

$k := 0.1$ Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)

$Ttsi := 1.0$ Thickness of TSI (minimum)

$e1 := 4$ Tray inner height, inches

$e2 := 24$ Tray inner width, inches

ATTACHMENT A

This section of the model is for co: ˀred tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 10.661$

$d := 0.611$ d is adjusted by pi over 4

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation of a 24"wide by d inches deep uncoveredl tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 156.333$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 54.419$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 90.136$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.002$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) + \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.326$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.324$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.294$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.131$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.211$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.636$

Given

$$\frac{Tc-Ts}{Rws} = (A1+A2+A3)\cdot(Ts-Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4-(Ta+273.16)^4\right)$$

$Ts := \text{Find}(Ts)$

$Ts = 65.8$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3) \cdot (Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$$Qcc = 20.025$$

$$Qrc := -0.53 \cdot 10^{-8} \cdot \varepsilon \cdot 2 \cdot \frac{e1 + e2 + b1 + b2}{12} \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$$Qrc = -6.081$$

$$QTSI := \frac{90 - Ts}{Rws}$$

$$QTSI = 74.75$$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$$ACFtsi = 0.691$$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 10.661$	Allowable heat generated for a ladder tray Z14FM10 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 4$	Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.5$	Thickness of TSI (maximum)
$e1 := 4$	Tray inner height, inches
$e2 := 24$	Tray inner width, inches

ATTACHMENT A

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 10.661$

$d := 0.611$ d is adjusted by pi over 4.

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation oof 24"wide and 3" deep uncovered fill tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 156.333$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 54.419$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot ((Ts + 273.16)^4 - (Ta + 273.16)^4)$$

$Ts := Find(Ts)$

$Ts = 90.136$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.002$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$	Top thickness of TSI, inches
$b2 := Ttsi$	Side thickness of TSI,inches
$b3 := Ttsi$	Bottom thickness of TSI,inches
$b4 := Ttsi$	Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\frac{1}{k \cdot 1.8 \cdot .2928}}{\left(\frac{e1}{b1} + 0.54\right) + \left(\frac{e2}{b2} + 0.54\right) + \left(\frac{e1}{b3} + 0.54\right) + \left(\frac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.48$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.478$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27 \cdot \left[\left(12 \cdot \frac{1.8}{e2 + 2 \cdot b1} \right)^{0.25} \right] \cdot \left(\frac{e2 + 2 \cdot b1}{12} \right) \cdot 0.527$$

$A1 = 0.303$ Convection coefficient for the toop surface of the wrapped tray

$$A2 := \left[0.12 \cdot \left(12 \cdot \frac{1.8}{e2 + 2 \cdot b1} \right)^{0.25} \right] \cdot \frac{e2 + 2 \cdot b1}{12} \cdot 0.527$$

$A2 = 0.135$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29 \cdot \left(12 \cdot \frac{1.8}{e1 + 2 \cdot b1} \right)^{0.25} \cdot \frac{e1 + 2 \cdot b1}{(12)} \cdot 2 \cdot 0.527$$

$A3 = 0.236$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.674$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3) \cdot (Ts - Ta)^{\frac{5}{4}} + 5.3 \cdot 10^{-9} \cdot \varepsilon tsi \cdot 2 \cdot \left(\frac{e1 + e2 + b1 + b2}{12} \right) \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := \text{Find}(Ts)$

$Ts = 62.181$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 15.331$

$$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon \cdot 2\cdot \frac{ei + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -4.764$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 58.206$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.61$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 14.797$ Allowable heat generated for a ladder tray Z14FM20 (Attachment 2)

$Ta := 50$ Ampient temperature MP2)

$Tc := 90$ Conductor maximum allowed temperature

$A := 4$ Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)

$\sigma := 5.3 \cdot 10^{-9}$ Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)

$\varepsilon := 0.1$ Emissivity of galvanized steel tray cover (Ref. 3.1.1)

$ACFcov := 0.59$ Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)

$\varepsilon tsi := 0.9$ Emissivity of TSI surface (Attachment 1)

$k := 0.1$ Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)

$Ttsi := 1.0$ Thickness of TSI (minimum)

$e1 := 4$ Tray inner height, inches

$e2 := 24$ Tray inner width, inches

ATTACHMENT 1A

This section of the model is for covered tray

Calcuiation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 14.797$

$d := 0.458$ d is adjusted by pi over 4

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation of a 24"wide by d i nches deep uncoveredl tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 162.649$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 56.618$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 91.445$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.026$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$	Top thickness of TSI, inches
$b2 := Ttsi$	Side thickness of TSI,inches
$b3 := Ttsi$	Bottom thickness of TSI,inches
$b4 := Ttsi$	Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\frac{1}{k \cdot 1.8 \cdot .2928}}{\left(\frac{e1}{b1} + 0.54\right) + \left(\frac{e2}{b2} + 0.54\right) + \left(\frac{e1}{b3} + 0.54\right) + \left(\frac{e2}{b4} + 0.54\right)}$$ (Ref.3.1.95)

$Rk = 0.326$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.301$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.294$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.131$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.211$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.636$

Given

$$\frac{Tc-Ts}{Rws}=(A1+A2+A3)\cdot(Ts-Ta)^{\frac{5}{4}}+5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4-(Ta+273.16)^4\right)$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 66.463$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3) \cdot (Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$$Qcc = 21.079$$

$$Qrc := -0.53 \cdot 10^{-8} \cdot \varepsilon \cdot 2 \cdot \frac{e1 + e2 + b1 + b2}{12} \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$$Qrc = -6.355$$

$$QTSI := \frac{90 - Ts}{Rws}$$

$$QTSI = 78.273$$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$$ACFtsi = 0.694$$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 14.797$	Allowable heat generated for a ladder tray Z14FM20-1 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 4$	Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.5$	Thickness of TSI (maximum)
$e1 := 4$	Tray inner height, inches
$e2 := 24$	Tray inner width, inches

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 14.797$

$d := 0.458$ d is adjusted by pi over 4.

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation oof 24"wide and 3" deep uncovered fill tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 162.649$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 56.618$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 91.445$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.026$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) + \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.48$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.455$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiatiion coefficents for the TSI surface (Ref.3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.303$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.135$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.236$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.674$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4 - (Ta+273.16)^4\right)$$

$Ts := \text{Find}(Ts)$

$Ts = 62.574$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$$Qcc = 15.951$$

$$Qrc := -0.53\cdot 10^{-8}\cdot\varepsilon\cdot 2\cdot\frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^{4} - (Ta + 273.16)^{4}\right)$$

$$Qrc = -4.926$$

$$QTSI := \frac{90 - Ts}{Rws}$$

$$QTSI = 60.289$$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$$ACFtsi = 0.609$$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 35.701$	Allowable heat generated for a ladder tray Z24FL10 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 4$	Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.0$	Thickness of TSI (minimum)
$e1 := 4$	Tray inner height, inches
$e2 := 24$	Tray inner width, inches

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 35.701$

$d := 0.2037$ d is adjusted by pi over 4

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation of a 24"wide by d i nches deep uncoveredl tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 174.535$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 60.756$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 93.88$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.064$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\frac{1}{k \cdot 1.8 \cdot .2928}}{\left(\frac{e1}{b1} + 0.54\right) + \left(\frac{e2}{b2} + 0.54\right) + \left(\frac{e1}{b3} + 0.54\right) + \left(\frac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.326$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.262$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2 + 2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2 + 2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.294$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2 + 2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2 + 2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.131$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1 + 2\cdot b1}\right)^{0.25}\cdot\frac{e1 + 2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.211$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.636$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1 + e2 + b1 + b2}{12}\right)\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 67.708$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$$Qcc = 23.091$$

$$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon\cdot 2\cdot \frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$$Qrc = -6.875$$

$$QTSI := \frac{90 - Ts}{Rws}$$

$$QTSI = 84.963$$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$$ACFtsi = 0.698$$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 35.701$ Allowable heat generated for a ladder tray Z24FL10 (Attachment 2)

$Ta := 50$ Ampient temperature MP2)

$Tc := 90$ Conductor maximum allowed temperature

$A := 4$ Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)

$\sigma := 5.3 \cdot 10^{-9}$ Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)

$\varepsilon := 0.1$ Emissivity of galvanized steel tray cover (Ref. 3.1.1)

$ACFcov := 0.59$ Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)

$\varepsilon tsi := 0.9$ Emissivity of TSI surface (Attachment 1)

$k := 0.1$ Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)

$Ttsi := 1.5$ Thickness of TSI (minimum)

$e1 := 4$ Tray inner height, inches

$e2 := 24$ Tray inner width, inches

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 35.701$

$d := 0.2037$ d is adjusted by pi over 4

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation of a 24"wide by d i nches deep uncoveredl tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 174.535$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 60.756$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 93.88$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.064$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$	Top thickness of TSI, inches
$b2 := Ttsi$	Side thickness of TSI,inches
$b3 := Ttsi$	Bottom thickness of TSI,inches
$b4 := Ttsi$	Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) + \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.48$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.417$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2 + 2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2 + 2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.303$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2 + 2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2 + 2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.135$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1 + 2\cdot b1}\right)^{0.25}\cdot\frac{e1 + 2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.236$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.674$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1 + e2 + b1 + b2}{12}\right)\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Ts := Find(Ts)$

$Ts = 63.291$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 17.096$

$$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon\cdot 2\cdot \frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -5.225$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 64.117$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.606$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 16.88$ Allowable heat generated for a ladder tray Z14FL20 (Attachment 2)

$Ta := 50$ Ampient temperature MP2)

$Tc := 90$ Conductor maximum allowed temperature

$A := 4$ Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)

$\sigma := 5.3 \cdot 10^{-9}$ Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)

$\varepsilon := 0.1$ Emissivity of galvanized steel tray cover (Ref. 3.1.1)

$ACFcov := 0.59$ Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)

$\varepsilon tsi := 0.9$ Emissivity of TSI surface (Attachment 1)

$k := 0.1$ Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)

$Ttsi := 1.0$ Thickness of TSI (maximum)

$e1 := 4$ Tray inner height, inches

$e2 := 24$ Tray inner width, inches

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 16.88$

$d := 0.407$ d is adjusted by pi over 4.

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation oof 24"wide and 3" deep uncovered fill tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 164.884$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 57.396$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 91.906$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.033$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) + \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.326$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.293$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.294$ Convection coefficient for the toop surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.131$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.211$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.636$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4 - (Ta+273.16)^4\right)$$

$Ts := \text{Find}(Ts)$

$Ts = 66.697$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 21.455$

$$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon \cdot 2\cdot \frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -6.452$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 79.525$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.694$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 16.88$	Allowable heat generated for a ladder tray Z14FL20 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 4$	Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.5$	Thickness of TSI (maximum)
$e1 := 4$	Tray inner height, inches
$e2 := 24$	Tray inner width, inches

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 16.88$

$d := 0.407$ d is adjusted by pi over 4.

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation oof 24"wide and 3" deep uncovered fill tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 164.884$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 57.396$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 91.906$ cable tray cover surface tempeiatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.033$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) + \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.48$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.447$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27 \cdot \left[\left(12 \cdot \frac{1.8}{e2 + 2 \cdot b1} \right)^{0.25} \right] \cdot \left(\frac{e2 + 2 \cdot b1}{12} \right) \cdot 0.527$$

$A1 = 0.303$ Convection coefficient for the toop surface of the wrapped tray

$$A2 := \left[0.12 \cdot \left(12 \cdot \frac{1.8}{e2 + 2 \cdot b1} \right)^{0.25} \right] \cdot \frac{e2 + 2 \cdot b1}{12} \cdot 0.527$$

$A2 = 0.135$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29 \cdot \left(12 \cdot \frac{1.8}{e1 + 2 \cdot b1} \right)^{0.25} \cdot \frac{e1 + 2 \cdot b1}{(12)} \cdot 2 \cdot 0.527$$

$A3 = 0.236$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.674$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3) \cdot (Ts - Ta)^{\frac{5}{4}} + 5.3 \cdot 10^{-9} \cdot \varepsilon tsi \cdot 2 \cdot \left(\frac{e1 + e2 + b1 + b2}{12} \right) \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := \text{Find}(Ts)$

$Ts = 62.711$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$$Qcc = 16.169$$

$$Qrc := -0.53\cdot 10^{-8}\cdot\varepsilon\cdot 2\cdot\frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$$Qrc = -4.983$$

$$QTSI := \frac{90 - Ts}{Rws}$$

$$QTSI = 61.019$$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$$ACFtsi = 0.608$$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 13.137$	Allowable heat generated for a ladder tray Z25BG20 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 4$	Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.0$	Thickness of TSI (minimum)
$e1 := 4$	Tray inner height, inches
$e2 := 24$	Tray inner width, inches

ATTACHMENT A

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 13.137$

$d := 0.509$ d is adjusted by pi over 4

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation of a 24"wide by d i nches deep uncoveredl tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 160.482$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 55.864$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 90.997$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.018$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$	Top thickness of TSI, inches
$b2 := Ttsi$	Side thickness of TSI,inches
$b3 := Ttsi$	Bottom thickness of TSI,inches
$b4 := Ttsi$	Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) + \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.326$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.308$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.294$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.131$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.211$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.636$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4 - (Ta+273.16)^4\right)$$

$Ts := Find(Ts)$

$Ts = 66.236$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 20.716$

$$Qrc := -0.53\cdot 10^{-8}\cdot\varepsilon\cdot 2\cdot\frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -6.261$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 77.061$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.693$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 13.137$	Allowable heat generated for a ladder tray Z25GB20 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 4$	Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.5$	Thickness of TSI (maximum)
$e1 := 4$	Tray inner height, inches
$e2 := 24$	Tray inner width, inches

ATTACHMENT A

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 13.137$

$d := 0.509$ d is adjusted by pi over 4.

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation oof 24"wide and 3" deep uncovered fill tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 160.482$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 55.864$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 90.997$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.018$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\frac{1}{k \cdot 1.8 \cdot .2928}}{\left(\frac{e1}{b1} + 0.54\right) + \left(\frac{e2}{b2} + 0.54\right) + \left(\frac{e1}{b3} + 0.54\right) + \left(\frac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.48$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.463$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.303$ Convection coefficient for the toop surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.135$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.236$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.674$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4 - (Ta+273.16)^4\right)$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 62.44$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 15.739$

$$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon\cdot 2\cdot \frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -4.871$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 59.578$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.609$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 5.07$ Allowable heat generated for a ladder tray Z52EA10 (Attachment 2)

$Ta := 50$ Ampient temperature MP2)

$Tc := 90$ Conductor maximum allowed temperature

$A := 1$ Surface area of tray, sqft/ft (6"wide x 1'long x top and bottom) (Ref. 3.1.8)

$\sigma := 5.3 \cdot 10^{-9}$ Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)

$\varepsilon := 0.1$ Emissivity of galvanized steel tray cover (Ref. 3.1.1)

$ACFcov := 0.59$ Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)

$\varepsilon tsi := 0.9$ Emissivity of TSI surface (Attachment 1)

$k := 0.1$ Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)

$Ttsi := 1.0$ Thickness of TSI (maximum)

$e1 := 4$ Tray inner height, inches

$e2 := 6$ Tray inner width, inches

ATTACHMENT A

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 5.07$

$d := 1.935$ d is adjusted by pi over 4.

$Quntray := Qt \cdot 6 \cdot d$ Allowed heat generation oof 6"wide and 3" deep uncovered fill tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 58.863$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 20.49$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.143 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 94.765$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.233$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$	Top thickness of TSI, inches
$b2 := Ttsi$	Side thickness of TSI,inches
$b3 := Ttsi$	Bottom thickness of TSI,inches
$b4 := Ttsi$	Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) \cdot \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.856$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.624$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.122$ Convection coefficient for the toop surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.054$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.211$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.386$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4 - (Ta+273.16)^4\right)$$

$Ts := Find(Ts)$

$Ts = 66.968$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 13.298$

$$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon\cdot 2\cdot\frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -2.626$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 36.931$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.792$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 5.07$ Allowable heat generated for a ladder tray Z52EA10 (Attachment 2)

$Ta := 50$ Ampient temperature MP2)

$Tc := 90$ Conductor maximum allowed temperature

$A := 1$ Surface area of tray, sqft/ft (6"wide x 1'long x top and bottom) (Ref. 3.1.8)

$\sigma := 5.3 \cdot 10^{-9}$ Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)

$\varepsilon := 0.1$ Emissivity of galvanized steel tray cover (Ref. 3.1.1)

$ACFcov := 0.59$ Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)

$\varepsilon tsi := 0.9$ Emissivity of TSI surface (Attachment 1)

$k := 0.1$ Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)

$Ttsi := 1.5$ Thickness of TSI (maximum)

$e1 := 4$ Tray inner height, inches

$e2 := 6$ Tray inner width, inches

ATTACHMENT A

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 5.07$

$d := 1.935$ d is adjusted by pi over 4.

$Quntray := Qt \cdot 6 \cdot d$ Allowed heat generation oof 6"wide and 3" deep uncovered fill tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 58.863$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 20.49$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.143 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 94.765$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.233$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1}+0.54\right)+\left(\dfrac{e2}{b2}+0.54\right)+\left(\dfrac{e1}{b3}+0.54\right)+\left(\dfrac{e2}{b4}+0.54\right)}$$ (Ref. 3.1.95)

$Rk = 1.225$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.992$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27 \cdot \left[\left(12 \cdot \frac{1.8}{e2 + 2 \cdot b1} \right)^{0.25} \right] \cdot \left(\frac{e2 + 2 \cdot b1}{12} \right) \cdot 0.527$$

$A1 = 0.133$ Convection coefficient for the toop surface of the wrapped tray

$$A2 := \left[0.12 \cdot \left(12 \cdot \frac{1.8}{e2 + 2 \cdot b1} \right)^{0.25} \right] \cdot \frac{e2 + 2 \cdot b1}{12} \cdot 0.527$$

$A2 = 0.059$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29 \cdot \left(12 \cdot \frac{1.8}{e1 + 2 \cdot b1} \right)^{0.25} \cdot \frac{e1 + 2 \cdot b1}{(12)} \cdot 2 \cdot 0.527$$

$A3 = 0.236$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.428$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3) \cdot (Ts - Ta)^{\frac{5}{4}} + 5.3 \cdot 10^{-9} \cdot \varepsilon tsi \cdot 2 \cdot \left(\frac{e1 + e2 + b1 + b2}{12} \right) \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 62.27$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 9.833$

$$Qrc := -0.53\cdot 10^{-8}\cdot\varepsilon\cdot 2\cdot\frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -2.013$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 27.951$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.689$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 11.313$ Allowable heat generated for a ladder tray Z22EA10 (Attachment 2)

$Ta := 50$ Ampient temperature MP2)

$Tc := 90$ Conductor maximum allowed temperature

$A := 1$ Surface area of tray, sqft/ft (6"wide x 1'long x top and bottom) (Ref. 3.1.8)

$\sigma := 5.3 \cdot 10^{-9}$ Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)

$\varepsilon := 0.1$ Emissivity of galvanized steel tray cover (Ref. 3.1.1)

$ACFcov := 0.59$ Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)

$\varepsilon tsi := 0.9$ Emissivity of TSI surface (Attachment 1)

$k := 0.1$ Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)

$Ttsi := 1.0$ Thickness of TSI (maximum)

$e1 := 4$ Tray inner height, inches

$e2 := 6$ Tray inner width, inches

ATTACHMENT A

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 11.313$

$d := 1.1714$ d is adjusted by pi over 4.

$Quntray := Qt \cdot 6 \cdot d$ Allowed heat generation of 6"wide and 3" deep uncovered fill tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 79.512$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 27.678$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.143 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 106.987$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.614$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$	Top thickness of TSI, inches
$b2 := Ttsi$	Side thickness of TSI,inches
$b3 := Ttsi$	Bottom thickness of TSI,inches
$b4 := Ttsi$	Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) + \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.856$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.242$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface ([Ref. 3.1.96)

$$A1 := 0.27 \cdot \left[\left(12 \cdot \frac{1.8}{e2 + 2 \cdot b1}\right)^{0.25}\right] \cdot \left(\frac{e2 + 2 \cdot b1}{12}\right) \cdot 0.527$$

$A1 = 0.122$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12 \cdot \left(12 \cdot \frac{1.8}{e2 + 2 \cdot b1}\right)^{0.25}\right] \cdot \frac{e2 + 2 \cdot b1}{12} \cdot 0.527$$

$A2 = 0.054$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29 \cdot \left(12 \cdot \frac{1.8}{e1 + 2 \cdot b1}\right)^{0.25} \cdot \frac{e1 + 2 \cdot b1}{(12)} \cdot 2 \cdot 0.527$$

$A3 = 0.211$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.386$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3) \cdot (Ts - Ta)^{\frac{5}{4}} + 5.3 \cdot 10^{-9} \cdot \varepsilon tsi \cdot 2 \cdot \left(\frac{e1 + e2 + b1 + b2}{12}\right) \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 75.607$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 22.244$

$$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon\cdot 2\cdot \frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -4.123$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 59.354$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.864$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 11.313$	Allowable heat generated for a ladder tray Z22EA10 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 1$	Surface area of tray, sqft/ft (6"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.5$	Thickness of TSI (maximum)
$e1 := 4$	Tray inner height, inches
$e2 := 6$	Tray inner width, inches

ATTACHMENT A

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 11.313$

$d := 1.1714$ d is adjusted by pi over 4.

$Quntray := Qt \cdot 6 \cdot d$ Allowed heat generation of 6"wide and 3" deep uncovered fill tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 79.512$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 27.678$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.143 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 106.987$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = -0.614$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$	Top thickness of TSI, inches
$b2 := Ttsi$	Side thickness of TSI,inches
$b3 := Ttsi$	Bottom thickness of TSI,inches
$b4 := Ttsi$	Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) + \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref.3.1.95)

$Rk = 1.225$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 0.611$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.133$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.059$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.236$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.428$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4 - (Ta+273.16)^4\right)$$

$Ts := \text{Find}(Ts)$

$Ts = 66.358$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3) \cdot (Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$$Qcc = 14.086$$

$$Qrc := -0.53 \cdot 10^{-8} \cdot \varepsilon \cdot 2 \cdot \frac{e1 + e2 + b1 + b2}{12} \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$$Qrc = -2.735$$

$$QTSI := \frac{90 - Ts}{Rws}$$

$$QTSI = 38.7$$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$$ACFtsi = 0.698$$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 4.407$ Allowable heat generated for a ladder tray Z24FL10 (Attachment 2)

$Ta := 50$ Ampient temperature MP2)

$Tc := 90$ Conductor maximum allowed temperature

$A := 4$ Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)

$\sigma := 5.3 \cdot 10^{-9}$ Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)

$\varepsilon := 0.1$ Emissivity of galvanized steel tray cover (Ref. 3.1.1)

$ACFcov := 0.59$ Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)

$\varepsilon tsi := 0.9$ Emissivity of TSI surface (Attachment 1)

$k := 0.1$ Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)

$Ttsi := 1.0$ Thickness of TSI (minimum)

$e1 := 4$ Tray inner height, inches

$e2 := 24$ Tray inner width, inches

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 4.407$

$d := 0.2037$ d is adjusted by pi over 4

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation of a 24"wide by d i nches deep uncoveredl tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 21.545$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 7.5$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 57.752$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = 4.3$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) + \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.326$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 4.626$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.294$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.131$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.211$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.636$

Given

$$\frac{Tc-Ts}{Rws}=(A1+A2+A3)\cdot(Ts-Ta)^{\frac{5}{4}}+5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4-(Ta+273.16)^4\right)$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 52.046$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$$Qcc = 1.555$$

$$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon\cdot 2\cdot \frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$$Qrc = -0.739$$

$$QTSI := \frac{90 - Ts}{Rws}$$

$$QTSI = 8.204$$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$$ACFtsi = 0.617$$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 4.407$ Allowable heat generated for a ladder tray Z24FL10 (Attachment 2)

$Ta := 50$ Ampient temperature MP2)

$Tc := 90$ Conductor maximum allowed temperature

$A := 4$ Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)

$\sigma := 5.3 \cdot 10^{-9}$ Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)

$\varepsilon := 0.1$ Emissivity of galvanized steel tray cover (Ref. 3.1.1)

$ACFcov := 0.59$ Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)

$\varepsilon tsi := 0.9$ Emissivity of TSI surface (Attachment 1)

$k := 0.1$ Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)

$Ttsi := 1.5$ Thickness of TSI (minimum)

$e1 := 4$ Tray inner height, inches

$e2 := 24$ Tray inner width, inches

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 4.407$

$d := 0.2037$ d is adjusted by pi over 4

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation of a 24"wide by d i nches deep uncoveredl tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 21.545$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 7.5$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 57.752$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = 4.3$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSi,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\frac{1}{k \cdot 1.8 \cdot .2928}}{\left(\frac{e1}{b1} + 0.54\right) + \left(\frac{e2}{b2} + 0.54\right) + \left(\frac{e1}{b3} + 0.54\right) + \left(\frac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.48$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 4.78$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.303$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.135$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.236$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.674$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Ts := \text{Find}(Ts)$

$Ts = 51.92$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$ Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 1.522$

$Qrc := -0.53\cdot 10^{-8}\cdot\varepsilon\cdot 2\cdot\frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$

$Qrc = -0.716$

$QTSI := \frac{90 - Ts}{Rws}$

$QTSI = 7.966$

Calculate Derating Factor of tray covered with TSI fire wrap

$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$

$ACFtsi = 0.608$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 3.983$ Allowable heat generated fo: a ladder tray Z24FL10 (Attachment 2)

$Ta := 50$ Ampient temperature MP2)

$Tc := 90$ Conductor maximum allowed temperature

$A := 4$ Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)

$\sigma := 5.3 \cdot 10^{-9}$ Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)

$\varepsilon := 0.1$ Emissivity of galvanized steel tray cover (Ref. 3.1.1)

$ACFcov := 0.59$ Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)

$\varepsilon tsi := 0.9$ Emissivity of TSI surface (Attachment 1)

$k := 0.1$ Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)

$Ttsi := 1.0$ Thickness of TSI (minimum)

$e1 := 4$ Tray inner height, inches

$e2 := 24$ Tray inner width, inches

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 3.983$

$d := 0.2037$ d is adjusted by pi over 4

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation of a 24"wide by d i nches deep uncoveredl tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 19.472$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 6.778$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot \left((Ts + 273.16)^4 - (Ta + 273.16)^4 \right)$$

$Ts := Find(Ts)$

$Ts = 57.117$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = 4.851$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\dfrac{1}{k \cdot 1.8 \cdot .2928}}{\left(\dfrac{e1}{b1} + 0.54\right) + \left(\dfrac{e2}{b2} + 0.54\right) + \left(\dfrac{e1}{b3} + 0.54\right) + \left(\dfrac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.326$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 5.177$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2 + 2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2 + 2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.294$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2 + 2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2 + 2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.131$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1 + 2\cdot b1}\right)^{0.25}\cdot\frac{e1 + 2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.211$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.636$

Given

$$\frac{Tc - Ts}{Rws} = (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1 + e2 + b1 + b2}{12}\right)\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 51.848$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$$Qcc = 1.369$$

$$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon\cdot 2\cdot \frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$$Qrc = -0.667$$

$$QTSI := \frac{90 - Ts}{Rws}$$

$$QTSI = 7.369$$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$$ACFtsi = 0.615$$

AMPACITY MODELING OF APPENDIX R WRAPPED TRAY

Data Input:

$Q := 3.983$	Allowable heat generated for a ladder tray Z24FL10 (Attachment 2)
$Ta := 50$	Ampient temperature MP2)
$Tc := 90$	Conductor maximum allowed temperature
$A := 4$	Surface area of tray, sqft/ft (24"wide x 1'long x top and bottom) (Ref. 3.1.8)
$\sigma := 5.3 \cdot 10^{-9}$	Stefan- Boltzmann constant, Wats/sqft-K^4 (Ref. 3.1.27)
$\varepsilon := 0.1$	Emissivity of galvanized steel tray cover (Ref. 3.1.1)
$ACFcov := 0.59$	Ampacity correction factor for tight cover cable tray (Ref. 3.1.10)
$\varepsilon tsi := 0.9$	Emissivity of TSI surface (Attachment 1)
$k := 0.1$	Thermal conductivity of TSI, BTU/hr-ft-degF (Attachment 1)
$Ttsi := 1.5$	Thickness of TSI (minimum)
$e1 := 4$	Tray inner height, inches
$e2 := 24$	Tray inner width, inches

This section of the model is for covered tray

Calculation for the allowable heat generation in a covred tray

$Qt := Q$ Allowable heat generation for a ladder type tray

$Qt = 3.983$

$d := 0.2037$ d is adjusted by pi over 4

$Quntray := Qt \cdot 24 \cdot d$ Allowed heat generation of a 24"wide by d i nches deep uncoveredl tray, Watts/ft (adjusted to circular area of cable)

$Quntray = 19.472$

$Qcover := ACFcov^2 \cdot Quntray$ Allowable heat generation for a covered, unwrapped tray, watts/ft

$Qcover = 6.778$ Watts / ft

Calculate the termal resistance at the tray surface

$Ts := 50$ Initial guess

Given

$$Qcover = 0.402 \cdot (Ts - Ta)^{\frac{5}{4}} + \sigma \cdot A \cdot \varepsilon \cdot ((Ts + 273.16)^4 - (Ta + 273.16)^4)$$

$Ts := Find(Ts)$

$Ts = 57.117$ cable tray cover surface temperatre

$$R := \frac{Tc - Ts}{Qcover}$$

$R = 4.851$ degC-ft/watts

Model for the TSI Encased Cable Tray

$b1 := Ttsi$ Top thickness of TSI, inches

$b2 := Ttsi$ Side thickness of TSI,inches

$b3 := Ttsi$ Bottom thickness of TSI,inches

$b4 := Ttsi$ Side thickness of TSI,inches

Calculate Thermal Resistance of TSI

$$Rk := \frac{\frac{1}{k \cdot 1.8 \cdot .2928}}{\left(\frac{e1}{b1} + 0.54\right) + \left(\frac{e2}{b2} + 0.54\right) + \left(\frac{e1}{b3} + 0.54\right) + \left(\frac{e2}{b4} + 0.54\right)}$$ (Ref. 3.1.95)

$Rk = 0.48$ degC-ft/watts

Calculate the Thermal resistance between the conductor and outer Surface of TSI

$Rws := R + Rk$ Total thermal resistance form conductor to outer surface of TSI

$Rws = 5.332$

Solve Heat Balance Equation, to determine outer Surface Temperature of TSI

Calculate the convection and radiation coefficents for the TSI surface (Ref. 3.1.96)

$$A1 := 0.27\cdot\left[\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\left(\frac{e2+2\cdot b1}{12}\right)\cdot 0.527$$

$A1 = 0.303$ Convection coefficient for the top surface of the wrapped tray

$$A2 := \left[0.12\cdot\left(12\cdot\frac{1.8}{e2+2\cdot b1}\right)^{0.25}\right]\cdot\frac{e2+2\cdot b1}{12}\cdot 0.527$$

$A2 = 0.135$ Convection coefficient for the bottom surface of the wrapped tray.

$$A3 := 0.29\cdot\left(12\cdot\frac{1.8}{e1+2\cdot b1}\right)^{0.25}\cdot\frac{e1+2\cdot b1}{(12)}\cdot 2\cdot 0.527$$

$A3 = 0.236$ Convection coefficient for the side surfaces of the wrapped tray

$A1 + A2 + A3 = 0.674$

Given

$$\frac{Tc-Ts}{Rws} = (A1+A2+A3)\cdot(Ts-Ta)^{\frac{5}{4}} + 5.3\cdot 10^{-9}\cdot \varepsilon tsi\cdot 2\cdot\left(\frac{e1+e2+b1+b2}{12}\right)\cdot\left((Ts+273.16)^4-(Ta+273.16)^4\right)$$

$Ts := \text{Find}(Ts)$

$Ts = 51.739$ Wrapped tray surface temperature degC.

Calculate Qc' and Qr'

$$Qcc := (A1 + A2 + A3)\cdot(Ts - Ta)^{\frac{5}{4}}$$

Heat transmission from surface of TSI to ambient air due to convection, Watts/ft

$Qcc = 1.345$

$$Qrc := -0.53\cdot 10^{-8}\cdot \varepsilon\cdot 2\cdot \frac{e1 + e2 + b1 + b2}{12}\cdot\left((Ts + 273.16)^4 - (Ta + 273.16)^4\right)$$

$Qrc = -0.648$

$$QTSI := \frac{90 - Ts}{Rws}$$

$QTSI = 7.176$

Calculate Derating Factor of tray covered with TSI fire wrap

$$ACFtsi := \sqrt{\frac{QTSI}{Quntray}}$$

$ACFtsi = 0.607$

ATTACHMENT A

1.25 in thick TSI

CONDUIT MODEL

The following is a model of Thermo-Lag on Conduit using the TU Test Results .

The thermal resistance model of a cable in conduit consists of the following thermal resistance components.

Ri	thermal resistance of the insulation/jacket
Rsd	thermal resistance between the outer cable jacket to the inside conduit wall
Rd	thermal resistance of the conduit
Rag	thermal resistance between the outer surface of the conduit and the inside surface of thermal Lag shell product.
Rthl	thermal resistance of the thermal lag shell
Re	thermal resistance between the outer surface of the thermal Lag and ambient air
Rtot	is the sum of the above thermal resistnace terms/ thermal resistance between the conductor and ambient air.

Methodology to develop an ampacity Model of a power calbe in Thermal Lagged conduit using TU test:

1. Calculate the heat generated by one conductor during both the base line condition (Q) and thermal lagged conduit conditions(Qp).

2. Using a known value of Qp, calculate Rtot, thermal resistance between conductor and ambient air, during test of thermal Lag conduit.

3. Calculate thermal resistance of thermal Lag (Rhtl) using accepted equation for calculating the thermal resistance of a cylinder. Equation 38 from Neher-McGrath technical paper is used to calculate Rthl.

4. Using equation for Re, thermal resistance between thermal Lag and ambient air, calculate Ts, surface temperature of thermal lag. Ts is solved using MathCad givene/find function. Once Ts is solved, Re is then calculated.

5. With Re, Rtot, and Rthl known, the thermal resistance between conductor and inside surface of thermal Lag (Ri_thl) can be calculated. Ri_thl is considered to be constant regardless of the Thermal Lag.

6. A new Rthl is calculated for a new therami Lag thickness, for MS2 the thickness is 1.25 inch.

7. Two equations are defined with respect to Qpp, heat generated for new thickness of thermal Lag. These equations are set equal to each and solved for TS. Qpp is then solved using the value of Ts.

8. The ampacity correction factor (ACF) for the thermal lag conduit is then solved.

ATTACHMENT A

1. Calculate Parameters Associated with Test Conditions

INPUT:

$\varepsilon TSI := 0.9$ emissivity of thermal Lag

$TSI := 0.5$ thickness of thermal Lag in test, inches

$\rho TSI := 577.7$ thermal resistivity of thermal lag, C-cm/watt (calculated from a value of thermal conductivity of 1.0BTU/hr-ft-F.

$Dcnd := 5.5$ outer diameter of conduit, inch.

$Rac := 0.023 \cdot 10^{-3}$ ac resistance of 750 kcmil Cu

$Ib := 571$ base current in TU test for the thermo-lagged 5 in conduit, amps

$Ip := 510$ base current in Tu test, amps

$np := 4$ number of conductors in conduit

$Tc := 90$ conductor termperature, C

$Ta := 40$ ambient temperature, C

Q, heat generated in Test Base Line Conditions

$Q := Ib^2 \cdot Rac$ heat generated by single conduitro, in base condition (watts/ft).

$Q = 7.499$ watts /ft

Qp, heat generated in test conditions of 1/2 inch thermal lag conduit

$Qp := Ip^2 \cdot Rac$ heat generated by single conductor, in derated conditions of test.

$Qp = 5.982$ watts/ft

Rtot, Total Thermal resistance betweeen conductor and ambient during Test

$Rtot := \frac{Tc - Ta}{Qp}$ thermal resistance between conductor and ambient air

$Rtot = 8.358$ C-ft/watt

ATTACHMENT A

Re, thermal resistance between Thermal Lag surface and ambient during test

$Dsp := Dcnd + 2 \cdot TSI$ $Ts := 50$ Initial guess surface temperature

$$Re := \frac{15.6 \cdot np}{Dsp \cdot \left(\frac{Ts - Ts}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\frac{Ta}{2} + \frac{Ts}{2}\right)\right]}$$

Calculate Ts, Ri-thl

$Dsp := Dcnd + 2 \cdot TSI$ Outer diameter of thermal lagged conduit, where the outer diameter of the conduit is 5.5 inch.

$Dsp = 6.5$ inch

Qp= (Ts-Ta)/Re Equation relating Re and Qp

$Ts = 50$ Initial guess

Given

$$Qp = \frac{Ts - Ta}{\left[\frac{15.6 \cdot np}{Dsp \cdot \left(\frac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\frac{Ta}{2} + \frac{Ts}{2}\right)\right]}\right]}$$

$Ts := Find(Ts)$

$Ts = 70.306$ degree C

ATTACHMENT A

Confirmation of Given/Find calculation:

$$\frac{Ts - Ta}{\left[\dfrac{15.6 \cdot np}{Dsp \cdot \left(\dfrac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\dfrac{Ta}{2} + \dfrac{Ts}{2}\right)\right]}\right]} = 5.982$$

watts/ft-/in^2

5.982 is equal to Qp thus conferming the value of Ts.

Calculate Re, thermal resistance between Thermal Lag surface and ambient air

$$Re := \frac{15.6 \cdot np}{Dsp \cdot \left(\dfrac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\dfrac{Ta}{2} + \dfrac{Ts}{2}\right)\right]}$$

$Re = 5.066$ C-ft/watt

Calculate Rthl, thermal resistance of thermal lag, based on thickness used in TU Test

$$Rthl := 0.012 \cdot np \cdot \rho TSI \cdot \log\left(\frac{Dsp}{Dcnd}\right)$$

thermal resistance of thermal lag ,equation adapted from Equation 38 of Neher/McGrath

$Rthl = 2.012$ C-ft/watt

Calculate Ri_thl, thermal resistance between conductor and thermal Lag

$$Ri\_thl := Rtot - Re - Rthl$$

thermal resistance between conductor and inside wall of thermal lag

$Ri\_thl = 1.28$ C-ft/watt

ATTACHMENT A

2. Calculate New Conditions

$TSI := 1.25$ new thickness of TSI, inch

$Dsp := Dcnd + 2 \cdot TSI$ outer diameter of thermal lagged conduit, inch

$Dsp = 8$ inch

$Rthl := 0.012 \cdot np \cdot \rho TSI \cdot \log\left(\frac{Dsp}{Dcnd}\right)$ thermal resistance of thermal lag, equation adapted from Equation 36 of Neher-McGrath (Ref. 3.1.82).

$Rthl = 4.512$

The new Qpp can be defined as follows:

$$Qpp := \frac{Tc - Ts}{Ri\_thl + Rthl}$$

$$Qpp := \frac{\frac{Ts - Ta}{15.6 \cdot np}}{Dsp \cdot \left(\frac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\frac{Ta}{2} + \frac{Ts}{2}\right)\right]}$$

Combining these two equations we can solve for Ts

$Ts := 50$ Initial guess of surface temperature

Given

$$\frac{Tc - Ts}{Ri\_thl + Rthl} = \frac{Ts - Ta}{\left[\frac{15.6 \cdot np}{Dsp \cdot \left(\frac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\frac{Ta}{2} + \frac{Ts}{2}\right)\right]}\right]}$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 62.613$ new surface temperature of thermal lag for new thermal lag thickness

ATTACHMENT A

Using the Ts and Qpp values determined above:

$$Qpp := \frac{Tc - Ts}{Ri\_thl + Rthl}$$

$Qpp = 4.728$

$$ACFtsi := \sqrt{\frac{Qpp}{Q}}$$

$ACFtsi = 0.794$ Ampacity correction factor for 1.25 in TSI conduit wrap

$$ACFTU := \sqrt{\frac{Qp}{Q}}$$

$ACFTU = 0.893$ Ampacity correction factor for 1/2 in TS! determined by TU

ATTACHMENT A

1.0 in thick TSI

CONDUIT MODEL

The following is a model of Thermo-Lag on Conduit using the TU Test Results .

The thermal resistance model of a cable in conduit consists of the following thermal resistance components.

Ri	thermal resistance of the insulation/jacket
Rsd	thermal resistance between the outer cable jacket to the inside conduit wall
Rd	thermal resistance of the conduit
Rag	thermal resistance between the outer surface of the conduit and the inside surface of thermal Lag shell product.
Rthl	thermal resistance of the termal lag shell
Re	thermal resistance between the outer surface of the thermal Lag and ambient air
Rtot	is the sum of the above thermal resistance terms/ thermal resistance between the
Ri_thl	conductor and ambient air.

Methodology to develop an ampacity Model of a power cable in Thermal Lagged conduit using TU test:

1. Calculate the heat generated by one conductor during both the base line condition (Q) and thermal lagged conduit conditions(Qp).

2. Using a known value of Qp, calculate Rtot, thermal resistance between conductor and ambient air, during test of thermal Lag conduit.

3. Calculate thermal resistance of thermal Lag (Rhtl) using accepted equation for calculating the thermal resistance of a cylinder. Equation 38 from Neher-McGrath technical paper is used to calculate Rthl.

4. Using equation for Re, thermal resistance between thermal Lag and ambient air, calculate Ts, surface temperature of thermal lag. Ts is solved using MathCad given/find function. Once Ts is solved, Re is then calculated.

5. With Re, Rtot, and Rthl known, the thermal resistance between conductor and inside surface of thermal Lagf (Ri_thl) can be calculated. Ri_thl is considered to be constant regardless of the Thermal Lag.

6. A new Rthl is calculated for a new theraml Lag thickness, for MS2 the thickness is 1.25 inch.
7. Two equations are defined with respect to Q", heat generated for new thickness of thermal Lag. These equations are set equal to each and solved for TS. Q" is then solved using the value of Ts.

8. The ampacity correction factor (ACF) for the thermal lag conduit is then solved.

ATTACHMENT A

1. Calculate Parameters Associated with Test Conditions

INPUT:

$\varepsilon TSI := 0.9$ emissivity of thermal Lag

$TSI := 0.5$ thickness of thermal Lag in test, inches

$\rho TSI := 577.7$ thermal resistivity of thermal lag, C-cm/watt (calculated from a value of thermal conductivity of 1.0BTU/hr-ft-F.

$Dcnd := 5.5$ outer diameter of conduit, inch.

$Rac := 0.023 \cdot 10^{-3}$ ac resistance of 750 kcmil Cu, page 13 of ETP104.1-0

$Ib := 571$ base current in Tu test, amps

$Ip := 510$ base current in Tu test, amps

$np := 4$ number of conductors in conduit

$Tc := 90$ conducctor termperature, C

$Ta := 40$ ambient temperature, C

Q, heat generated in Test Base Line Conditions

$Q := Ib^2 \cdot Rac$ heat generated by single conduitro, in base condition (I^2R).

$Q = 7.499$ watts /ft

Qp, heat generated in test conditions of 1/2 inch thermal lag conduit

$Qp := Ip^2 \cdot Rac$ heat generated by single conductor, in derated conditions of test.

$Qp = 5.982$ watts/ft

Rtot, Total Thermal resistance betweeen conductor and ambient during Test

$Rtot := \frac{Tc - Ta}{Qp}$ thermal resistance between conductor and ambient air

$Rtot = 8.358$ C-ft/watt

ATTACHMENT A

Re, thermal resistance between Thermal Lag surface and ambient during test

$Dsp := Dcnd + 2 \cdot TSI$ $\quad Ts := 50$ Initial guess surface temperature

$$Re := \frac{15.6 \cdot np}{Dsp \cdot \left(\frac{Ts - Ts}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\frac{Ta}{2} + \frac{Ts}{2}\right)\right]}$$

Calculate Ts, Ri-thl

$Dsp := Dcnd + 2 \cdot TSI$ Outer diameter of thermal lagged conduit, where the outer diameter of the conduit is 5.5 inch.

$Dsp = 6.5$ inch

Qp= (Ts-Ta)/Re Equation relating Re and Qp

$Ts = 50$ Initial guess

Given

$$Qp = \frac{Ts - Ta}{\left[\frac{15.6 \cdot np}{Dsp \cdot \left(\frac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\frac{Ta}{2} + \frac{Ts}{2}\right)\right]}\right]}$$

$Ts := Find(Ts)$

$Ts = 70.306$

ATTACHMENT A

Confirmation of Given/Find calculation:

$$\frac{Ts - Ta}{\left[\dfrac{15.6 \cdot np}{Dsp \cdot \left(\dfrac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\dfrac{Ta}{2} + \dfrac{Ts}{2}\right)\right]}\right]} = 5.982$$

5.982 is equal to Qp thus conferming the value of Ts.

Calculate Re, thermal resistance between Thermal Lag surface and ambient air

$$Re := \frac{15.6 \cdot np}{Dsp \cdot \left(\dfrac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\dfrac{Ta}{2} + \dfrac{Ts}{2}\right)\right]}$$

$Re = 5.066$ C-ft/watt

Calculate Rthl, thermal resistance of thermal lag, based on thickness used in TU Test

$$Rthl := 0.012 \cdot np \cdot \rho TSI \cdot \log\left(\frac{Dsp}{Dcnd}\right)$$

thermal resistance of thermal lag ,equation adapted from Equation 38 of Neher/McGrath

$Rthl = 2.012$ C-ft/watt

Calculate Ri_thl, thermal resistance between conductor and thermal Lag

$$Ri\_thl := Rtot - Re - Rthl$$

thermal resistance between conductor and inside wall of thermal lag

$Ri\_thl = 1.28$ C-ft/watt

ATTACHMENT A

2. Calculate New Conditions

$TSI := 1.0$ new thickness of TSI, inch Minimum

$Dsp := Dcnd + 2 \cdot TSI$ outer diameter of thermal lagged conduit, inch

$Dsp = 7.5$ inch

$Rthl := 0.012 \cdot np \cdot \rho TSI \cdot \log\left(\frac{Dsp}{Dcnd}\right)$ thermal resistance of thermal lag, equation adapted from Equation 38 of Neher-McGrath

$Rthl = 3.735$

The new Qpp can be defined as follows:

$$Qpp := \frac{Tc - Ts}{Ri\_thl + Rthl}$$

$$Qpp := \frac{Ts - Ta}{Dsp \cdot \left(\frac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\frac{Ta}{2} + \frac{Ts}{2}\right)\right]}$$

Combining these two equations we can solve for Ts

$Ts := 50$ Initial guess of surface temperature

Given

$$\frac{Tc - Ts}{Ri\_thl + Rthl} = \frac{Ts - Ta}{\left[\frac{15.6 \cdot np}{Dsp \cdot \left(\frac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\frac{Ta}{2} + \frac{Ts}{2}\right)\right]}\right]}$$

$Ts := \mathrm{Find}(Ts)$

$Ts = 64.648$ new surface temperature of thermal lag for new thermal lag thickness

ATTACHMENT A

Using the Ts and Qpp values determined above:

$$Qpp := \frac{Tc - Ts}{Ri\_thl + Rthl}$$

$$Qpp = 5.055$$

$$ACFtsi := \sqrt{\frac{Qpp}{Q}}$$

$$ACFtsi = 0.821$$

Ampacity correction factor for 1.0 in TSI conduit wrap

ATTACHMENT 1A

1.5 in thick TSI

CONDUIT MODEL

The following is a model of Thermo-Lag on Conduit using the TU Test Results .

The thermal resistance model of a cable in conduit consists of the following thermal resistance components.

Ri	thermal resistance of the insulation/jacket
Rsd	thermal resistance between the outer cable jacket to the inside conduit wall
Rd	thermal resistance of the conduit
Rag	thermal resistance between the outer surface of the conduit and the inside surface of thermal Lag shell product.
Rthl	thermal resistance of the termal lag shell
Re	thermal resistance between the outer surface of the thermal Lag and ambient air
Rtot	is the sum of the above thermal resistance terms/ thermal resistance between the
Ri_thl	conductor and ambient air.

Methodology to develop an ampacity Model of a power cable in Thermal Lagged conduit using TU test:

1. Calculate the heat generated by one conductor during both the base line condition (Q) and thermal lagged conduit conditions(Qp).

2. Using a known value of Qp, calculate Rtot, thermal resistance between conductor and ambient air, during test of thermal Lag conduit.

3. Calculate thermal resistance of thermal Lag (Rhtl) using accepted equation for calculating the thermal resistance of a cylinder. Equation 38 from Neher-McGrath technical paper is used to calculate Rthl.

4. Using equation for Re, thermal resistance between thermal Lag and ambient air, calculate Ts, surface temperature of thermal lag. Ts is solved using MathCad given/find function. Once Ts is solved, Re is then calculated.

5. With Re, Rtot, and Rthl known, the thermal resistance between conductor and inside surface of thermal Lagf (Ri_thl) can be calculated. Ri_thl is considered to be constant regardless of the Thermal Lag.

6. A new Rthl is calculated for a new theraml Lag thickness, for MS2 the thickness is 1.25 inch.
7. Two equations are defined with respect to Q", heat generated for new thickness of thermal Lag. These equations are set equal to each and solved for TS. Q" is then solved using the value of Ts.

8. The ampacity correction factor (ACF) for the thermal lag conduit is then solved.

ATTACHMENT A

1. Calculate Parameters Associated with Test Conditions

INPUT:

$\varepsilon TSI := 0.9$ emissivity of thermal Lag

$TSI := 0.5$ thickness of thermal Lag in test, inches

$\rho TSI := 577.7$ thermal resistivity of thermal lag, C-cm/watt (calculated from a value of thermal conductivity of 1.0BTU/hr-ft-F.

$Dcnd := 5.5$ outer diameter of conduit, inch.

$Rac := 0.023 \cdot 10^{-3}$ ac resistance of 750 kcmil Cu, page 13 of ETP104.1-0

$Ib := 571$ base current in Tu test, amps

$Ip := 510$ base current in Tu test, amps

$np := 4$ number of conductors in conduit

$Tc := 90$ conductor termperature, C

$Ta := 40$ ambient temperature, C

Q, heat generated in Test Base Line Conditions

$Q := Ib^2 \cdot Rac$ heat generated by single conduitro, in base condition (I^2R).

$Q = 7.499$ watts /ft

Qp, heat generated in test conditions of 1/2 inch thermal lag conduit

$Qp := Ip^2 \cdot Rac$ heat generated by single conductor, in derated conditions of test.

$Qp = 5.982$ watts/ft

Rtot, Total Thermal resistance betweeen conductor and ambient during Test

$Rtot := \frac{Tc - Ta}{Qp}$ thermal resistance between conductor and ambient air

$Rtot = 8.358$ C-ft/watt

ATTACHMENT A

Re, thermal resistance between Thermal Lag surface and ambient during test

$$Dsp := Dcnd + 2 \cdot TSI \qquad Ts := 50$$ Initial guess surface temperature

$$Re := \frac{15.6 \cdot np}{Dsp \cdot \left(\frac{Ts - Ts}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\frac{Ta}{2} + \frac{Ts}{2}\right)\right]}$$

Calculate Ts, Ri-thl

$Dsp := Dcnd + 2 \cdot TSI$ Outer diameter of thermal lagged conduit, where the outer diameter of the conduit is 5.5 inch.

$Dsp = 6.5$ inch

Qp= (Ts-Ta)/Re Equation relating Re and Qp

$Ts = 50$ Initial guess

Given

$$Qp = \frac{Ts - Ta}{\left[\frac{15.6 \cdot np}{Dsp \cdot \left(\frac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\frac{Ta}{2} + \frac{Ts}{2}\right)\right]}\right]}$$

$Ts := Find(Ts)$

$Ts = 70.306$

ATTACHMENT A

Confirmation of Given/Find calculation:

$$\frac{Ts - Ta}{\left[\dfrac{15.6\cdot np}{Dsp\cdot\left(\dfrac{Ts-Ta}{Dsp}\right)^{0.25} + 1.6\cdot\varepsilon TSI\cdot\left[1 + 0.0167\cdot\left(\dfrac{Ta}{2}+\dfrac{Ts}{2}\right)\right]}\right]} = 5.982$$

5.982 is equal to Qp thus conferming the value of Ts.

Calculate Re, thermal resistance between Thermal Lag surface and ambient air

$$Re := \frac{15.6\cdot np}{Dsp\cdot\left(\dfrac{Ts-Ta}{Dsp}\right)^{0.25} + 1.6\cdot\varepsilon TSI\cdot\left[1 + 0.0167\cdot\left(\dfrac{Ta}{2}+\dfrac{Ts}{2}\right)\right]}$$

$Re = 5.066$ C-ft/watt

Calculate Rthl, thermal resistance of thermal lag, based on thickness used in TU Test

$$Rthl := 0.012\cdot np\cdot \rho TSI\cdot \log\left(\frac{Dsp}{Dcnd}\right)$$

thermal resistance of thermal lag ,equation adapted from Equation 38 of Neher/McGrath

$Rthl = 2.012$ C-ft/watt

Calculate Ri_thl, thermal resistance between conductor and thermal Lag

$$Ri\_thl := Rtot - Re - Rthl$$

thermal resistance between conductor and inside wall of thermal lag

$Ri\_thl = 1.28$ C-ft/watt

ATTACHMENT A

2. Calculate New Conditions

$TSI := 1.5$ new thickness of TSI, inch Minimum

$Dsp := Dcnd + 2 \cdot TSI$ outer diameter of thermal lagged conduit, inch

$Dsp = 8.5$ inch

$Rthl := 0.012 \cdot np \cdot \rho TSI \cdot \log\left(\frac{Dsp}{Dcnd}\right)$ thermal resistance of thermal lag, equation adapted from Equation 38 of Neher-McGrath

$Rthl = 5.242$

The new Qpp can be defined as follows:

$$Qpp := \frac{Tc - Ts}{Ri\_thl + Rthl}$$

$$Qpp := \frac{Ts - Ta}{Dsp \cdot \left(\frac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\frac{Ta}{2} + \frac{Ts}{2}\right)\right]}$$

Combining these two equations we can solve for Ts

$Ts := 50$ Initial guess of surface temperature

Given

$$\frac{Tc - Ts}{Ri\_thl + Rthl} = \frac{Ts - Ta}{\left[\frac{15.6 \cdot np}{Dsp \cdot \left(\frac{Ts - Ta}{Dsp}\right)^{0.25} + 1.6 \cdot \varepsilon TSI \cdot \left[1 + 0.0167 \cdot \left(\frac{Ta}{2} + \frac{Ts}{2}\right)\right]}\right]}$$

$Ts := \text{Find}(Ts)$

$Ts = 60.918$ new surface temperature of thermal lag for new thermal lag thickness

ATTACHMENT A

Using the Ts and Qpp values determined above:

$$Qpp := \frac{Tc - Ts}{Ri\_thl + Rthl}$$

$$Qpp = 4.458$$

$$ACFtsi := \sqrt{\frac{Qpp}{Q}}$$

$ACFtsi = 0.771$ Ampacity correction factor for 1.5 in TSI conduit wrap

ATTACHMENT B

TABLE OF CONTENTS

This attachment contains the calculations for the allowed ampacity in each of the above listed trays and the type of cable installed in the tray. Each appendix is a separate calculation performed in MathCad on a Macintosh Centris 650 computer. Verification that the calculations are correct are based upon the results of the 6 test runs included herein. The test runs were ran at a fill and wire diameter taken from the ICEA P-54-440 and the values compared against the values presented in the two years identified above of the standard. The results indicate that the calculations are being performed correctly.

THERMAL MODEL Z23HA10

Values
10% fill on 4"
0.509 in/B14
R=0.031357 5/1000/ft
CaD=2.178
500MCMTPLX

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 0.509 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K} \right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides excluded

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \, °K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K} \right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1 \right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K} \right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} \right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc \right]$$

$Tc = 357.577 \, °K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 160.481\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho}{8\cdot w}\cdot d\cdot Tc^4\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 5.583\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}$$

$$\Delta Tc = 5.583\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 44.417\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 13.137\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 2.1781 \cdot in$ Cable outer diameter

$R := 0.0313575 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 721.338 \cdot amp$ Tray Z23HA10 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 641.991 \cdot amp$ Ampacity at 50C

From IPCEA 80% of the ampacity of 500MCM at 40C is 464 amps (580 x .8) Adjusting to 50C gives:

$Iair80 := 464 \cdot 0.89 \cdot amp$

$Iair80 = 412.96 \cdot amp$ maximum ampacity allowed at 50C

THERMAL MODEL Z23HB10

Values
19% fill on 4"
0.968 in/B14
R=0.0313575/1000ft
CaD=2.178
500MCMTPLX

1.0 Tray Thermal Data

$w := 12\cdot in$ Width in Tray

$d := 0.968\cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40)\cdot K$ Ampient Temperature

$Tc := unknown\cdot K$ Surface Temperature

$Tm := (273.16 + 90)\cdot K$ Max Cable Temperature

$$h := 0.101\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot\frac{watt}{ft^2\cdot K}$$ Overall Convective Heat transfer Coefficient

$$h := (0.101)\cdot\frac{watt}{ft^2\cdot K}$$

$$\sigma := 0.530\cdot 10^{-8}\cdot\frac{watt}{ft^2\cdot K^4}$$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400\cdot K\cdot\frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4\cdot\frac{ft^2}{ft}$$ Surface area of cable mass per unit length sides excluded

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16\ {}^\circ K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d}{8\cdot w}\cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot h\cdot(As\cdot\rho\cdot d)}{8\cdot w} + 1\right]\cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot h\cdot(As\cdot\rho\cdot d)}{8\cdot w}\right]\cdot Ta - \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d}{8\cdot w}\cdot Ta^4, Tc\right]$$

$Tc = 347.548\ {}^\circ K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 117.978\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 15.612\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}$$

$$\Delta Tc = 15.612\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 34.388\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 10.157\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 2.178 \cdot in$ Cable outer diameter

$R := 0.0313575 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 634.226 \cdot amp$ Tray Z23HB10 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 564.462 \cdot amp$ Ampacity at 50C

From IPCEA 80% of the ampacity of 500MCM at 40C is 464 amps. Adjusting to 50C gives:

$Iair80 := 464 \cdot 0.89 \cdot amp$

$Iair80 = 412.96 \cdot amp$

maximum ampacity allowed at 50C

THERMAL MODEL Z23GE10

Values
22% fill 4" tray"
1.12 in/ B14
R=0.0313575/1000ft
CaD=2.178
500MCMTPLX

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 1.12 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coeffic ient

$$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length sides excluded

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \,{}^\circ K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 352.541 \,{}^\circ K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 138.718\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 10.619\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}$$

$$\Delta Tc = 10.619\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 39.381\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 5.161\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 2.1781 \cdot in$ Cable outer diameter

$R := 0.0313575 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 452.109 \cdot amp$ Ampacity at 40C

$I50 := I40 \cdot 0.89$

$I50 = 402.377 \cdot amp$ Ampacity at 50C

rom IPCEA 80% of the ampacity of 500MCM at 40C is 464 amps.
Adjusting to 50C gives:

$Iair80 := 464 \cdot 0.89 \cdot amp$

$Iair80 = 412.96 \cdot amp$ Maximum ampacity allowed at 50C.

THERMAL MODEL Z23GE10

Values
22% fill on 4"
1.12 in/ B10
R=0.0594925/1000ft
CaD=1.719
250MCMTPLX

1.0 Tray Thermal Data

$w := 24 \cdot in$ — Width in Tray

$d := 1.12 \cdot in$ — Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ — Ampient Temperature

$Tc := unknown \cdot K$ — Surface Temperature

$Tm := (273.16 + 90) \cdot K$ — Max Cable Temperature

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coeffic ient

$$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$$\varepsilon := 0.8$$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length sides excluded

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \,°K$ — Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 352.541 \,°K$

APPENDIX D PAGE 2

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 138.718\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises
2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 10.619\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 10.619\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 39.381\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 5.161\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.719 \cdot in$ Cable outer diameter

$R := 0.0594925 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 259.049 \cdot amp$ Tray Z23GE10 Ampacity at 40C

Correction factor to get to 50C

$I50 := I40 \cdot 0.89$

$I50 = 230.553 \cdot amp$ Ampacity at 50C

$I80 := 374 \cdot .8 \cdot amp$ From IPCEA the 80% of the free air value 299, I80 > I40 thus the I50 value is the correct value to use.

$I80 = 299.2 \cdot amp$

THERMAL MODEL Z14FM10

VALUE
12% FILL in 4" Tray
0.611 in/ B03
R=0.84875/1000ft
CaD=0.774"
3/C#8 AWG

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 0.611 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides excluded

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \,°K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 356.631 \,°K$

APPENDIX E PAGE 2

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot\left(Tc^4-Ta^4\right)$$

$$W = 156.331\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc \qquad \Delta Tc = 6.529\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 6.529\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta \qquad \Delta Ta = 43.471\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta \qquad \Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 10.661\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 0.774 \cdot in$ Cable outer diameter

$R := 0.84875 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 44.385 \cdot amp$ Tray Z14FM10 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 39.502 \cdot amp$ Ampacity at 50C

Since I50 is less than 80% of the free air value at 50C I50 is the correct value.

THERMAL MODEL Z14FM20

Values
9% fill on 4"
0.458 in
R=2.15/1000ft
CaD=0.603
3/C#12AWG

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 0.458 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coeffic ient

$$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 492.496 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length sides excluded

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \,°K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 357.062 \,°K$

APPENDIX F PAGE 2

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 158.217\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 6.098\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 6.098\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 43.902\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 14.394\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 0.603 \cdot in$ Cable outer diameter

$R := 2.15 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 25.245 \cdot amp$ Tray Z14FM20 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 22.468 \cdot amp$ Ampacity at 50C

Since 80% of the free air value is 26.24 amps I50 above is less than this value, I50 is the correct value to use.

APPENDIX G Page 1

THERMAL MODEL Z24FL10

1.0 Tray Thermal Data

		VALUE
$w := 24 \cdot in$	Width in Tray	4% FILL in 4" Tray
$d := 0.2037 \cdot in$	Depth of cables in Tray	0.2037 in/B29
		R=0.06890625/1000ft
		CaD=0.738"
$Ta := (273.16 + 40) \cdot K$	Ampient Temperature	4/0MCM
$Tc := unknown \cdot K$	Surface Temperature	
$Tm := (273.16 + 90) \cdot K$	Max Cable Temperature	

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coeffic ient

$$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$$\varepsilon := 0.8$$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length sides excluded

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \,{}^\circ K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 360.729 \,{}^\circ K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc - Ta) + \sigma\cdot As\cdot\varepsilon\cdot(Tc^4 - Ta^4)$$

$$W = 174.535 \cdot \frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w} + 1\right]\cdot Tc - \frac{h\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w} + \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right] - \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.159$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 2.43 \cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}$$

$$\Delta Tc = 2.43 \cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 47.569 \cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 49.999 \cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 35.701 \cdot \frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 0.738 \cdot in$ Cable outer diameter

$R := 0.06890625 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 271.802 \cdot amp$ Tray Z24FL10 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 241.903 \cdot amp$ Ampacity at 50C

I80 (80% of the free air value) is 320 amps (400amp x 0.8) . This is greater than the 271.802 amps thus the I50 value is the correct value to use.

APPENDIX H

THERMAL MODEL Z14FM20

VALUE
9% FILL in 4" Tray
0.458 in/B09
R=0.06890625/1000ft
CaD=1.485"
4/0MCMTPLX

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 0.458 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides excluded

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \, {}^{\circ}K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 358.068 \, {}^{\circ}K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot\left(Tc^4-Ta^4\right)$$

$$W = 162.65\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc \qquad \Delta Tc = 5.092\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 5.092\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta \qquad \Delta Ta = 44.908\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta \qquad \Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 14.797\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.485 \cdot in$ Cable outer diameter

$R := 0.06890625 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 352.104 \cdot amp$ Tray Z14FM20 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 313.372 \cdot amp$ Ampacity at 50C

I80 is 268 amps (335 x 0.8) at 40C. Since I80<I40 the I80 value adjusted to 50C is used

$Iair80 := 268 \cdot 0.89 \cdot amp$

$Iair80 = 238.52 \cdot amp$ This is the maximum allowable ampacity.

VALUE
8% FILL in 4" Tray
0.407 in/B29
R=0.06890625/1000ft
CaD=0.738"
4/0MCM

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 0.407 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ambient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coeffic ient

$$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length sides excluded

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \,°K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 358.573 \,°K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 164.887\ \frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 4.587\ K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 4.587\ K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 45.413\ K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\ K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 16.88\ \frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 0.738 \cdot in$ Cable outer diameter

$R := 0.06890625 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 186.897 \cdot amp$ Tray Z24FL20 Ampacity at 40C

Correction factor to get to 50C

$I50 := I40 \cdot 0.89$

$I50 = 166.338 \cdot amp$ Ampacity at 50C

I80 is 320 amps (400 x .8). Since this is > than I40, the I50 value is the value to use.

VALUE
10% FILL in 4" Tray
0.509 in/ B03
R=0.84875/1000ft
CaD=0.774"
3/C#8

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 0.509 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides excluded

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \cdot K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 357.577 \cdot K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 160.481\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 5.583\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}$$

$$\Delta Tc = 5.583\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 44.417\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 13.137\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 0.774 \cdot in$ Cable outer diameter

$R := 0.84875 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 49.27 \cdot amp$ Tray Z25BG20 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 43.85 \cdot amp$ Ampacity at 50C

Since I50 is less than 80% of the free air value at 50C [52.48 amps] I50 is the correct value to use.

THERMAL MODEL Z14FM10

Values
12% fill on 4"
0.611 in/ B01
R=2.15/1000ft
CaD=0.603
3/C#12AWG

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 0.611 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides exclluded

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \,°K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 356.631 \,°K$

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2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot As \cdot (Tc - Ta) + \sigma \cdot As \cdot \varepsilon \cdot (Tc^4 - Ta^4)$$

$$W = 156.331 \cdot \frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - \frac{h \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot As \cdot \rho \cdot d \cdot Ta}{8 \cdot w} + \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d \cdot Tc^4}{8 \cdot w}\right] - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d \cdot Ta^4}{8 \cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 6.529 \cdot K$$

$$\Delta Tc := \frac{W \cdot \rho \cdot d}{8 \cdot w} \qquad \Delta Tc = 6.529 \cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 43.471 \cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50 \cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d \cdot w} \qquad Q = 10.661 \cdot \frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 0.603 \cdot in$ Cable outer diameter

$R := 2.15 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 21.726 \cdot amp$ Tray Z14FM10 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 19.336 \cdot amp$ Ampacity at 50C

Since 80% of the free air value is greater than I50 above is less than this value, I50 is the correct value to use.

THERMAL MODEL Z14FM10

VALUE
12% FILL in 4" Tray
0.611 in/ B09
R=0.06890625/1000ft
CaD=1.485"
4/0MCMTPLX

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 0.611 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknow \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides excluded

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \, {}^\circ K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 356.631 \, {}^\circ K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 156.331\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 6.529\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}$$

$$\Delta Tc = 6.529\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 43.471\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 10.661\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.485 \cdot in$ Cable outer diameter

$R := 0.06890625 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 298.867 \cdot amp$ Tray Z14FM10 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 265.991 \cdot amp$ Ampacity at 50C

The ampacity in air at 40C is 335, 80% is equal to 268 amps. Since 268 amps is < I40 the free air value (80%) adjusted to 50C is the correct value to use.

$I80 := 268 \cdot amp \cdot 0.89$

$I80 = 238.52 \cdot amp$ adjusted to 50C

THERMAL MODEL Z23FA30

Values
25% fill on 4"
1.27 in/ B10
R=0.0594925/1000ft
CaD=1.719
250MCMTPLX

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 1.27 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coefficient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides excluded

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \, {}^{\circ}K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 351.5 \, {}^{\circ}K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc - Ta) + \sigma\cdot As\cdot\varepsilon\cdot(Tc^4 - Ta^4)$$

$$W = 134.325\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w} + 1\right]\cdot Tc - \frac{h\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w} + \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right] - \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises
2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 11.66\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 11.66\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 38.34\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 4.407\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.719 \cdot in$ Cable outer diameter

$R := 0.0594925 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 239.387 \cdot amp$ Tray Z23FA30 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 213.055 \cdot amp$ Ampacity at 50C

$I80 := 374 \cdot .8 \cdot amp$ Since 80% of the free air value is 299 amps, I50 is the correct value to use.

$I80 = 299.2 \cdot amp$

THERMAL MODEL Z23FA25

Values
27% fill on 4"
1.375 in/ B10
R=0.0594925/1000ft
CaD=1.719
250MCMTPLX

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 1.375 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coefficient

$$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length sides excluded

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \,°K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 350.808 \,°K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 131.427\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 12.352\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}\qquad \Delta Tc = 12.352\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 37.648\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}\qquad Q = 3.983\cdot\frac{\frac{watt}{ft}}{in^2}$$

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Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.719 \cdot in$ Cable outer diameter

$R := 0.0594925 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 227.569 \cdot amp$ Tray Z23FA25 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 202.537 \cdot amp$ Ampacity at 50C

$I80 := 374 \cdot .8 \cdot amp$ Since the 80% of free air value is > I40 use I50 as correct value.

$I80 = 299.2 \cdot amp$

THERMAL MODEL Z24FL10

Values
4% fill on 4"
0.2037 in/C86
R=3.41/1000ft
CaD=0.576
7/C#14AWG

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 0.2037 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides excluded

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \,^{\circ}K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 360.729 \,^{\circ}K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 174.535\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.159$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 2.43\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 2.43\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 47.569\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 49.999\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 35.701\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 7$ number of conductors

$CaD := 0.576 \cdot in$ Cable outer diameter

$R := 3.41 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 19.742 \cdot amp$ Tray Z14FM20 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 17.57 \cdot amp$ Ampacity at 50C

80% of free air value is 22.96 amps at 50 C.
I50 is correct value to use.

THERMAL MODEL Z25BG20

Values
35% fill on 4"
1.78 in
R=3.41/1000ft
CaD=0.468
3/C#14AWG

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 1.78 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides excluded

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \,{}^{\circ}K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 348.389 \,{}^{\circ}K$

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2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 121.411\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 14.771\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 14.771\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 35.229\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 2.842\cdot\frac{\frac{watt}{ft}}{in^2}$$

APPENDIX AA PAGE 3

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 0.468 \cdot in$ Cable outer diameter

$R := 3.41 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 6.913 \cdot amp$ Tray Z14FM20 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 6.153 \cdot amp$ Ampacity at 50C

THERMAL MODEL Z25BG20

Values
35% fill on 4"
1.78 in/C02
R=3.41/1000ft
CaD=0.45
2/C#14AWG

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 1.78 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides excluded

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \text{ °K}$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 348.389 \text{ °K}$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 121.411\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 14.771\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 14.771\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 35.229\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 2.842\cdot\frac{\frac{watt}{ft}}{in^2}$$

APPENDIX AB PAGE 3

Ampacity Calculation

$n := 2$ number of conductors

$CaD := 0.45 \cdot in$ Cable outer diameter

$R := 3.41 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 8.141 \ \mathrm{amp}$ Tray Z14FM20 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 7.246 \ \mathrm{amp}$ Ampacity at 50C

THERMAL MODEL Z25BG20

Values
35% fill on 4"
1.78 in/B01
R=2.15/1000ft
CaD=0.603
3/C#12AWG

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 1.78 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530\ 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides excluded

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16\ {}^{\circ}K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 348.389\ {}^{\circ}K$

APPENDIX AC PAGE 2

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 121.411\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 14.771\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 14.771\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 35.229\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 2.842\cdot\frac{\frac{watt}{ft}}{in^2}$$

APPENDIX AC PAGE 3

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 0.603 \cdot in$ Cable outer diameter

$R := 2.15 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 11.217 \cdot amp$ Tray Z14FM20 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 9.984 \cdot amp$ Ampacity at 50C

THERMAL MODEL Z25BG20

Values
35% fill on 4"
1.78 in/C62
R=1.35/1000ft
CaD=0.522
2/C#10AWG

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 1.78 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coeffic ient

$$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length sides excluded

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \,°K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 348.389 \,°K$

APPENDIX AD PAGE 2

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 121.411\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 14.771\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 14.771\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 35.229\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 2.842\cdot\frac{\frac{watt}{ft}}{in^2}$$

APPENDIX AD PAGE 3

Ampacity Calculation

$n := 2$ number of conductors

$CaD := 0.522 \cdot in$ Cable outer diameter

$R := 1.35 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 15.009 \, amp$ Tray Z14FM20 Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 13.358 \, amp$ Ampacity at 50C

THERMAL MODEL Z52EA10

Values
38% fill on 4"
1.935 in/B14
R=0.033251456/1kft
CaD=3.05
750MCMTPLX
AL

1.0 Tray Thermal Data

$w := 6 \cdot in$ Width in Tray

$d := 1.935 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coeffic ient

$$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length sides excluded

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \, ^\circ K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation
2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 332.019 \, ^\circ K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 58.864\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$Tm = 363.16$

2.4 Temperature Rises

2.4.1 Cab ie Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 31.141\ {}^{\circ}K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}\qquad \Delta Tc = 31.141\ {}^{\circ}K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 18.859\ {}^{\circ}K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\ {}^{\circ}K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 5.07\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 3.05 \cdot in$ Cable outer diameter

$R := 0.033251456 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 609.377 \cdot amp$ Tray Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 542.346 \cdot amp$ Ampacity at 50C

I air =588 amps at 40 C

$I80 := 588 \cdot .8 \cdot .89$

$I80 = 418.656$

THERMAL MODEL Z22EA10

Values
23% fill on 4"
1.1714 in/B14
R=0.06543487/1000ft
CaD=2.39
350MCMTPLX
AL

1.0 Tray Thermal Data

$w := 6 \cdot in$ Width in Tray

$d := 1.1714 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coeffic ient

$$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length sides excluded

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \,°K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 337.696 \,°K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot\left(Tc^4-Ta^4\right)$$

$$W = 79.509\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 25.464\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}$$

$$\Delta Tc = 25.464\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 24.536\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 11.313\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 2.39 \cdot in$ Cable outer diameter

$R := 0.06543487 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 508.461 \cdot amp$ Tray Ampacity at 40C

$I50 := I40 \cdot 0.89$ Correction factor to get to 50C

$I50 = 452.531 \cdot amp$ Ampacity at 50C

Iair = 368 amps at 40C.

$I80 := 368 \cdot .8 \cdot .89$

$I80 = 262.016$

ATTACHMENT B

TESTS FOR MATHCAD VERIFICATION

To prove the validity of the MathCad ampacity several tests were run using the depth and cable diameters provided in the ICEA tables. The ampacities presented in the ICEA table for each test made was then compared to the calculated value to ensure the calculation was providing conservative values. The results are tabulated below:

TEST	Appendix	Cable	Depth	ICEA	MATHCAD	Variance
1	PP	3/C #8	1.5	38	36.766	3.249%
2	QQ	3/C #8	2.0	31	30.137	2.784%
3	TT	500MCM	1.5	438	397.554	9.234%
4	UU	500MCM	3.0	272	242.456	10.863%
5	RR	4/0	3.0	135	124.212	7.991%
6	SS	4/0	2.5	153	142.199	7.059%

From the above it is apparent that the values calculated in all cases are conservative.

ATTACHMENT B

TESTS FOR MATHCAD VERIFICATION

To prove the validity of the MathCad ampacity several tests were run using the depth and cable diameters provided in the ICEA tables. The ampacities presented in the ICEA table for each test made was then compared to the calculated value to ensure the calculation was properly functioning. The results are tabulated below:

TEST	Appendix	Cable	Depth	ICEA	MATHCAD	Variance
1	P	3/C #8	1.5	38	33.799	11.056%
2	Q	3/C #8	2.0	31	27.924	9.922%
3	T	500MCM	1.5	438	365.473	16.559%
4	U	500MCM	3.0	272	227.309	16.431%
5	R	4/0	3.0	135	116.425	13.739%
6	S	4/0	2.5	153	132.606	13.329%

From the above it is apparent that the values calculated in all cases are conservative.

THERMAL MODEL

TEST 1

1.5 in/ B03
R=0.84875/1000ft
CaD=1.02"
3/C#8 AWG

TABLE 3-16 (ICEA)
P-54-440, 1986

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 1.5 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coeffic ient

$$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length neglecting tray sides

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \cdot K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 350.021 \cdot K$

APPENDIX P PAGE 2

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc - Ta) + \sigma\cdot As\cdot\varepsilon\cdot(Tc^4 - Ta^4)$$

$$W = 128.148\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w} + 1\right]\cdot Tc - \frac{h\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w} + \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right] - \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc \qquad \Delta Tc = 13.139\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 13.139\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 36.861\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 3.56\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.02 \cdot in$ Cable outer diameter

$R := 0.84875 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 33.799 \cdot amp$ Ampacity at 40C

ICEA TABLE 16 VALUE IS 38 AMPS. RESULTS ARE CONSERVATIVE.

$$V := \left[\left(\frac{I40}{38 \cdot amp} \right) - 1 \right] \cdot -100$$

$V = 11.056$ % VARIATION

THERMAL MODEL

TEST 1

1.5 in/ B03
R=0.84875/1000ft
CaD=1.02"
3/C#8 AWG

TABLE 16 (ICEA)
P-54-440, 1979

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 1.5 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coeffic ient

$$h := (0.201) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length neglecting tray sides

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \,°K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 347.614 \,°K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot\left(Tc^{4}-Ta^{4}\right)$$

$$W = 151.633\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^{4}}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^{4}}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc \qquad \Delta Tc = 15.546\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 15.546\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta \qquad \Delta Ta = 34.454\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta \qquad \Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 4.212\cdot\frac{\frac{watt}{ft}}{in^{2}}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.02 \cdot in$ Cable outer diameter

$R := 0.84875 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 36.766 \cdot amp$ Ampacity at 40C

ICEA TABLE 16 VALUE IS 38 AMPS. RESULTS ARE CONSERVATIVE.

$$V := \left[\left(\frac{I40}{38 \cdot amp} \right) - 1 \right] \cdot -100$$

$V = 3.249$ % VARIATION

THERMAL MODEL

TEST 2

2.0 in/ B03
R=0.84875/1000ft
CaD=1.02"
3/C#8 AWG

TABLE 3-16 (ICEA)
P-54-440, 1986

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 2.0 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides of tray not included.

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \, {}^{\circ}K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 347.217 \, {}^{\circ}K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc - Ta) + \sigma\cdot As\cdot\varepsilon\cdot(Tc^4 - Ta^4)$$

$$W = 116.63\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w} + 1\right]\cdot Tc - \frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w} + \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right] - \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc \qquad \Delta Tc = 15.943\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 15.943\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta \qquad \Delta Ta = 34.057\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta \qquad \Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 2.43\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.02 \cdot in$ Cable outer diameter

$R := 0.84875 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 27.924 \cdot amp$ Ampacity at 40C

ICEA TABLE 16 VALUE IS 31 AMPS. RESULTS ARE CONSERVATIVE.

$$V := \left[\left(\frac{I40}{31 \cdot amp} \right) - 1 \right] \cdot -100$$

$V = 9.922$ % VARIATION

THERMAL MODEL

TEST 2

2.0 in/ B03
R=0.84875/1000ft
CaD=1.02"
3/C#8 AWG

TABLE 16 (ICEA)
P-54-440, 1979

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 2.0 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.201) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides of tray not included.

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \, ^\circ K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation
2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 344.589 \, ^\circ K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 135.847\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc \qquad \Delta Tc = 18.571\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 18.571\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 31.429\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 2.83\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.02 \cdot in$ Cable outer diameter

$R := 0.84875 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 30.137 \cdot amp$ Ampacity at 40C

ICEA TABLE 16 VALUE IS 31 AMPS. RESULTS ARE CONSERVATIVE.

$$V := \left[\left(\frac{I40}{31 \cdot amp} \right) - 1 \right] \cdot -100$$

$V = 2.784$ % VARIATION

THERMAL MODEL

TEST 3
1.5 in
R=0.0313575/1000ft
CaD=2.12
500MCMTPLX

TABLE 3-8
(ICEA,P54-440, 1986)

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 1.5 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coeffic ient

$$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length sides not included

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \,^{\circ}K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation
2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 350.021 \,^{\circ}K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc - Ta) + \sigma\cdot As\cdot\varepsilon\cdot(Tc^4 - Ta^4)$$

$$W = 128.148\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w} + 1\right]\cdot Tc - \frac{h\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w} + \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right] - \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$Tm = 363.16$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$\Delta Tc := Tm - Tc$

$\Delta Tc = 13.139\cdot K$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}$$

$\Delta Tc = 13.139\cdot K$

2.4.2 Air Temperature Drop

$\Delta Ta := Tc - Ta$

$\Delta Ta = 36.861\cdot K$

2.4.2 Total temperature Drop

$\Delta T := \Delta Tc + \Delta Ta$

$\Delta T = 50\cdot K$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 3.56\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 2.12 \cdot in$ Cable outer diameter

$R := 0.0313575 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 365.473 \cdot amp$ Ampacity at 40C

ICEA VALUE AT 40 C IS 438 AMPS. THIS VALUE IS CONSERVATIVE.

$$V := \left(\frac{I40}{438 \cdot amp} - 1\right) \cdot -100$$

$V = 16.559$ % VARIATION

THERMAL MODEL

TEST 3
1.5 in
R=0.0313575/1000ft
CaD=2.12
500MCMTPLX

TABLE 8 (ICEA)
(P-54-440 1979)

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 1.5 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.201) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides not included

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \cdot K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 347.614 \cdot K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 151.633\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 15.546\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}$$

$$\Delta Tc = 15.546\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 34.454\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 4.212\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 2.12 \cdot in$ Cable outer diameter

$R := 0.0313575 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 397.554 \cdot amp$ Ampacity at 40C

ICEA VALUE AT 40 C IS 438 AMPS. THIS VALUE IS CONSERVATIVE.

$$V := \left(\frac{I40}{438 \cdot amp} - 1\right) \cdot -100$$

$V = 9.234$ % VARIATION

THERMAL MODEL

TEST 4
3.0 in
R=0.0313575/1000ft
CaD=2.12
500MCMTPLX

TABLE3- 8 (ICEA)
(P54-440, 1986)

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 3.0 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$$ Overall Convective Heat transfer Coeffic ient

$$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$$

$$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$$\rho := 400 \cdot K \cdot \frac{cm}{watt}$$ effective thermal resistivity of cable mass

$$As := 4 \cdot \frac{ft^2}{ft}$$ Surface area of cable mass per unit length sides not included

$$Tc := \frac{Tm + Ta}{2}$$

$Tc = 338.16 \,°K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 342.83 \,°K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 99.144\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.159$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 20.33\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}$$

$$\Delta Tc = 20.33\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 29.67\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 49.999\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 1.377\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 2.12 \cdot in$ Cable outer diameter

$R := 0.0313575 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 227.309 \cdot amp$ Ampacity at 40C

ICEA VALUE AT 40 C IS 272 AMPS. THIS VALUE IS CONSERVATIVE.

$$V := \left(\frac{I40}{272 \cdot amp} - 1\right) \cdot -100$$

$V = 16.431$ % VARIATION

THERMAL MODEL

TEST 4
3.0 in
R=0.0313575/1000ft
CaD=2.12
500"MCMTPLX

TABLE 8 (ICEA)
P-54-440, 1979

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 3.0 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.201) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides not included

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \,°K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 340.031 \,°K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot\left(Tc^4-Ta^4\right)$$

$$W = 112.797\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$Tm = 363.16$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 23.129\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w}$$

$$\Delta Tc = 23.129\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 26.871\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 1.567\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 2.12 \cdot in$ Cable outer diameter

$R := 0.0313575 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 242.456 \cdot amp$ Ampacity at 40C

ICEA VALUE AT 40 C IS 272 AMPS. THIS VALUE IS CONSERVATIVE.

$$V := \left(\frac{I40}{272 \cdot amp} - 1\right) \cdot -100$$

$V = 10.862$ % VARIATION

TEST 5
3.0 in
R=0.06890625/1000ft
CaD=1.61"
4/0MCM

TABLE 3- 9 ICEA
P-54-440, 1986

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 3.0 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.101) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides not in cluded.

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \text{ °K}$

Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation
2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 342.83 \text{ °K}$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 99.144\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.159$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 20.33\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 20.33\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 29.67\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 49.999\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 1.377\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.61 \cdot in$ Cable outer diameter

$R := 0.06890625 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 116.452 \cdot amp$ Tray Z24FL20 Ampacity at 40C

ICEA TABLE 9 VALUE IS 135 AMPS. THIS VALUE IS CONSERVATIVE.

$$V := \left(\frac{I40}{135 \cdot amp} - 1\right) \cdot -100$$

$V = 13.739$ % VARIANCE

TEST 5
3.0 in
R=0.06890625/1000ft
CaD=1.61"
4/0MCM

TABLE 9 ICEA
P-54-440, 1979

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 3.0 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature
$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.201) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides not in cluded.

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \,^{\circ}K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermai Calculation
2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 340.031 \,^{\circ}K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc - Ta) + \sigma\cdot As\cdot\varepsilon\cdot(Tc^4 - Ta^4)$$

$$W = 112.797\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc - \frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w} + \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right] - \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 23.129\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 23.129\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 26.871\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 1.567\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.61 \cdot in$ Cable outer diameter

$R := 0.06890625 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 124.212 \cdot amp$ Tray Z24FL20 Ampacity at 40C

ICEA TABLE 9 VALUE IS 135 AMPS. THIS VALUE IS CONSERVATIVE.

$$V := \left(\frac{I40}{135 \cdot amp} - 1\right) \cdot -100$$

$V = 7.991$ % VARIANCE

TEST 6
2.5 in
R=0.0658875/1000ft
CaD=1.61"
4/0MCM

1.0 Tray Thermal Data

$w := 24\cdot in$ Width in Tray

$d := 2.5\cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40)\cdot K$ Ampient Temperature

TABLE 3- 9 ICEA
P-54-440, 1986

$Tc := unknown\cdot K$ Surface Temperature

$Tm := (273.16 + 90)\cdot K$ Max Cable Temperature

$h := 0.101\cdot\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot\frac{watt}{ft^2\cdot K}$ Overall Convective Heat transfer Coefficient

$h := (0.201)\cdot\frac{watt}{ft^2\cdot K}$

$\sigma := 0.530\cdot 10^{-8}\cdot\frac{watt}{ft^2\cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400\cdot K\cdot\frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4\cdot\frac{ft^2}{ft}$ Surface area of cable mass per unit length sides not included

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16\ {}^\circ K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d}{8\cdot w}\cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot h\cdot(As\cdot\rho\cdot d)}{8\cdot w} + 1\right]\cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}}\cdot h\cdot(As\cdot\rho\cdot d)}{8\cdot w}\right]\cdot Ta - \frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d}{8\cdot w}\cdot Ta^4, Tc\right]$$

$Tc = 342.109\ {}^\circ K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 123.192\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises
2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 21.051\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 21.051\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 28.949\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w}$$

$$Q = 2.053\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.61 \cdot in$ Cable outer diameter

$R := 0.06890625 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 142.199 \cdot amp$ Tray Z24FL20 Ampacity at 40C

ICEA TABLE 9 VALUE IS 153 AMPS. THIS VALUE IS CONSERVATIVE.

$$V := \left(\frac{I40}{153 \cdot amp} - 1\right) \cdot -100$$

$V = 7.059$ % VARIATION

TEST 6
2.5 in
R=0.06890625/1000ft
CaD=1.61"
4/0MCM

TABLE 9 ICEA
P 54-440 1986

1.0 Tray Thermal Data

$w := 24 \cdot in$ Width in Tray

$d := 2.5 \cdot in$ Depth of cables in Tray

$Ta := (273.16 + 40) \cdot K$ Ampient Temperature

$Tc := unknown \cdot K$ Surface Temperature

$Tm := (273.16 + 90) \cdot K$ Max Cable Temperature

$h := 0.101 \cdot \left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot \frac{watt}{ft^2 \cdot K}$ Overall Convective Heat transfer Coeffic ient

$h := (0.201) \cdot \frac{watt}{ft^2 \cdot K}$

$\sigma := 0.530 \cdot 10^{-8} \cdot \frac{watt}{ft^2 \cdot K^4}$ Stephan-Boltzman Constant

$\varepsilon := 0.8$ Effective thermal emmisivity of cable mass and tray surface.

$\rho := 400 \cdot K \cdot \frac{cm}{watt}$ effective thermal resistivity of cable mass

$As := 4 \cdot \frac{ft^2}{ft}$ Surface area of cable mass per unit length sides not included

$Tc := \frac{Tm + Ta}{2}$

$Tc = 338.16 \,^{\circ}K$ Initial assumed value for Surface Temp. (Tc)

2.0 Thermal Calculation

2.1 calculated Value for Surface Temperature(Tc)

$$Tc := root\left[\frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Tc^4 + \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w} + 1\right] \cdot Tc - Tm - \left[\frac{\left(\frac{Tc}{K} - \frac{Ta}{K}\right)^{\frac{1}{4}} \cdot h \cdot (As \cdot \rho \cdot d)}{8 \cdot w}\right] \cdot Ta - \frac{\sigma \cdot As \cdot \varepsilon \cdot \rho \cdot d}{8 \cdot w} \cdot Ta^4, Tc\right]$$

$Tc = 342.109 \,^{\circ}K$

2.2 Calculated value of total heat(W) per unit length generated in cable tray

$$W := h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot(Tc-Ta)+\sigma\cdot As\cdot\varepsilon\cdot(Tc^4-Ta^4)$$

$$W = 123.192\cdot\frac{watt}{ft}$$

2.3 Recalculated Max Cable Temperature(Tm)

$$Tm := \left[\left[\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot(As\cdot\rho\cdot d)}{8\cdot w}+1\right]\cdot Tc-\frac{h\cdot\left(\frac{Tc}{K}-\frac{Ta}{K}\right)^{\frac{1}{4}}\cdot As\cdot\rho\cdot d\cdot Ta}{8\cdot w}+\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Tc^4}{8\cdot w}\right]-\frac{\sigma\cdot As\cdot\varepsilon\cdot\rho\cdot d\cdot Ta^4}{8\cdot w}$$

$$Tm = 363.16$$

2.4 Temperature Rises

2.4.1 Cab le Mass temperature Rise

$$\Delta Tc := Tm - Tc$$

$$\Delta Tc = 21.051\cdot K$$

$$\Delta Tc := \frac{W\cdot\rho\cdot d}{8\cdot w} \qquad \Delta Tc = 21.051\cdot K$$

2.4.2 Air Temperature Drop

$$\Delta Ta := Tc - Ta$$

$$\Delta Ta = 28.949\cdot K$$

2.4.2 Total temperature Drop

$$\Delta T := \Delta Tc + \Delta Ta$$

$$\Delta T = 50\cdot K$$

2.5 Heat generated per unit area

$$Q := \frac{W}{d\cdot w} \qquad Q = 2.053\cdot\frac{\frac{watt}{ft}}{in^2}$$

Ampacity Calculation

$n := 3$ number of conductors

$CaD := 1.61 \cdot in$ Cable outer diameter

$R := 0.06890625 \cdot \frac{ohm}{1000 \cdot ft}$ Resistance taken from Okonite book

$$I40 := \frac{CaD}{2} \cdot \sqrt{\frac{Q \cdot \pi}{n \cdot R}}$$

$I40 = 142.199 \cdot amp$ Tray Z24FL20 Ampacity at 40C

ICEA TABLE 9 VALUE IS 153 AMPS. THIS VALUE IS CONSERVATIVE.

$$V := \left(\frac{I40}{153 \cdot amp} - 1\right) \cdot -100$$

$V = 7.059$ % VARIATION

CALC. N 96-	ENG-01528E2	R00		PAGE C1 OF C5	
CONTROL CABLE LOADING					
TRAY Z14FM10					
Z1B5145/C	LIST	LOAD	1B5158/B	LIST	LOAD
X1	33X+BGR+		X1	42O+42C+RG	0.6
	42O+42C	1.17	11	42	0.5
21	42C	0.5	12	42	0.5
22	42O	0.5	3R	R	0.045
3R	R	0.045	3G	G	0.045
3G	G	0.045			
51	B,33X	0.0775			
32009 6 R11			32009 7 R9		
Z1CH192/B	LIST	LOAD	Z1HV8247/C	LIST	LOAD
P1	RG	0.09	2	HY8247	0.1392
1	FY192	0.776	N1	HY8247	0.1392
N1	FY192	0.776			
3R	R	0.045			
3G	G	0.045			
32009 53 R6			32021 12 R5		
Z1HV8247/D	LIST	LOAD	Z2HV8249/C	LIST	LOAD
12	HY8247	0.1392	2	HY8249	0.1392
22	HY8247	0.1392	N1	HY8249	0.1392
3R	R	0.045			
3G	G	0.045			
N1	RGB	0.135			
3B	B	0.045			
32021 12 R5			32021 14 R5		
Z1HV8249/D	LIST	LOAD	Z1MCV02/B	LIST	LOAD
12	HY8249	0.1392	1	42X +R	0.112
22	HY8249	0.1392	11	42X +R	0.112
3R	R	0.045			
3G	G	0.045			
N1	RGB	0.135			
3B	B	0.045			
32021 14 R5			32009 44 R4		

ATTACHMENT C.1

CALC. NO. 96-	ENG-01528E2	R00		PAGE C2 OF C5	
CONTROL CABLE LOADING					
Z1CH196/B	LIST	LOAD			
P1	RGB+74	0.1535			
1	FY196	0.0776			
N1	RGB+74+	0.2311			
	FY196	0.0776			
3R	R	0.045			
3G	G	0.045			
3B	B	0.045			
32009 54 R6					

CALC. NO. 96-	ENG-01528E2	R00		PAGE C3 OF C5	
CONTROL CABLE LOADING					
Z25XA10					
Z2CH517/E	LIST	LOAD	Z2CH517F	LIST	LOAD
HY517	11	0.0776	HY517	11	0.0776
R	33R	0.045	R	33R	0.045
G	33G	0.045	G	33G	0.045
RTN	N11	0.1676	RTN	N11	0.1676
32009 35 R4.			32009 35 R4.		
Z2CH519/E	LIST	LOAD	Z2CH519/F	LIST	LOAD
HY519	11	0.0776	HY519	11	0.0776
R	33R	0.045	RTN	N1	0.1676
G	33G	0.045	R	3R	0.045
RTN	N11	0.1676	G	3G	0.045
32009 37 R5			32009 37 R5		
Z2HV2525/F	LIST	LOAD	Z2HV2525/G	LIST	LOAD
RTN	P1	0.2126	HY2525	41	0.0776
HY2525	21	0.0776	HY2525	51	0.0776
HY2525	11	0.0776	RTN	P11	0.2126
HY2525	1	0.0776	G	33G	0.045
HY2525	N1	0.0776	R	33R	0.045
R	3R	0.045	B	33B	0.045
G	3G	0.045			
B	3B	0.045			
32009 39 R6			32009 39 R6		
Z2HV2525/H	LIST	LOAD	Z2NF09/F	LIST	LOAD
HY2525	61	0.0776	H21 ARM	11	1.57
HY2525	N11	0.0776	H21 FLD	12	0.807
32009 39 R6			ARM H21	13	1.57
			FLD H21	N11	0.852
			32020 42 R10		
Z2NF09/G	LIST	LOAD	Z2HV5279/P	LIST	LOAD
H21FLD	1	1.57	HY5279	21	0.281
H21FLD	2	0.807	HY5279,74-1,B	N	0.3445
H21 ARM	3	1.57			
H21 FLD,W	N1	0.852			
32020 42 R10			32012 22 R10		

ATTACHMENT C.2

CALC. NO. 96-	ENG-01528E2	R00		PAGE C4 OF C5	
CONTROL CABLE LOADING					
Z2HV5279/R	LIST	LOAD	Z2HV5279S	LIST	LOAD
74-1,B,G,R,HY5279	P	0.4343	74-1,B	N11	0.281
R	33R	0.045	74-1,B	N21	0.0635
G	33G	0.045	HY5279	51	0.281
			74-1	P	0.0185
			74-1,B	31	0.0635
			74-1,B	41	0.0635
			RTN	P11	0.3335
			3LT	3R	0.135
			3LT	3G	0.135
32012 22 R10			32012 22 R10		

CALC. NO. 96-	ENG-01528E2	R00		PAGE C5 OF	C5
ATTACHMENT 8					
CONTROL CABLE LOADING					
TRAY Z24FL20					
Z2B6105/G	LIST	LOAD	Z2B6105/K	LIST	LOAD
X31	42X+42X+42X		11	42X-6	0.0667
	42	2.2831	12	42X-6+42X-7	0.1334
4	42	2.083	13	42X-8	0.0667
191	NONE		1	42X-6	0.0667
U	42X+42X+42X	0.2001	2	42X-7	0.0667
			3	42X-8	0.0667
32009 42A R1			32009 42A R1		
Z2HV8133/C	LIST	LOAD	Z2HV8133/D	LIST	LOAD
2	HY8133	0.1392	12	HY8133	0.1392
N1	HY8133	0.1392	22	HY8133	0.1392
			3R	R	0.045
			3G	G	0.045
			N1	HY8133+RGB	0.2742
			3B	B	0.045
32021 13 R5			32021 13 R5		
Z2HV8248/C	LIST	LOAD	Z2HV8248/D	LIST	LOAD
2	HY8248	0.1392	12	HY8248	0.1392
N1	HY8248	0.1392	22	HY8248	0.1392
			3R	R	0.045
			3G	G	0.045
			N1	RGB,74-1	0.154
			3B	B	0.045
32021 15 R5			32021 15 R5		
2B41A16/F	LIST	LOAD	Z2MCV04/J	LIST	LOAD
21	FX+F+CR+63	0.304	1	42X	0.0667
31	FX+F+CR	0.174	11	42X	0.0667
41	63(HGA)	0.0325			
X1	GR	0.09			
3R	R	0.045			
3G	G	0.045			
32025 33 R6					
			32009 46 R5		

ATTACHMENT D

It is seen that the ampacity of a cable is directly proportional to its overall diameter (D). Thus, increasing the insulation thickness on a given conductor increases its diameter and thus increases its ampacity when installed in a cable tray, for a given percent tray fill and the same temperature limits.

Here it must be pointed out that the ampacities of the bulky rubber insulated cables in trays are not at all the same as ampacities for the small crosslinked polyethylene insulated cables with very thin insulations. For example, a number 12 AWG rubber insulated cable with a diameter of .24 inches may have an allowable heat intensity (from Figure 4) to give an ampacity of 24 amps; the same conductor insulated with crosslinked polyethylene would have a diameter of only about .16 inches and therefore, from equation (9), an ampacity of 16 amps. It thus becomes necessary to distinguish between thin wall and thick wall insulated cables; throughout this paper, reference to polyethylene cable implies thin wall insulation and rubber implies thick wall insulation.

The above difference in ampacity comes from the fact that for a given percent tray fill, more crosslinked polyethylene (thin wall) insulated *conductors* can be packed into the tray than rubber (thick wall) insulated *conductors*. Since the total amount of heat which may be generated in the tray must remain constant, the heat per conductor must be less for the small diameter cables than for the large ones.

With the allowable heat intensities from Figure 4 and using them in equation (9), the ampacities of several cable sizes and percent tray fills can be obtained. The results are shown in Figure 5, which is a graphical ampacity table for typical single conductor rubber insulated copper conductors installed in 3-inch by 24-inch cable trays. For comparison, the presently published ampacities for the same type cable are also plotted; they are for the assumed case of maximum derating which is for 43 or more conductors in the tray, and thus are 50% of the ampacity of a three conductor cable in air.

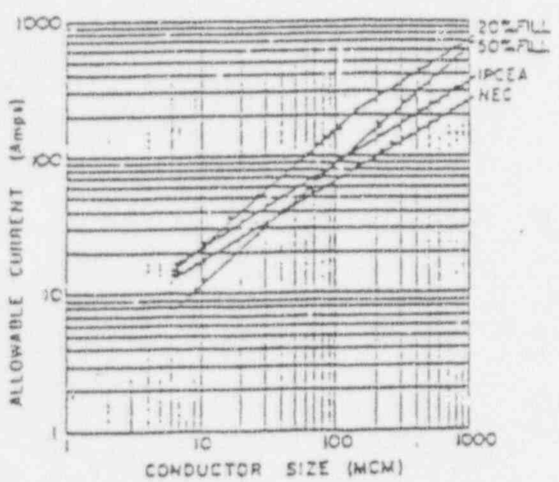

Fig. 5. Ampacities of typical rubber insulated copper cables in 3" x 24" trays as determined by this study and compared with IPCEA and NEC values for trays containing more than 43 conductors, 90° C operating temperature in a 40° C ambient.

This graphical comparison, along with test results presented later, makes it quite clear that the present ampacities for trays with high percent fills are too high for small conductor sizes, while being too low for the large conductor sizes. Note that for the thin wall XLP insulated cables, the ampacities are even lower than for the thick wall rubber cables, and the safety of the present ampacities would be even more questionable.

This point is made to supplement one of the favorable properties of the small diameter XLP cables. Specifically, more XLP cables can be installed in a cable tray than other kinds of insulated cables, and thus there is economy in using fewer cable trays. Along with being able to install more cables in a tray it is essential that the thin wall cables carry less current than the heavier insulated cables. If this is not done, there will be overheating of the XLP cables and the accelerated loss of cable life resulting in premature cable failures.

The best observation to be made from the theory is related to heat generation in cable trays being in proportion to the cross-sectional area of each cable. A somewhat evident justification for this requirement can be seen from the following reasoning.

The most elementary equation describing convection heat flow is

$$q = hA_s \Delta T$$

where h is the convection heat transfer coefficient, A_s is the surface area convecting heat to the air, and ΔT is temperature difference between the cable surface and the ambient air. The basic equation for conduction heat transfer is

$$q = kA_c \frac{\Delta T}{\Delta x}$$

where k is the thermal conductivity of the heat conducting medium, A_c is the cross-sectional area through which heat flows, and ΔT is the temperature drop over a distance Δx in the direction of heat flow. Note that convection heat flow is proportional to surface area while conduction heat flow is proportional to cross-sectional area. Since conduction is the governing method of heat flow within a tightly packed cable mass, we should be concerned with cross-sectional areas of cables rather than peripheral or surface areas.

TEST PROCEDURE

Five different cable tray arrangements have been thoroughly tested in order to determine the heat transfer properties of each arrangement. Two of the tests involved randomly arranged cables of various sizes in 24-inch wide trays and three tests were performed on 12-inch wide trays with only one cable size in the tray. Table I summarizes the various tests which were performed and Figure 6 shows the overall test setup.

TABLE I - Summary of Tests Conducted to Support Analytical Results

TRAY SIZE	PERCENT FILL	CABLE SIZES TESTED	INSULATION TYPE	
3"x24"	20	#12 to 4/0	Rubber	thick wall
3"x24"	55	#12 to 4/0	Rubber	thick wall
3"x12"	40	3/C-#12	Rubber	thick wall
3"x12"	40	3/C-#12	XLP	thin wall
3"x12"	50	1/C-500	XLP	thin wall

Some details of the testing which were common to all tests can be seen from Figure 6. 600 volt rated copper conductor cables were laid in a 24-foot long cable tray and temperatures were measured at three different tray cross sections; one was in the mid-length of the tray and two others at the quarter lengths. In many cases cables

ATTACHMENT D

The system temperature drop is the sum of the drop through the packed cable mass (ΔT_c) and the drop through the air (ΔT_a) around the cable tray.

Therefore

$$\Delta T = \Delta T_c + \Delta T_a \quad (4)$$

The drop through the cable mass (ΔT_c) can be obtained from the equation given by Holman[8] for a rectangular slab with uniform internal heat generation.

$$\Delta T_c = \frac{W \rho d}{8w} \quad (5)$$

where ρ = effective thermal resistivity of cable mass
d = depth of cable mass
w = width of cable mass and tray
W = the total heat generated in the tray per unit length

Equation (5) is specifically for one dimensional heat flow out the top and bottom of the tray and it ignores any heat flow out the sides of the tray. This is a realistic simplification which is accurate for 6-inch and wider cable trays.

The temperature drop through the air (ΔT_a) is obtained from a heat balance between convection and radiation heat flow. Using basic equations from McAdams[9] we find

$$W = hA_s\Delta T_a + \sigma A_s \epsilon [T_c^4 - T_a^4] \quad (6)$$

where $hA_s\Delta T_a$ = the heat loss from the tray due to convection
$\sigma A_s \epsilon [T_c^4 - T_a^4]$ = the heat loss from the tray due to radiation
and h = overall convection heat transfer coefficient for tray
A_s = surface area of cable mass per unit tray length
σ = Stefan-Boltzmann constant
ϵ = effective thermal emissivity of cable mass and tray surface
T_c = average cable mass surface temperature

The three equations (4), (5), and (6) have three unknowns and they can be solved to get the total allowable heat which can be generated in a cable tray (W). Since equation (6) is quite non-linear, the solution to the three equations must be obtained by iteration; thus, for general application the solution for W is done most easily on a computer.

Having the total heat generated in the cable tray, the heat generation per unit area is simply

$$Q = \frac{W}{(d \times w)} \quad (7)$$

The ampacity of each cable in the tray is finally determined with equations (1) & (2).

THEORETICAL RESULTS

The solution to equations (4), (5), and (6) for W and several degrees of cable tray fill will result in curves similar to those shown in Figure 4. It is seen that as the cable tray percent fill increases, the allowable heat intensity decreases due to greater temperature drop in the tightly packed cable mass. Figure 4 was made for an effective thermal resistivity of the cable mass being 400°C cm/watt, and the test results to be presented later show this value to be valid for either rubber or polyethylene insulated cables which are tightly packed.

At this point we must define cable tray percent fill as the sum of the cross-sectional areas of all cables in the tray (including conductor, insulation, and jacket) divided by the total available cross-sectional area in the cable tray (width times height). It can be seen that a cable tray which is packed as tight as possible and level across the top is filled to about 75%, because about 25% of the tray area is void area between the circular cables. From the above percent tray fill definition it is apparent that a 6-inch deep tray with 20% fill has the same depth of packed cable as a 3-inch deep tray with 40% fill.

In applying equations (1) and (2) to get the ampacity of specific conductor sizes in a given cable tray, an interesting observation can be made. The cable ampacity (I) is given by

$$I = \sqrt{\frac{QA}{nR}} \quad (8)$$

and substituting for the circular cross-sectional area of each cable (A) we get

$$I = \frac{D}{2}\sqrt{\frac{Q\pi}{nR}} \quad (9)$$

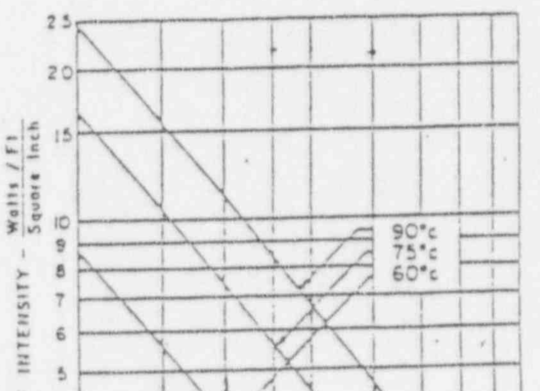

Fig. 4. Allowable heat intensity (Q) to maintain rubber-like or polyethylene cables at the specified temperature in 3-inches deep by 24-inches wide trays operating in a 40°C ambient

ATTACHMENT D

by knowing the cross-sectional area of each composite cable. Thus the problem now remains to establish the allowable heat intensity for various cable tray configurations.

The reasoning presented thus far is significantly different from that used for cable tray ratings we now use. To show this, consider a large cable tray randomly filled with, say 300 tightly packed 600 volt cables of assorted sizes. According to the ratings published so far, every cable in this tray must be derated to 50% of the ampacity for a 3-conductor cable in air.[4,5,6,7] Figure 2 shows that seven single conductor #12 cables can occupy about the same area in the tray as one 4/0 cable. Comparing the heat which is generated within the equal areas of cables it can be seen that three to four times more heat is produced in the bundle of seven #12 cables as in a single #4/0 cable, even though the two configurations occupy the same area in the filled tray. This effect is exactly what we want to eliminate in a cable tray installation because it is possible to get bundles of small cables which produce locally intense heat sources and result in hot spots within the cable tray cross-section.

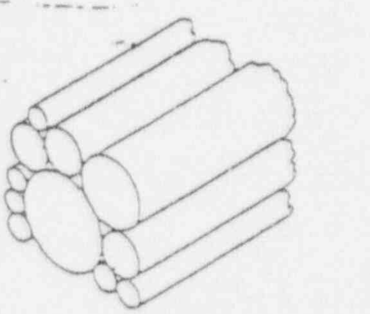

Fig. 1. Cross-section slice from a randomly arranged, closely packed cable tray.

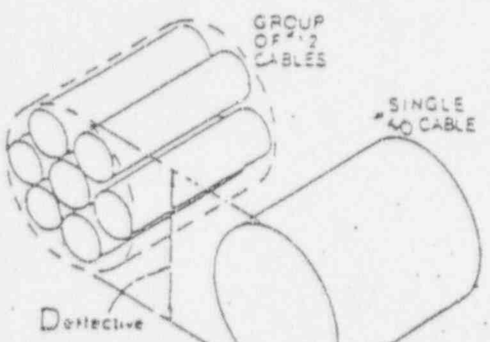

Fig. 2. Physical size comparison of typical rubber insulated cables.

This comparison can be made over and over with the present ampacities for cables in trays. The result is that small conductor size cables are allowed to "work" harder than the large size cables when they are all placed in a common random tray. Actually, all cables should be worked uniformly by coming to the same operating temperature in the tray.

ANALYTICAL MODEL

Whenever cable ampacities can be established with calculations, instead of an empirical approach, a better understanding of the overall heat transfer mechanism is possible. A simple analytical solution to the heat transfer from the general, hypothetical cable tray in Figure 3 has been made, and some rather subtle findings from the analysis will be pointed out.

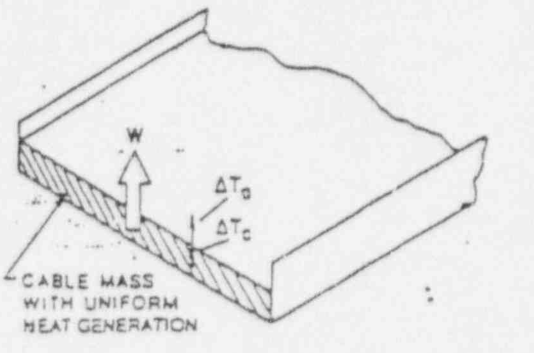

Fig. 3. Simplified analytical model for heat transfer from a tightly packed cable tray containing all power cable.

Before proceeding with the analysis, two additional conditions must be specified. The first condition is cables in any tray must be installed at a constant, or uniform, depth. This is to prevent cables from being heaped on one side of a tray with a resulting vacant space on the other side. The second condition is to assume, at first, that all the cables in the tray are power cables which will uniformly generate heat throughout the tray. These conditions allow the random mixture of cable to be treated as a homogeneous rectangular mass with uniform heat generation.

The task now is to simply find the allowable heat intensity (Q) for trays containing variable amounts of cable. Once we find the heat intensity, the heat which can be generated by each individual conductor (q) can be calculated from

$$q = \frac{QA}{n} \tag{1}$$

where n = number of conductors in cable

A = cross-sectional area of the n-conductor cable.

Q = allowable heat per unit area generated in the tray

and, of course,

$$q = I^2R \tag{2}$$

where

I = maximum allowable current for a conductor

R = a.c. resistance of conductor at the maximum operating temperature of the insulation material in the cable tray.

Heat generated in any tightly packed cable tray must pass through two media: 1) the cable mass, and 2) the air immediately around the tray. Since heat flows through the media there is a resulting temperature drop in each, as shown in Figure 3, ΔT_c through the cables and ΔT_a through the air.

To determine the total amount of heat (W) which can be dissipated by a cable tray in an ambient temperature (T_a), and maintain its highest temperature at or below the operating temperature (T_m) of the cable insulation in the tray, we must limit system temperature drop (ΔT) to

$$\Delta T = T_m - T_a \tag{3}$$

ATTACHMENT D

AMPACITIES FOR CABLES IN RANDOMLY FILLED TRAYS

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ABSTRACT

The allowable current which may be carried by a given conductor size cable has been thoroughly investigated in almost every conceivable type of cable installation. One area which has not had much attention up to now is the allowable current which can be carried by cables in cable trays, or troughs. This paper presents a completely general method for calculating the ampacities of cables in cable trays; it has been derived from elementary heat transfer theory and amply verified with many full-scale tests. The method shows that currently published ampacities for small cables in highly filled trays must be reduced, but the large cable ampacities can be safely increased.

INTRODUCTION

In the studies which have been made on the current carrying ability of electric power cables, the most simple case of one cable operating in air has been expanded to multiple cables in a conduit,[1] multiple cables or conduits in stacked banks,[2] and several cables pulled into steel raceways.[3] The results of these studies are incorporated to various extents in both the AIEE-IPCEA Power Cable Ampacities and the National Electric Code.

The ampacities, or derating factors, which have been determined so far are for cables which are in some form of an orderly arrangement; a further simplification which has been easily justified in the past is all the conductors considered were the same size. Unfortunately, this simplifying treatment cannot be justified when considering ampacities of randomly arranged cables in trays.

A typical cable tray installation which is found in the electric power generation and distribution industry can be visualized as a 3-inch deep 24-inch wide metal trough containing anywhere from 20 to 400 randomly arranged single or multiconductor power and control cables ranging in size from #12 AWG to 750 MCM. This array of cables is usually secured along the cable tray with some ties to prevent the cables already in the tray from shifting if additional cables should be pulled into the tray. During construction as cables are secured in the tray, group by group, they can become packed together tight enough that air is unable to circulate through the mass of cables. With the physical ties and the normal vibration which is present in most plants, even many of the initially loose cable arrays can be expected to settle and thus become more or less restricting to air flow.

Several other variables tend to complicate the determination of ampacities of cables in trays. Some of the more apparent ones are the fullness of a tray, diversity of loading of cables in a tray, determining the location of the hottest spot over the tray cross-section, and the amount of power cable (which generates heat) in proportion to the amount of control cable (which generates negligible heat) in a tray. All the above variables can be, and are accounted for in the method described herein.

Paper 70 TP 557-PWR recommended and approved by the Insulated Conductors Committee of the IEEE Power Group for presentation at the IEEE Summer Power Meeting and EHV Conference, Los Angeles, Calif., July 12-17, 1970. Manuscript submitted September , 1969; made available for printing April 28, 1970.

PROBLEM DEFINITION

The first of many variables to be examined is the extent to which the cables in any tray are packed. It is apparent that cables in a very loose arrangement are essentially immersed in air which can freely flow through the vacant space in a tray. As the space between cables is reduced, by packing cables closer together, free flow of air through the pack is gradually restricted. Taking this to the point where adjacent cables are touching each other on all sides, the continuous free space between cables becomes practically nonexistent and only small air pockets remain between the cables.

Applying this reasoning to heat flow from cables in a cable tray we see that a loose packing is desirable since air can naturally flow around each cable. The heat will then rise out of the pack and be replaced with cooler air from the bottom. When cables become tightly packed, there is no air flow through the bundle, and thus heat cannot be carried out of the bundle by natural air flow. In fact, the only way for heat to flow out of the tight bundle is by heat conduction through the conglomeration of cable conductors, insulation, and air pockets.

Cable ampacities in randomly filled trays must be based on the assumption that cables are tightly packed and that we cannot depend on heat being carried out of the bundle by air flowing through it. Without question, this tightly packed condition does not exist in every cable tray, but it does randomly occur often enough that, for safety, each cable tray must be designed as though it was going to be tightly packed. It is not even necessary that the entire cable tray be tightly packed, since a packed width of only about three inches is sufficient to produce a hot spot in an otherwise cool tray.

With the criterion of tight cable packing established, it is then required to determine how the heat generation is distributed in the tray cross-section. The many cable sizes possible, both single and multiconductor, and each carrying a different current apparently makes it quite difficult to place allowable currents on such a heterogeneous mixture. However, looking at the problem from the standpoint that we do not want any hot spots in the cable tray, the problem can be solved.

Hot spots in a thermal system are produced by locally intense heat sources; thus, in every area of the cable tray we must eliminate such conditions. In other words, the heat generated in every area of a cable tray cross-section must be uniform. This is the key to the entire problem of ampacities for randomly arranged cables in cable trays, and the concept of uniform heat generation cannot be overemphasized.

Consider Figure 1 showing a hypothetical slice of area from a typical, tightly packed cable tray. The heat intensity within each unit area, expressed in watts/ft. per square inch of cross sectional area, must be constant all the way down to the smallest unit area inside the tray, which is the smallest cable in the tray. We therefore place ampacities of cables, such as shown in Figure 1, in proportion to the overall cross-sectional area of the individual cables, including the conductor and insulation.

If we know the allowable heat intensity for a given cable tray, we can immediately place ampacities on every cable in the tray

ATTACHMENT E

B61 MCC Bus Loading

Reference:
Drawing 25203 30011 Sheet 39 Rev. 16 (Ref. 3.1.39)
Drawing 25203 30011 Sheet 40 Rev. 21 (Ref. 3.1.38)
Drawing 25203 30011 Sheet 41 Rev. 18 (Ref. 3.1.15)
EWR M296024 (Ref. 3.1.45)
Only the continuous loads specified on these drawings are considered. MOV loads are not continuous and do not contribute to heat loading of cable in tray. (Assumption 4.3) (Note the feeder cable load is determined in accordance with Assumption 4.2)

BREAKER	RATING	AMPS	MULT.	LOAD
AF4	100HP	125.18	1.25	156.47
BF1	.25HP	.31	1.00	.31
CF1	25HP	31.29	1.00	31.29
HF1	45KVA	17.90*	1.0	17.90*
HF3	0.75HP	0.94	1.00	0.94
BR3	6.75KW	0	1.00	0
BR4	6.75KW	0	1.00	0
CR3	15KVA	18.04	1.00	18.04
CR4	15KVA	18.04	1.00	18.04
CR5	15KVA	18.04	1.00	18.04
DR2	5HP	6.26	1.00	6.26
DR4	15KVA	3.15*	1.00	3.15*
ER2	4.5KW	6.37	1.00	6.37
ER3	0.75HP	0.94	1.00	0.94
FR1	1.93KW	2.73	1.00	2.73
GR1	5.8KW	8.21	1.00	8.21
GR4	15HP	18.78	1.00	18.78
HR4	40HP	50.07	1.00	50.07
ER4B	30KVA	36.08	1.00	36.08
ER5	3HP	3.76	1.00	3.76
TOTAL				**397.38**

* See following page for details.

$$FLA = \frac{HP \times 746}{\sqrt{3} \times E \times EFF \times PF}$$ [EFF = 0.88, PF = 0.85]

$$AMPS = \frac{KW \times 1000}{E \times PF \times \sqrt{3}}$$

$$AMPS = \frac{KVA \times 1000}{E \times \sqrt{3}}$$

ATTACHMENT E

Note 1 - per Drawing 25203-30012 Sheet 12 (Ref. 3.1.41) the connected load is 2220 watts.

$$I = \frac{2220}{480 \times \sqrt{3} \times 0.85} = 3.15 \text{ amps} \quad [DR4]$$

Note 2 - The Boric Acid Tank Heaters are no longer required since the concentration of boric acid has been reduced. The load for these heaters is thus 0 amps. [BR3, BR4]

Note 3 - UAC2 per Drawing 25203-30022 Sheet 12 Revision 23 (Ref. 3.1.40) has a connected load of 12648 watts.

$$I = \frac{12648}{480 \times \sqrt{3} \times 0.85} = 17.90 \text{ amps} \quad [HF1]$$

ATTACHMENT F

B62 MCC Bus Loading

Reference:
Drawing 25203 30011 Sheet 42 Rev. 21(Ref. 3.1.55)
Drawing 25203 30011 Sheet 43 Ref. 17 (Ref. 3.1.66)
Only the continuous loads identified on the drawing(s) are considered. MOV loads are not continuous and do not contribute to heat loading of cable in tray. (Assumption 4.3) (Note the feeder cable load is determined in accordance with Assumption 4.2)

BREAKER	RATING	AMPS	MULT.	LOAD
DF4	30KVA	32*	1.00	32*
EF2	UPS	81**	1.00	81**
BR2	3HP	3.76	1.00	3.76
CR2	5HP	6.26	1.00	6.26
CR3	15KVA	18.04	1.00	18.04
CR4	15KVA	18.04	1.00	18.04
CR5	15KVA	18.04	1.00	18.04
DR1	25HP	31.29	1.00	31.29
DR2	7.5HP	9.39	1.00	9.39
DR3	15KVA	18.04	1.00	18.04
FR1	20HP	25.04	1.00	25.04
FR4	59KW	83.49	1.00	83.49
CR1	15HP	18.78	1.00	18.78
ER2B	40HP	50.07	1.25	62.59
FR2	20HP	25.04	1.00	25.04
TOTAL				**450.8**

* = 80% of breaker value used.
**=References 3.1.74 and 3.1.75 identify the battery charger and inverter loads as 31 and 50 amps respecitively.

$$FLA = \frac{HP \times 746}{\sqrt{3} \times E \times EFF \times PF}$$ (EFF = .88, PF = .85)

$$AMPS = \frac{KW \times 1000}{E \times PF \times \sqrt{3}}$$

$$AMPS = \frac{KVA \times 1000}{E \times \sqrt{3}}$$

INDEPENDENT REVIEWER EVALUATION

(Enter "X" or "NA" to indicate applicability to review)

1.	Are the commitments provided in the Safety Analysis Report (SAR) and the Design Inputs documents correctly incorporated into the design documents?	X
2.	Does the proposed design affect or modify a Unit Safety Technical Specification in any way? If yes, will the initiation of a Technical Specification Change Request (TSCR) be required? (Re: NGP 4.02/NARC)	N/A
3.	Will the implementation of the proposed design require the initiation of a Final Safety Analysis Report (FSAR) change? (Re: NGP 4.03/NARC)	N/A
4.	Are assumptions necessary to perform the design activity adequately described and reasonable? Are the assumptions identified for subsequent reverification when the detailed design activities are complete?	X
5.	Does the design meet the requirements of applicable codes, standards, and regulatory requirements?	X
6.	Has applicable construction and operating experience been considered?	X
7.	Have the design interface requirements been satisfied?	X
8.	Was an appropriate design method used?	X
9.	Are the specified parts, equipment and processes suitable for the required application and have all conditions been considered?	X
10.	Are accessibility and other design provisions adequate for performance of needed in-service inspections, maintenance, and repair? Are adequate maintenance features included and requirements satisfied? Is adequate accessibility provided for performance of the expected inservice inspection required during plant life?	N/A
11.	Has the design properly considered radiation exposure to the public and Unit personnel? (ALARA, Reg Guide 8.8, NGP 5.16)	N/A
12.	Have adequate preoperational and subsequent periodic test requirements been appropriately incorporated into the design?	N/A
13.	Are appropriate Quality Assurance and ANS Safety Classification requirements specified such as inspections to be performed, acceptance criteria, specialized training/skills needed, personnel qualifications, material procurement, and material handling requirements?	N/A
14.	Are the applicable codes, standards, and regulatory requirements, including issue and addenda properly identified?	X
15.	Are the inputs correctly stated and incorporated into the design package and the output reasonable compared to inputs?	X

INDEPENDENT REVIEWER EVALUATION

16.	Are the specified materials compatible with each other and with the design environmental conditions to which the material will be exposed? (Nonmetallic materials require an evaluation of their suitability relative to temperature and radiation environments - Normal and Post-Accident.) Are non-metallic components or parts relied upon structurally, where there integrity under varied conditions is not assured by engineering analysis?	N/A
17.	Have adequate maintenance features and requirements been specified?	N/A
18.	Are the acceptance criteria incorporated in the design documents sufficient to allow verification that the design requirements have been satisfactorily accomplished? Are adequate preoperational and subsequent periodic test requirements appropriately specified?	X
19.	Are adequate handling, storage, cleaning, and shipping requirements specified?	N/A
20.	Are adequate identification requirements specified?	X
21.	Are requirements for record preparation, review, approval, retention, etc., adequately specified?	X
22.	Is the design such that potential crud traps are not built into radioactive fluid lines (long-radius elbows, quantity of valves minimized, ball valves used to extent possible)?	N/A
23.	Have new equipment tag numbers been identified?	N/A
24.	Are equipment failure effects on existing critical components addressed?	N/A
25.	Has the affect on seismic structures been addressed?	N/A
26.	Are all welds identified (allow for use of piping being removed)?	N/A
27.	Are installation fire safeguards identified?	N/A
28.	Will the authorized inspector be contacted and a repair package submitted?	N/A
29.	Are necessary spare parts identified?	N/A
30.	Are any barriers (i.e., fire, C02, halon, ventilation, water, flood, tornado, high energy line break, and radiation) being altered or penetrated and are the barrier design basis requirements being met?	N/A
31.	Have human factors requirements been considered (workplace design, accessibility, lighting and noise, human computer interaction, man machine interface, labeling, layout, etc.)?	N/A
32.	Is the design consistent with Station Spill Prevention Control and Countermeasure Plan(SPCC)?	N/A
33.	Would the design change increase the potential for flooding, reduce the capability to isolate or cope with local compartment flooding, or locate essential equipment where it would be susceptible to flooding?	N/A

INDEPENDENT REVIEWER EVALUATION

34.	Have the failure modes and affects with adjacent high energy piping systems been considered for pipe whip, jet impingement, and/or environmental effects (Stress Analysis Engineering should be contacted if a review is required).	N/A
35.	Has consideration been given in the design process for power supply surge withstand capability and minimizing the probability, affect and/or generation of electromagnetic noise interference on the design modification or adjacent systems?	N/A
36.	Has NPRDS component failure history been considered?	N/A
37.	Has the design change properly considered all operational aspects; i.e., has the design change taken challenges to the operator into consideration?	X
38.	Are appropriate measures specified to prevent debris/foreign material from entering Unit systems, and is the potential impact of debris/ foreign material on relevant Unit systems assessed? Has the design considered the non-use of materials which could plug containment sumps (Re: NRC Bulletin 93-02)?	N/A
39.	Have all Quality Software requirements been considered?	X
40.	Have applicable vendor manuals been checked, to ensure designs incorporate appropriate installation guidelines?	N/A
41.	Has the use of low Cobalt material been specified for systems which communicate with the reactor coolant system (e.g., valve seats)?	N/A
42.	Has the Design incorporated ALARA principles to reduce occupational exposure?(Re: NGP 5.27/Engineering Design Standard 37120)	N/A
43.	Is Structural Integrity assured (including Fatigue and Corrosion)?	N/A
44.	Have weep holes for drainage been installed in non-safety related components (lighting panels, termination boxes, and motor connection boxes) which are located in harsh environments? (Re: ISEG Report E91 -006)?	N/A
45.	Have all SBOQA(Station Blackout) requirements been considered?	X
46.	Has Relay Selection (electrical contact rating and life cycles) been analyzed, and documented?	N/A
47.	Have pressure locking and thermal binding of gate valves been considered?	N/A
48.	Have additions/deletions to the containment inventories of Zinc, Aluminum and Steel been recorded and the Containment Inventory Tracking Program updated?	N/A
49.	Are conclusions drawn in the 10 CFR 50.59 Evaluation fully supported by adequate discussion in the text or the 10 CFR 50.59 Evaluation itself?	X

INDEPENDENT REVIEWER EVALUATION

50.	Has the integrated design package considered appropriate supplemental reviews by other engineering disciplines (seismic, electrical, etc.) and affected departments (Operations, Maintenance, etc.)?	X
51.	Are drawings, sketches, calculations, references, etc. included in the design package appropriately?	X
52.	Are calculations included or referenced in the design package that requires revision, reviewed and approved with appropriate changes?	X
53.	Has the design considered the elimination of possible obstructions to ladders (OSHA 1910.27)?	N/A
54.	Has the design ensured that adjacent unit(s) interfaces were addressed?	X

I have completed my Independent Review of this package by utilizing the "Design Review" method. All concerns were addressed satisfactorily

Michael H Champagne — 12-13-96
Preparer(s) Signature(s) — Date