Calculation 19-AI-08

Calculation to include pages 1-12

SARGENT & LUNDY ENGINEERS CHICAGO	Calcs. For DERATING FOR A 3 HOUR TSI TRAY WRAP	Calc. No. 19-AI-8
	[X] Safety–Related / Non–Safety–Related	Rev. 0 Date 6-1-82
		Page 1 of 12

Client ILLINOIS POWER CO.	Prepared by W G Blathe EAD Date 6-1-82
Project CLINTON	Reviewed by James M. Pabich EAD Date 6-8-82
Proj. No. 4536 Equip. No.	Approved by Mark A. Zar EPED Date 8-11-82

I. PAGE REVISION SUMMARY

A. ALL PAGES ARE REVISION 0

File 19.

RESPONSIBLE DIVISION-EPED

REVIEWER'S COMMENTS This calculation has been reviewed by a detailed check of the original.

J. M. Pabich 6-8-82

Form GQ-3.08.1 Rev. 2

SARGENT & LUNDY ENGINEERS CHICAGO	Calcs. For DERATING FOR A 3 HOUR TSI TRAY WRAP	Calc. No. 14-AI-8
	☒ Safety-Related ☐ Non-Safety-Related	Rev. 0 Date 6-1-82
		Page 2 of 12

Client ILLINOIS POWER CO.	Prepared by W G Bloethe	Date 6-1-82
Project CLINTON	Reviewed by J. M. PABICH	Date 6-8-82
Proj. No. 4536 Equip. No.	Approved by	Date

II. INTRODUCTION

A. PURPOSE

THE PURPOSE OF THIS CALCULATION IS TO DETERMINE THE AMOUNT OF DERATING WHEN A 3 HOUR RATED COATING OF TSI, INC. THERMOLAG MASTIC IS APPLIED TO A CABLE TRAY.

B. REFERENCES

1. BAUMEISTER, T. ed. MARK'S STANDARD HANDBOOK FOR MECHANICAL ENGINEERS. NEW YORK: MCGRAW-HILL BOOK CO. 1967

2. LETTER FROM R. FELDMAN OF TSI, INC. TO W G BLOETHE DATED MARCH 29, 1982

3. ICEA STANDARD S-68-516 (NEMA WC 8-1976) "ICEA/NEMA STANDARDS' PUBLICATION ETHYLENE-PROPYLENE-RUBBER-INSULATED WIRE AND CABLE FOR THE TRANSMISSION AND DISTRIBUTION OF ELECTRICAL ENERGY (REV 1980)

4. LASALLE (PROJECT 4266-00) CALCULATION 4266-EAD-13 (CABLE TRAY HEAT INTENSITY) BY W G BLOETHE DATED FEBRUARY 5, 1982 AND APPROVED FEBRUARY 8, 1982

5. HADDAD, S.Z.; BLOETHE, W. G.; STOLT, H.K.; LAMKIN, D.G.; AND SYKORA, G. "TESTS AT BRAIDWOOD STATION ON THE EFFECTS OF FIRE STOPS ON THE AMPACITY RATING OF POWER CABLES" PROCEEDINGS OF THE 44Th AMERICAN POWER CONFERENCE (1982)

Form GQ-3.08.1 Rev. 2

SARGENT & LUNDY ENGINEERS CHICAGO	Calcs. For DERATING FOR A 3HOUR TSI TRAY WRAP	Calc. No 19-AI-8
	[X] Safety-Related / Non-Safety-Related	Rev. 0 Date 6-1-82
		Page 3 of 12

Client ILLINOIS POWER CO.	Prepared by WG Bloethe	Date 6-1-82
Project CLINTON	Reviewed by J. M. PABICH	Date 6-8-82
Proj. No. 4536 Equip. No.	Approved by	Date

6. HOLMAN, J.P. HEAT TRANSFER, NEW YORK: MC GRAW HILL BOOK CO, 1968

7. KAMINSKI, D.A. (ed) HEAT TRANSFER DATA BOOK. SCHENECTADY, N.Y.; GENERAL ELECTRIC CO. 1977

8. BULLER, F.H. AND NEHER, J.H. "THE THERMAL RESISTANCE BETWEEN CABLES AND A SURROUNDING PIPE OR DUCT WALL" AIEE TRANSACTIONS, VOLUME 69, 1950, pp 342-349

C. DATA AND ASSUMPTIONS

1. ASSUME AN AMBIENT TEMPERATURE OF 40°C (564°R)
2. ASSUME THAT THE CABLE TRAY IS 24" WIDE AND 6" HIGH
3. THE MAXIMUM HEAT DENSITY FOR 2" DEPTH OF FILL IS 2.79 $W \cdot ft^{-1}/in^2$ OF CABLE AREA (REF II.B.4)
4. THE AMPACITY OF CABLES WITH CLOSED COVERS MUST BE DERATED BY 15% (REF II.B.5)
5. THE EMISSIVITY OF A GALVANIZED STEEL SURFACE IS 0.23 (REF II.B.1)
6. THE MAXIMUM CONTINUOUS CONDUCTOR TEMPERATURE IS 90°C (654°R)

SARGENT & LUNDY ENGINEERS CHICAGO

Calcs. For DERATING FOR A 3HOUR TSI TRAY WRAP	Calc. No. 19-AI-8
[X] Safety-Related / [ ] Non-Safety-Related	Rev. 0 Date 6-1-82
	Page 4 of 12

Client ILLINOIS POWER CO.	Prepared by WG Bloethe	Date 6-1-82
Project CLINTON	Reviewed by J. M. PABICH	Date 6-8-82
Proj. No. 4536 Equip. No.	Approved by	Date

7. CHARACTERISTICS OF THERMOLAG COATING (REF II.B.2)
   a. THE THERMAL CONDUCTIVITY IS 0.1 $BTU \cdot hr^{-1} \cdot ft^{-1} \cdot {}^{\circ}R^{-1}$
   b. THE EMISSIVITY IS 0.3
   c.
8. THESE CALCULATIONS WILL BE BASED ON A DEPTH OF FILL OF 2"

9. ASSUME A COATING THICKNESS OF 1¼"

Form GO-3.08.1 Rev. 2

SARGENT & LUNDY ENGINEERS CHICAGO	Calcs. For DERATING FOR A 3HOUR TSI TRAY WRAP	Calc. No. 14-AJ-8
	☒ Safety–Related ☐ Non–Safety–Related	Rev. 0 Date 6-1-82
		Page 5 of 12

Client ILLINOIS POWER CO.	Prepared by W G Bloethe	Date 6-1-82
Project CLINTON	Reviewed by J. M. PABICH	Date 6-8-82
Proj. No. 4536 Equip. No.	Approved by	Date

IV. HEAT GENERATED BY CABLES

A. EQUIVALENT CABLE AREA

F = Depth of fill = 2"
W = tray width = 24"

$$A_{eq} = \frac{\pi}{4}(F \times W)$$

$$A_{eq} = \frac{\pi}{4} \times 2 \times 24 = 37.70 \text{ in}^2$$

B. ALLOWABLE HEAT GENERATION FOR OPEN TRAY HD_{max} = maximum heat dens.

$$Q_{open} = A_{eq} \times HD_{max}$$

$$Q_{open} = 37.70 \times 2.79 = 105.18 \text{ W/ft} = 359.13 \text{ BTU} \cdot \text{hr}^{-1} \cdot \text{ft}^{-1}$$

C. ALLOWABLE HEAT GENERATION FOR TRAY WITH TIGHT LID

a. FOR OPEN TRAY

$$Q_{open} = \sum I^2 R$$

b. FOR CLOSED TRAY

$$Q_{close} = \sum \left[(1-.15)I\right]^2 R \Rightarrow$$

[.15 = derating for closed tray (II, C, 4)]

$$\frac{Q_{close}}{Q_{open}} = \frac{(1-.15)^2 \sum I^2 R}{\sum I^2 R}$$

$$Q_{close} = (1-.15)^2 Q_{open}$$

c. $Q_{close} = (1-.15)^2 \times 105.18 = 75.99 \text{ W} \cdot \text{ft}^{-1}$

$$= 259.47 \text{ BTU} \cdot \text{hr}^{-1} \cdot \text{ft}^{-1}$$

SARGENT & LUNDY ENGINEERS CHICAGO

Calcs. For DERATING FOR A 3 HOUR TSI TRAY WRAP

[X] Safety-Related [ ] Non-Safety-Related

Calc. No. 14-AI-8 Rev. 0 Date 6-1-82 Page 6 of 12

Client ILLINOIS POWER CO.
Project CLINTON
Proj. No. 4536 Equip. No.

Prepared by W G Blaethe Date 6-1-82
Reviewed by J. M. PABICH Date 6-8-82
Approved by Date

IV. TEMPERATURE OF THE OUTSIDE OF A CABLE TRAY WITH TIGHT COVERS

A. RADIATION FORMULA (COVERED TRAY)

$$Q_r = \sigma \epsilon A [T_1^4 - T_2^4] \quad \text{(REF II.B.6)}$$

WHERE Q_r IS THE HEAT DISSIPATED BY RADIATION
ϵ IS THE EMISSIVITY ~~= .1713×10^-8 BTU hr^-1 ft^-2 °R^-4~~
A IS THE SURFACE AREA
T_1 IS THE SURFACE TEMPERATURE
T_2 IS THE AMBIENT TEMPERATURE
σ IS THE STEFAN-BOLTZMAN CONSTANT $= .1713 \times 10^{-8}\ BTU \cdot hr^{-1} \cdot ft^{-2} \cdot °R^{-4}$

1. AREA PER FOOT OF TRAY D = tray depth = 6"

$A = 2 (D+W) \times L$

$$A = 1 \times \frac{2}{12}(6+24) = 5\ ft^2 \text{ PER FOOT OF TRAY}$$

2. $Q_R = .1713 \times 10^{-8} \times 0.23 \times 5 [T_1^4 - 564^4]$

$= 1.97 \times 10^{-9} [T_1^4 - 564^4]$

B CONVECTION FORMULAE

1. $Q_c = h A_c (T_1 - T_2)$ (REF II.B.1)

WHERE Q_c IS THE HEAT DISSIPATED BY CONVECTI[ON]
h IS A FILM COEFICIENT
A_c IS THE AREA OF THE PARTICULAR SURFACE INVOLVED
$A_c = L \times 1 ft$ per foot of tray

Form GQ-3.08.1 Rev. 2

SARGENT & LUNDY ENGINEERS CHICAGO	Calcs. For DERATING FOR A 3 HOUR TSI TRAY WRAP	Calc. No. 14AJ-8
	[X] Safety-Related / Non-Safety-Related	Rev. 0 Date 6-1-82
		Page 7 of 12

Client ILLINOIS POWER CO.	Prepared by W G Bloethe	Date 6-1-82
Project CLINTON	Reviewed by J. M. PABICH	Date 6-8-82
Proj. No. 4536 Equip. No.	Approved by	Date

2. TRAY SIDES

a. $h = 0.28 \left[\frac{(T_1 - T_2)}{L}\right]^{1/4}$ (REF II, B.1) $L = D = .5 ft.$

b. $Q_{CS} = 2 \times 0.28 \left[\frac{T_1 - T_2}{0.5}\right]^{1/4} \times (0.5 \times 1)(T_1 - T_2)$

$= 0.33 (T_1 - T_2)^{5/4}$

3. TRAY TOP

a. $h = 0.27 \left[\frac{(T_1 - T_2)}{L}\right]^{1/4}$ (REF II, B.1) $L = W = 2 ft.$

b. $Q_{CT} = 0.27 \left[\frac{T_1 - T_2}{2}\right]^{1/4} \times (2 \times 1)(T_1 - T_2)$

$Q_{CT} = 0.45 (T_1 - T_2)^{5/4}$

4. TRAY BOTTOM

a. $h = 0.12 \left[\frac{T_1 - T_2}{L}\right]^{1/4}$ (REF II, B.1) $L = W = 2 ft.$

b. $Q_{CB} = 0.12 \left[\frac{T_1 - T_2}{2}\right]^{1/4} (2 \times 1)(T_1 - T_2)$

$= 0.20 (T_1 - T_2)^{5/4}$

SARGENT & LUNDY ENGINEERS CHICAGO	Calcs. For DERATING FOR A 3 HOUR TSI TRAY WRAP	Calc. No. 14-AI-8
	[X] Safety-Related / Non-Safety-Related	Rev. 0 Date 6-1-82
		Page 8 of 12

Client ILLINOIS POWER CO.	Prepared by W G Bloethe	Date 6-1-82
Project CLINTON	Reviewed by J. M. PABICH	Date 6-8-82
Proj. No. 4536 Equip. No.	Approved by	Date

5. TOTAL HEAT TRANSFER BY CONVECTION

$$Q_C = Q_{CS} + Q_{CT} + Q_{CB} = 0.33(T_1-T_2)^{5/4} + 0.45(T_1-T_2)^{5/4} + 0.20(T_1-T_2)^{5/4}$$

$$= 0.99\,(T_1-T_2)^{5/4} \qquad \underline{T_2 = 564°R}$$

6. THE TOTAL HEAT TRANSFERRED IS

$$Q_T = Q_R + Q_C$$

7. ALLOWABLE TEMPERATURE OF CLOSED (COVERED) CABLE TRAY;

$BTU \cdot hr^{-1} \cdot ft^{-1}$

T_1 (°R) (Surface temp of tray)	Q_R	Q_C	Q_T	
580	24.04	32.41	56.45	
600	56.41	88.14	144.55	
620	92.19	152.54	244.73	
622	95.97	159.34	255.31	
624	99.78	166.20	265.98	
623	97.87	162.76	260.63	
622.9	97.68	162.42	260.10	
622.8	97.49	162.08	259.56	
622.78	97.45	162.01	259.46	← Maximum Allowable Heat Generat.

NOTE: THE TEMPERATURE OF THE CABLE TRAY ASSEMBLY IS NOT UNIFORM. THE VALUE OF 622.78°R IS AN AVERAGE VALUE WHICH WILL BE USED FOR CALCULATION OF THE THERMAL RESISTANCE BETWEEN THE CABLE MASS AND THE COVER.

Form GQ-3.08.1 Rev. 2

SARGENT & LUNDY ENGINEERS CHICAGO	Calcs. For DERATING FOR A 3 HOUR TSI TRAY WRAP	Calc. No. 19-AI-8
	☒ Safety–Related ☐ Non–Safety–Related	Rev. 0 Date 6-1-82
		Page 9 of 12

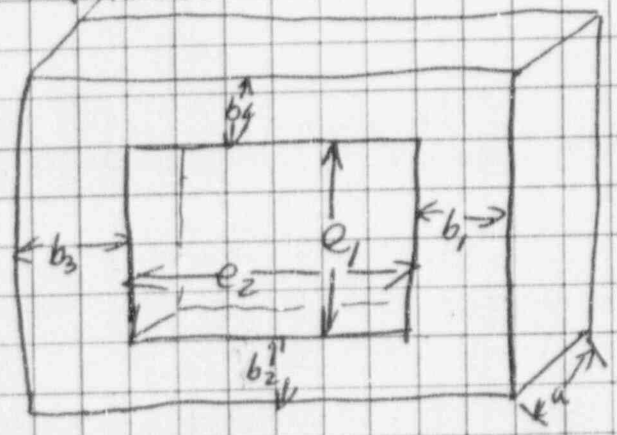
Client ILLINOIS POWER CO.	Prepared by W G Blathe	Date 6-1-82
Project CLINTON	Reviewed by J. M. PARICH	Date 6-8-82
Proj. No. 4536 Equip. No.	Approved by	Date

B. THERMAL RESISTANCE BETWEEN CABLE MASS AND TRAY ASSEMBLY

$$R_1 = \frac{\Delta T}{Q} = \frac{654.7 - 622.78}{259.47} = 0.12\ {}^\circ R \cdot hr \cdot BTU^{-1}$$

IV. THERMAL RESISTANCE OF MASTIC COATING

A. FORMULA



$$R = \frac{\frac{1}{ka}}{\left(\frac{e_1}{b_1}+.54\right)+\left(\frac{e_2}{b_2}+.54\right)+\left(\frac{e_1}{b_3}+.54\right)+\left(\frac{e_2}{b_4}+.54\right)}$$ (REF I.B.7)

WHERE k IS THE MATERIAL CONDUCTIVITY = $.1\ BTU \cdot hr^{-1} \cdot ft^{-1} \cdot {}^\circ R^{-1}$

$a = 1\ ft$

$b_1 = b_2 = b_3 = b_4 = 1.25$ inches

$e_1 = 6$ inches

$e_2 = 24$ inches

SARGENT & LUNDY ENGINEERS CHICAGO	Calcs. For DERATING FOR A 3 HOUR TSI TRAY WRAP	Calc. No. 19-AI-8
	☒ Safety-Related ☐ Non-Safety-Related	Rev. 0 Date 6-1-82
		Page 10 of 12

Client ILLINOIS POWER CO.	Prepared by W G Bloethe	Date 6-1-82
Project CLINTON	Reviewed by J. M. PABICH	Date 6-8-82
Proj. No. 4536 Equip. No.	Approved by	Date

B. RESISTANCE

$$R = \frac{1/.14}{\left(\frac{6}{1.25}+.54\right)+\left(\frac{24}{1.25}+.54\right)+\left(\frac{6}{1.25}+.54\right)+\left(\frac{24}{1.25}+.54\right)}$$

$= 0.20\ °R \cdot hr \cdot BTU^{-1}$

C. TOTAL RESISTANCE BETWEEN CABLE MASS AND COATING SURFACE

$R_{TOT} = R_1 + R$

$R_{TOT} = 0.12 + 0.20 = 0.32\ °R \cdot hr \cdot BTU^{-1}$

VI. HEAT TRANSFER FORMULAE FOR THE WRAPPED SURFACE

A. RADIATION

1. SURFACE AREA

BECAUSE OF THE LOW CONDUCTIVITY OF THE MASTIC, IGNORE THE HEAT DISSIPATED BY THE CORNERS OF THE MASTIC NOT DIRECTLY OVER THE TRAY.

2. THE SURFACE TEMPERATURE OF THE MASTIC WILL NOT BE UNIFORM. THE CALCULATED TEMPERATURE IS ONLY AN AVERAGE VALUE. IT SHOULD BE NOTED THAT THE ASSUMPTION OF AN ISOTHERMAL SURFACE HAS BEEN USED IN EVALUATING HEAT TRANSFER IN DUCTS. (SEE APPENDIX I OF REFERENCE II.B.8)

Form GQ-3.08.1 Rev. 2

SARGENT & LUNDY ENGINEERS CHICAGO	Calcs. For DERATING FOR A 3 HOUR TSI TRAY WRAP	Calc. No. 19-AI-8
	[X] Safety-Related / [ ] Non-Safety-Related	Rev. 0 Date 6-1-82
		Page 11 of 12

Client ILLINOIS POWER CO.	Prepared by W G Bloethe	Date 6-1-82
Project CLINTON	Reviewed by J. M. PABICH	Date 6-8-82
Proj. No. 4536 Equip. No.	Approved by	Date

3. RADIATION FORMULA (MASTIC)

$$Q_r = \sigma \epsilon A [T_1^4 - T_2^4]$$

$$= .1713 \times 10^{-8} \times .3 \times 5 [T_1^4 - 564^4]$$

$$= 2.57 \times 10^{-9} [T_1^4 - 564^4]$$

VII. HEAT GENERATION IN WRAPPED TRAY

A. $\Delta T_{mastic+tray} = Q_T \times R_{tot}$

SURFACE TEMP (°R)	$Q_{R_{mastic}}$ (BTU·hr⁻¹ PER FOOT OF TRAY)	Q_C	Q_T	ΔT MASTIC +TRAY (°R)	CABLE TEMP (°R)
580	31.35	32.41	63.77	20.31	600.31
600	73.58	88.14	161.72	51.51	651.51
602	78.05	94.25	172.30	54.87	656.87
601	75.81	91.19	166.99	53.19	654.19
600.8	75.36	90.57	165.94	52.85	653.65

SO 653.65°R = 90°C = MAXIMUM ALLOWABLE CABLE TEMPERATURE

SO THE CABLES CAN BE LOADED TO 166 BTU·hr⁻¹ per foot of tray

VIII. CABLE DERATING

A. DERIVATION OF AMPACITY FACTOR

1. HEAT GENERATED BY CABLES

$$Q = \Sigma I_n^2 R \quad (= \Sigma I^2 R)$$

2. TAKING THE RATIO OF TWO HEATS

$$\frac{Q' = \Sigma I'^2 R}{Q = \Sigma I^2 R} = \frac{\Sigma I'^2}{\Sigma I^2} = \frac{\Sigma (f_a I)^2 R}{\Sigma I^2 R} = f_a^2 \frac{\Sigma I^2 R}{\Sigma I^2 R}$$

f_a = ampacity factor

3. THEN

$$\sqrt{\frac{Q'}{Q}} = \frac{\Sigma I'}{\Sigma I} = f_a$$

4. AMPACITY FACTOR FOR WRAPPED TRAY

$$f_a = \sqrt{\frac{166}{359.13}} = 0.68$$

$Q' = Q_{T\ \text{WRAPPED TRAY}}$
$Q = Q_{T\ \text{OPEN TRAY}}$

$$f_{a_1} = \sqrt{\frac{Q'}{Q'_1}} = \sqrt{\frac{166}{259.47}} = 0.80$$

BASED ON THE CLOSED TRAY AMPACITY

$Q'_1 = Q_{T\ \text{CLOSED TRAY}}$

IF D_f = DERATING FACTOR

$D_f = 1 - f_a$

D_F for open tray ampacities $= 1 - .68 = 0.32$ (40°C ambient)

D_F for closed tray ampacities $= 1 - .80 = 0.20$ (40°C ambient)

NOTE:
CLOSED TRAY AMPACITIES AT 40°C AMBIENT ARE SHOWN IN CALCULATION 19-G-1

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SARGENT & LUNDY ENGINEERS CHICAGO	Calcs. For CABLE AMPACITIES IN 40°/50°C CABLE TRAYS	Calc. No. 19-G-1
	X Safety–Related / Non–Safety–Related	Rev. Date
		Page of

Client ILLINOIS POWER CO	Prepared by Date
Project CLINTON – UNITS 1 & 2	Reviewed by Date
Proj. No. 4536/4597 Equip. No.	Approved by Date

REV STATUS SH. NO	REV
1	1
2	0

ISSUE SUMMARY

REV NO	SHEETS REVISED	PREPARED BY	DATE	REVIEWED BY	DATE	APPROVED BY	DATE
1	1	N. Sharma	7-16-76	Dean Mizuma	9/21/76	P.A. Lewis	9/23/76

271 92 DFDA

Form GQ-3.08.1 Rev. 1