EN-014 (1797)

NUCLEAR ENGINEERING DEPARTMENT

Calculation Cover Sheet
Cook Nuclear Plant

Electrical Systems/Components

CALCULATION No. PS-CABLE-001

SAFETY RELATED YES X NO ___

SYSTEM ALL

TITLE THERMO-LAG AMPACITY DERATING

RFC/MM/PM/PR/CR/TM No. ___

FILE LOCATION ___

INDIANA MICHIGAN POWER COMPANY

UNIT No. 1 & 2

CALCULATED BY: [signature] DATE 10-10-97

VERIFIED BY: John Kutyo DATE 10/23/97

APPROVED BY: [signature] DATE 10/22/97

CALCULATION DESCRIPTION: Review ampacity derating of those cables located in tray covered with Thermo-lag.

METHOD OF VERIFICATION: ALTERNATE CALCULATION ✓ REVIEW ✓

REVISION

NO.	REASON FOR CHANGE	Calculated By	Date	Verified By	Date	Approved By	Date

9711280217 971124
PDR ADOCK 05000315
P PDR

1.0 INTRODUCTION

This calculation reviews the ampacity derating of all cables in power tray, protected with 1-hour Thermo-lag. The ampacity derating is reviewed from two perspectives, development of correction factors and the comparison of tray loads to test results. The cables and their tray are identified in Attachment 1.

2.0 DERATING FACTORS

The derating approach for analyzing the ampacity of cables in tray wrapped with Thermo-lag is two tiered.

First, cables have been derated for placement in a tray with other cables, in accordance with a maintained spacing correction factor derived from IPCEA P-46-426, Table VII. This factor has been applied to the open air ampacity of the respective cables.

Second, the Texas Utilities (TU) Thermo-lag derating factor of 32% has been conservatively applied to the respective derated cable ampacity to account for the Thermo-lag thermal barrier installed around the subject trays.

This approach derates each cable first to account for its physical placement, and secondly to account for Thermo-lag.

3.0 BASIS

3.1 Design Standard 1-2-EDS-642 directs that all power cables shall be configured in a single layer with maintained spacing when installed in a power tray. All cables in trays wrapped with Thermo-lag have been derated in accordance with IPCEA P-46-426 because of it's treatment of cables with maintained spacing. ICEA P-54-440 was not used because it was developed for fully loaded cables with no space between them.

A correction factor of 0.8 has been derived from IPCEA P-46-426, Table VII to account for configurations of 12 or more horizontal cables in a single layer. This correction factor has been applied to all cables in trays wrapped with one-hour Thermo-lag, except tray 1AI-P4 where an 0.87 correction factor has been used (only three cables present in tray). These derated ampacities are listed in Attachment 1.

In order to predict correction factors for fills greater than those discussed in IPCEA P-46-426 (up to 6 horizontal cables), it is necessary to determine the impact the neighboring cables will have on the cable of concern. The worst condition is when the cable of concern is in the center of the cable group. The correction factors for the cables are expected to be influenced by two factors, the change in the effective ambient temperature caused by the heat generated by the other cables in the tray and the changes in the thermal resistance from the center cable to the ambient due to the presence of the neighboring cables which impact thermal convection and radiation from the cable to the ambient.

As noted in the IPCEA table, the cables directly adjacent to the cable of concern have the highest impact (a 13% reduction for the first two cables directly adjacent to the center cable). As the number of cables increase, the impact on the environment of the cable of concern is reduced due to the physical separation that exists, and therefore, the correction factor is reduced by only 1% for the addition of a fifth or sixth cable in the raceway. It is expected that there will be a point where the addition of cables in the horizontal plane will no longer influence the environment of the cable of concern and will result in no additional cable derating. Hence, the correction factor will reach a limit that it does not fall below, regardless of the number of cables in the horizontal path.

MATHCAD software was used to determine the correction factor of 0.8. First, a mathematical model was developed which represents the correction factors already identified in the IPCEA standard. The model consists of three components. The first is an exponential term to reflect the effect of the increase in the cable thermal resistance due to adjoining cables, the second is also an exponential term that reflects the effect of additional heat generation in the raceway, and the third is a constant to represent the limiting value of the derating multiplier. MATHCAD was then utilized to calibrate this model utilizing the known correction factors in the IPCEA standard and to calculate the correction factors for quantities of cables greater than the maximum value of 6. The result of this mathematical model determined that after 12 cables, the correction factor remained constant at 0.8. Therefore, a conservative derating factor of 0.8 can be used for fills greater than 6 cables. The MATHCAD file and results can be found in Attachment 2.

This model assumes that all cables are carrying their respective rated ampacity. If a cable is carrying little or no current, then there is no significant increase in the ambient temperature. Hence, the effect on the environment of the cable of concern is negligible. The majority of cables at D.C. Cook plant are lightly loaded and therefore the correction factor of 0.8 is conservative.

3.2 The TU derating factor of 32% for cables in trays wrapped with 1-hour Thermo-lag has been applied to cables in trays wrapped with 1-hour Thermo-lag at DC Cook. The application of the TU 32% derating factor is considered appropriate and conservative for application at DC Cook for the following reasons:

- The trays used for the TU testing and the trays used at DC Cook are both ventilated ladder type, with no cover.

- The TU testing was comprised of 126 3/C #6 CU cables energized at 15.9A in 24" x 4" tray. This configuration required the dissipation of 49W (126 x 3 x $15.9A^2$ x 5.14E-04Ω) through 4.67ft of Thermo-lag that surrounds the tray. Therefore the ratio of unit heat generated to unit area of dissipation for the TU testing was 10.5W/ft.

  The bounding ratio of heat generated (25.18W) to area of dissipation (3ft) for DC Cook is 8.4W/ft (using the wattage of tray 1A-P20 as the bounding case). A comparison of the heat generated to area of dissipation ratios shows that applying the TU derating factor is conservative for DC Cook applications.

- The TU testing utilized an additional thermal barrier, SilTemp cloth. This is not used at DC Cook (a source of conservatism when applying the TU derating factor to DC Cook).

- The TU testing utilized 1/2" Thermo-lag panels, as does DC Cook.

4.0 EXCEPTIONS

A review of Attachment 1 indicates that 2560G/1AI-P4 does not have a margin between its connected load and the available ampacity after being derated in accordance with sections 3.1 and 3.2.

Tray 1AI-P4 contains just three cables, two of which have minor motor operated valve loads (<0.5A). Given the short operating time of these valves (< 2 minutes), the cables powering them in effect contribute no heat to the steady state inner-tray environment. Therefore these two cables may be disregarded with respect to the derating of the third cable, 2560G (i.e.- 2560G need not be derated for placement in tray with other cables). This third cable supplies power to a welding receptacle rated for 60A. To justify the loading of this cable the nature of load must be considered. The nature of the load is infrequent and intermittent, therefore the emergency overload rating of the cable should be considered. For XLPE type insulation, the emergency overload rating is 130°C.

This temperature rating of the cable is for those situations in which the load current is higher than normal but is not expected to last more than 100 hours at any given time or more than a total of 500 hours in the life of the cable (Reference 5). Adjusting for a change in heat rise of the cable (90°C to 130°C) in accordance with IPCEA-P-46-426 eq. 5, a free air emergency overload ampacity of 87A is calculated. Applying the 32% TU factor derates it to 59A.

The portable welding equipment commonly used at DC Cook draws less than 50A. Also, it is expected that during the life of the welding receptacle it would be used within the time parameters associated with the emergency overload rating of the cable. Therefore this cable and its loading is considered acceptable.

5.0 COMPARISON OF TEST RESULTS

As an alternate means of review of the loading of Thermo-lag wrapped trays listed in Attachment 1, direct comparisons and correlations between tests and actual configurations have been made in Attachment 3. This is highly relevant to the study of ampacity loading of Thermo-lag wrapped trays.

In 1983, the Canton Test Lab performed Test CL-542 (Attachment 4) to simulate the effects of 1/2" Thermo-lag on conductor temperatures of spaced cables. These tests replicated actual installed raceway configurations, including the number and size of cables, loading and spacing. As an example, CL-542 Tests 1 and 3 were designed to replicate trays 1AZ-P8 and 1A-P20, respectively. Direct comparison or correlation of data provided by these tests and trays under review, provides an excellent means of assurance that the temperature ratings of the spaced cables will not be exceeded at the stated loadings while the parent tray is wrapped in 1/2" Thermo-lag.

Attachment 3, Tables 1 and 2, provide a direct comparison between data from CL-542 test 1 and 3 and the cables contained in trays 1AZ-P8 and 1A-P20. The test currents used in the test were equal to or greater than the actual loading of the respective cables. A review of these tables shows that no cables exceed their temperture rating (90°C) while energized at their design loads, in fact, all conductor temperatures are less than 70°C.

Attachment 3, Tables 3 through 8, provide correlations between data from CL-542 test 3 and other trays which are considered to be enveloped by this test. A review of these tables shows that tray 1A-P20 envelopes all other trays in both number of cables and loading.

REFERENCES

1. IPCEA P-46-426
2. ICEA P-54-440
3. Texas Utilities Test Report
4. DC Cook Electrical Design Standard 1-2-EDS-642
5. EPRI Power Plant Reference Guide - Wire and Cable
6. DC Cook Tray Contents Listing
7. DC Cook Conduit and Cable Drawings

ATTACHMENTS

1. Derating tables
2. MATHCAD files
3. Test results applied to trays
4. CL-542 test report
5. Design Verification

TRAY# 1AI-P1
TRAY SIZE 12"W x6"D
FIRE BARRIER 1 HOUR RATED THERMO-LAG

CABLE NO	CABLE TYPE	CBL OD	FLA	OPEN AIR AMPACITY	80% OPEN AIR AMPACITY	32% TSI DERATING	% MARGIN
8255R	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8174R	3TC#12CU	0.32	4.00	36	28.8	19.58	79.58
8177R	3TC#12CU	0.32	4.00	36	28.8	19.58	79.58
8113R	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8119R	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8300R	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8304R	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8308R	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8311R	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8294R	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8026R	3TC#12CU	0.32	2.10	36	28.8	19.58	89.28
8027R	3TC#12CU	0.32	1.00	36	28.8	19.58	94.89
1623R	3TC#12CU	0.32	2.00	36	28.8	19.58	89.79
1642R	4/C#12CU	0.52	10.00	36	28.8	19.58	48.94
2536R	3TC#8AL	0.60	25.00	52	41.6	28.29	11.62
9086R	3TC#12CU	0.32	1.60	36	28.8	19.58	91.83
9092R	3TC#12CU	0.32	1.60	36	28.8	19.58	91.83
9645R	3TC#12CU	0.32	2.90	36	28.8	19.58	85.19
8755RH	3TC#6AL	0.69	37.00	69	55.2	37.54	1.43
80083R	3TC#12CU	0.32	3.48	36	28.8	19.58	82.23
28765R	3 1/C 4/0CU		SPARE				

Note: 4/C #12CU ampacity is derived from only 3 conductors utilized

TRAY# 1AI-P2
TRAY SIZE 12"W x6"D
FIRE BARRIER 1 HOUR RATED THERMO-LAG

CABLE NO	CABLE TYPE	CBL OD	FLA	OPEN AIR AMPACITY	80% OPEN AIR AMPACITY	32% TSI DERATING	% MARGIN
8116G	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8119G	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8185G	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8194G	3TC#12CU	0.32	3.20	36	28.8	19.58	83.66
8197G	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8250G	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8300G	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8304G	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8308G	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8311G	3TC#12CU	0.32	0.33	36	28.8	19.58	98.31
8270G	3TC#12CU	0.32	0.70	36	28.8	19.58	96.43
2978G	3TC#6AL		SPARE				
2559G	3TC#6AL		SPARE				
8756GH	3TC350MCM AL	1.9	150.80	397	317.6	215.97	30.17
8751GH	3TC#6AL	0.69	15.50	69	55.2	37.54	58.71
8753GH	3TC#2AL	0.93	49.40	127	101.6	69.09	28.50
8755GH	3TC#6AL	0.69	37.00	69	55.2	37.54	1.43
1500G	3TC 2/0 AL	1.27	50.30	206	164.8	112.06	55.11

TRAY# 1AI-P4
TRAY SIZE 12"W x6"D
FIRE BARRIER 1 HOUR RATED THERMO-LAG

CABLE NO	CABLE TYPE	CBL OD	FLA	OPEN AIR AMPACITY	87% OPEN AIR AMPACITY	32% TSI DERATING	% MARGIN
8116G	3TC#12CU	0.32	0.40	36	31.32	21.30	98.12
8119G	3TC#12CU	0.32	0.40	36	31.32	21.30	98.12
2560G	3TC#6AL	0.69	60.00	69	60.03	40.82	-46.99

Welding recepticle sw. rating. Intermittent connected load.

TRAY# 1A-P20
TRAY SIZE 12"W x6"D
FIRE BARRIER 1 HOUR RATED THERMO-LAG

CABLE NO	CABLE TYPE	CBL OD	FLA	OPEN AIR AMPACITY	80% OPEN AIR AMPACITY	32% TSI DERATING	% MARGIN
8113R	3TC#12CU	0.32	0.71	36	28.8	19.58	96.37
8119R	3TC#12CU	0.32	0.71	36	28.8	19.58	96.37
1623R	3TC#12CU	0.32	2.60	36	28.8	19.58	86.72
1642R	4/C#12CU	0.54	6.40	36	28.8	19.58	67.32
8026R	3TC#12CU	0.32	2.70	36	28.8	19.58	86.21
8027R	3TC#12CU	0.32	1.20	36	28.8	19.58	93.87
8294R	3TC#12CU	0.32	0.71	36	28.8	19.58	96.37
2349R	3TC#12CU	0.32	1.90	36	28.8	19.58	90.30
3249R	3TC#6AL	0.69	12.70	69	55.2	37.54	66.17
1509R	3TC#12CU		SPARE				
2353R	4/C#12CU	0.52	16.00	36	28.8	19.58	18.30
2354R	4/C#12CU	0.54	16.00	36	28.8	19.58	18.30
2355R	3TC#12CU	0.32	1.50	36	28.8	19.58	92.34
2356R	3TC#4AL	0.8	36.00	94	75.2	51.14	29.60
8984R	3TC#12CU	0.32	15.60	36	28.8	19.58	20.34
8987R	3TC#12CU	0.32	15.60	36	28.8	19.58	20.34
1656R	3TC#2AL	0.93	60.00	127	101.6	69.09	13.15
9217R	3TC#12CU	0.32	0.71	36	28.8	19.58	96.37
9221R	3TC#12CU	0.32	0.71	36	28.8	19.58	96.37
2348R	3TC#12CU	0.32	6.80	36	28.8	19.58	65.28
2962R	3TC#12CU	0.32	6.80	36	28.8	19.58	65.28
2361R	3TC#6AL	0.69	31.40	69	55.2	37.54	16.35
1440R	3TC#2AL	0.93	60.00	127	101.6	69.09	13.15
8753RH	3TC#4AL	0.8	49.00	94	75.2	51.14	4.18

Note: 4/C #12CU ampacity is derived from only 3 conductors utilized

TRAY# 1AZ-P8
TRAY SIZE 12"W x6"D
FIRE BARRIER 1 HOUR RATED THERMO-LAG

CABLE NO	CABLE TYPE	CBL OD	FLA	OPEN AIR AMPACITY	80% OPEN AIR AMPACITY	32% TSI DERATING	% MARGIN
1470R	3TC#12CU	0.32	3.80	36	28.8	19.58	80.60
1469R	3TC#12CU	0.32	16.00	36	28.8	19.58	18.30
8067R	3TC#12CU	0.32	1.20	36	28.8	19.58	93.87
8024R	3TC#12CU	0.32	1.10	36	28.8	19.58	94.38
8187R	3TC#12CU	0.32	8.48	36	28.8	19.58	56.70
8026R	3TC#12CU	0.32	2.70	36	28.8	19.58	86.21
8027R	3TC#12CU	0.32	1.20	36	28.8	19.58	93.87
2349R	3TC#12CU	0.32	1.90	36	28.8	19.58	90.30
1476R	3TC#12CU		SPARE				
1488R	3TC#12CU	0.32	3.80	36	28.8	19.58	80.60
1991R	3TC#2AL	0.93	60.00	127	101.6	69.09	13.15
6666R-	3TC#12CU	0.32	2.50	36	28.8	19.58	87.23

TRAY# 1AZ-P9
TRAY SIZE 12"W x6"D
FIRE BARRIER 1 HOUR RATED THERMO-LAG

CABLE NO	CABLE TYPE	CBL OD	FLA	OPEN AIR AMPACITY	80% OPEN AIR AMPACITY	32% TSI DERATING	% MARGIN
8113R	3TC#12CU	0.32	0.71	36	28.8	19.58	96.37
8119R	3TC#12CU	0.32	0.71	36	28.8	19.58	96.37
1623R	3TC#12CU	0.32	2.60	36	28.8	19.58	86.72
1642R	4/C#12CU	0.52	6.40	36	28.8	19.58	67.32
8026R	3TC#12CU	0.32	2.70	36	28.8	19.58	86.21
8027R	3TC#12CU	0.32	1.20	36	28.8	19.58	93.87
2349R	3TC#12CU	0.32	1.90	36	28.8	19.58	90.30
9217R	3TC#12CU	0.32	0.17	36	28.8	19.58	99.13
9221R	3TC#12CU	0.32	0.17	36	28.8	19.58	99.13
1440R	3TC#2AL	0.93	60.00	127	101.6	69.09	13.15
8753RH	3TC#4AL	0.8	49.00	94	75.2	51.14	4.18

Note: 4/C #12CU ampacity is derived from only 3 conductors utilized

TRAY# 2AI-P2
TRAY SIZE 12"W x6"D
FIRE BARRIER 1 HOUR RATED THERMO-LAG

CABLE NO	CABLE TYPE	CBL OD	FLA	OPEN AIR AMPACITY	80% OPEN AIR AMPACITY	32% TSI DERATING	% MARGIN
3010G	3TC#12CU	0.32	1.75	36	28.8	19.58	91.06
3012G	4/C#12CU	0.52	16.00	36	28.8	19.58	18.30
3013G	4/C#12CU	0.52	16.00	36	28.8	19.58	18.30
8987G	3TC#12CU	0.32	16.00	36	28.8	19.58	18.30
9217G	3TC#12CU	0.32	0.71	36	28.8	19.58	96.37
3014G	3TC#6CU	0.85	36.00	89	71.2	48.42	25.64
8984G	3TC#10CU	0.46	15.60	48	38.4	26.11	40.26

Note: 4/C #12CU ampacity is derived from only 3 conductors utilized

TRAY# 2AZ-P3
TRAY SIZE 12"W x6"D
FIRE BARRIER 1 HOUR RATED THERMO-LAG

CABLE NO	CABLE TYPE	CBL OD	FLA	OPEN AIR AMPACITY	80% OPEN AIR AMPACITY	32% TSI DERATING	% MARGIN
8332G	3TC#12CU	0.32	3.80	36	28.8	19.58	80.60
9665G	3TC#12CU		SPARE				
1970G	4/C#12CU	0.52	6.70	36	28.8	19.58	65.79
9696G	3TC#12CU		SPARE				
3001G	3TC#2CU	1.08	1.38	162	129.6	88.13	98.43
13945G	3TC#2CU	1.08	73.00	162	129.6	88.13	17.17
3010G	3TC#12CU	0.32	1.50	36	28.8	19.58	92.34
3012G	4/C#12CU	0.52	16.00	36	28.8	19.58	18.30
3013G	4/C#12CU	0.52	16.00	36	28.8	19.58	18.30
8987G	3TC#12CU	0.32	16.00	36	28.8	19.58	18.30
3014G	3TC#6AL	0.69	36.00	69	55.2	37.54	4.09
9965G	4/C#12CU	0.52	7.9	36	28.8	19.58	59.66
9958G	3TC#12CU	0.32	1.00	36	28.8	19.58	94.89
8645G	3TC#12CU	0.32	2.90	36	28.8	19.58	85.19
8138G	3TC#12CU		CONTROL				
8204G	3TC#12CU	0.32	18.00	36	28.8	19.58	8.09
8317G	3TC#12CU	0.32	3.80	36	28.8	19.58	80.60
8756GH	3TC#2/0AL	1.27	96.40	206	164.8	112.06	13.98
8050GH	7/C#12CU		CONTROL				
8053GH	3TC#8CU	0.72	12.89	66	52.8	35.90	64.10

Note: 4/C #12CU ampacity is derived from only 3 conductors utilized

TRAY# 2AZ-P10
TRAY SIZE 12"W x6"D
FIRE BARRIER 1 HOUR RATED THERMO-LAG

CABLE NO	CABLE TYPE	CBL OD	FLA	OPEN AIR AMPACITY	80% OPEN AIR AMPACITY	32% TSI DERATING	% MARGIN
8755RH	3TC#2AL	0.93	50.30	127	101.6	69.09	27.19
8753RH	3TC#4AL	0.8	50.30	94	75.2	51.14	1.63
8756RH	3TC 2/0AL	1.27	100.50	206	164.8	112.06	10.32
1500R	3TC#2AL	0.93	50.30	127	101.6	69.09	27.19
8206R	3TC#12CU	0.32	18.00	36	28.8	19.58	8.09
9962R	3TC#12CU		SPARE				
9951R	3TC#12CU	0.32	0.80	36	28.8	19.58	95.92
9901R	3TC#12CU	0.32	2.99	36	28.8	19.58	84.73
9908R	3TC#12CU	0.32	2.99	36	28.8	19.58	84.73
16666R	3TC#12CU	0.32	2.14	36	28.8	19.58	89.07
8327R	3TC#12CU	0.32	2.99	36	28.8	19.58	84.73
8024R	3TC#12CU	0.32	1.00	36	28.8	19.58	94.89
2481R	3TC#2CU	1.08	1.38	162	129.6	88.13	98.43
8274R	3TC#12CU	0.32	2.20	36	28.8	19.58	88.77
9221R	3TC#12CU	0.32	0.71	36	28.8	19.58	96.37
9217R	3TC#12CU	0.32	0.71	36	28.8	19.58	96.37
8030R	3TC#12CU	0.32	1.34	36	28.8	19.58	93.16
8560R	3TC#12CU	0.32	3.29	36	28.8	19.58	83.20

The Mathcad software (version 6.0 by MathSoft Inc.) contains a function that allows the user to solve a system of simultaneous equations with an equal number of equations and unknowns (50 max.). This method returns numbers for the unknown variables. There are four steps to solving a system of simultaneous equations. These are:

1.) Provide an initial guess for the unknowns. Mathcad solves equations by making a series of guesses which ultimately converge on the correct answer. The initial guesses provide Mathcad with a place to start searching for solutions.

2.) The word *Given* is typed, followed by the series of equations.

3.) The series of equations and inequalities in any order below the word Given.

4.) Type any equation that involves the *Minerr* function. The *Minerr* function returns a vector of answers that solve the system of equations.

The equation used in this mathematical model is:

$a+b^*e(t_1/\tau_1)+c^*e(t_2/\tau_2) = mf(t)$

where: a is a constant representing limiting value of derating factor
b & τ_1 are variables in an exponential to reflect the effect of the increase in cable thermal resistance due to adjoining cables
c & $\tau 2$ are variables in an exponential to reflect the effect of additional heat generation in the raceway.

Guesses

$a := 0.75$ $\quad b := 0.15$ $\quad c := 0.1$ $\quad m := 2.2$ $\quad n := 1.7$

Given

$a + b + c = 1.0$ where t = 0

$$a + b\cdot\exp\left(\frac{1}{m}\right) + c\cdot\exp\left(-\frac{1}{n}\right) = 0.93$$

$$a + b\cdot\exp\left(\frac{2}{m}\right) + c\cdot\exp\left(-\frac{2}{n}\right) = 0.87$$

$$a + b\cdot\exp\left(\frac{3}{m}\right) + c\cdot\exp\left(\frac{3}{n}\right) = 0.84$$

$$a + b\cdot\exp\left(\frac{5}{m}\right) + c\cdot\exp\left(\frac{5}{n}\right) = 0.82$$

$$\begin{pmatrix} aa \\ bb \\ cc \\ mm \\ nn \end{pmatrix} := \mathrm{Minerr}(a,b,c,m,n) \qquad MF := \begin{pmatrix} 1 \\ 0.93 \\ 0.87 \\ 0.84 \\ 0.83 \\ 0.82 \end{pmatrix}$$

MF is a vector of the data included in Table VII of ICEA P-42-426.

$aa = 0.8$

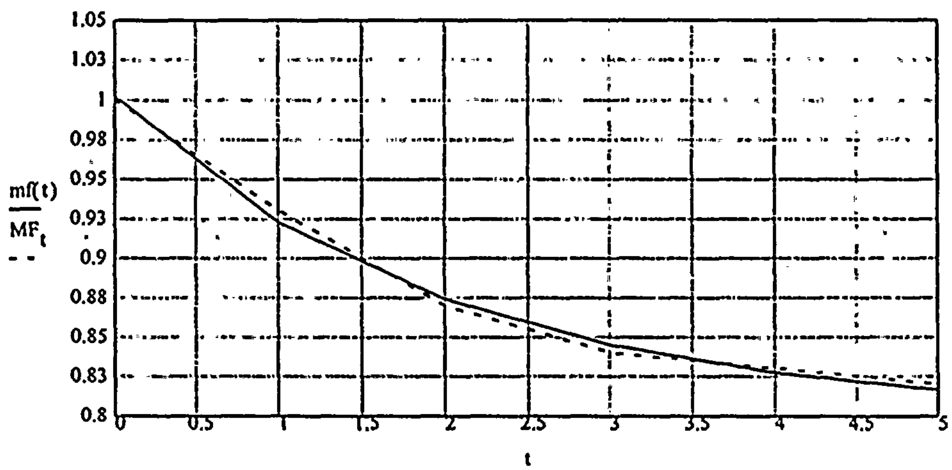
$bb = 0.129$

$cc = 0.073$

$mm = 1.974$

$nn = 1.991$

$$mf(t) := aa - bb \cdot \exp\left(\frac{t}{mm}\right) + cc \cdot \exp\left(\frac{t}{nn}\right) \qquad t := 0, 1 .. 5 \qquad mf(20) = 0.8$$



$$error(t) := \left(\frac{mf(t) - MF_t}{MF_t}\right)^2 \qquad terror := \sum_t error(t) \qquad terror = 1.568 \cdot 10^{-4}$$

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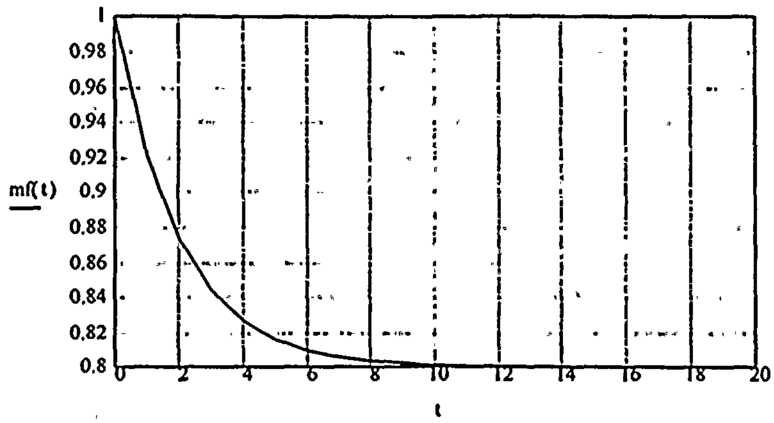
t 0..20



mf(t)
1.002
0.922
0.874
0.845
0.827
0.817
0.81
0.806
0.804
0.803
0.802
0.801
0.801
0.801
0.801
0.8
0.8
0.8
0.8
0.8
0.8

Comparison of CL-542 Test 1 Results to Tray 1AZ-P8

CABLE SIZE[1]	TEST CURRENT[1]	RUNS IN TRAY[1]	HIGHEST CONDUCTOR TEMP. (°C)[1]	CABLE(S) SIMULATED
3TC#12CU	3.8	7	45.6	1470R, 8067R, 8024R, 8026R, 8027R, 2349R, 16666R-2
3TC#12CU	20.0	3	59.7	1469R, 8187R, 1488R
3TC#2AL	60.0	1	55.7	1991R

TABLE 1

Comparison of CL-542 Test 3 Results to Tray 1A-P20

CABLE SIZE[2]	TEST CURRENT[2]	RUNS IN TRAY[2]	HIGHEST CONDUCTOR TEMP. (°C)[2]	CABLE(S) SIMULATED
3TC#12CU	0.71	5	54.6	8113R,8119R 8294R,9217R,9221R
3TC#12CU	2.8	5	57.9	1623R,8026R, 8027R,2349R,2355R
3TC#12CU	6.8	2	60.4	2348R,2962R
3TC#12CU	16.0	2	67.3	8984R,8987R
4/C#12CU	6.8	1	55.2	1642R,
4/C#12CU	16.0	2	62.7	2353R,2354R
3TC#6AL	16.0	1	57.6	3249R,
3TC#6AL	36.0	1	65.9	2361R
3TC#4AL	36.0	1	57.9	2356R,
3TC#4AL	53.0	1	68.8	8753RH
3TC#2AL	60.0	2	63.7	1656R,1440R

TABLE 2

[1] Test data conforms to the actual cables sizes, number of runs, loading and configuration of tray 1AZ-P8.
[2] Test data conforms to the actual cables sizes, number of runs, loading and configuration of tray 1A-P20.

CABLE SIZE	Tray 1A-P20 # of runs / loading (A)	Tray 1AI-P1 # of runs / loading (A)
3TC#12CU	5 / 0.71	8/0.33
3TC#12CU	5 / 2.8	5 / 2.10
3TC#12CU	2 / 6.8	4 /4.0
3TC#12CU	2 / 16.0	-
4/C#12CU	1 / 6.8	-
4/C#12CU	2 / 16.0	1 / 10.0
3TC#8AL	-	1 / 25.0
3TC#6AL	1 / 16.0	-
3TC#6AL	1 / 36.0	1 / 37.0
3TC#4AL	1 / 36.0	-
3TC#4AL	1 / 53.0	-
3TC#2AL	2 / 60.0	
# of energized cables	23	20
# of unused cables	1	1
actual watts	25.18	7.17
highest temperature	68.8°C	-

TABLE 3

CABLE SIZE	Tray 1A-P20 # of runs / loading (A)	Tray 1AI-P2 # of runs / loading (A)
3TC#12CU	5 / 0.71	10/1.0
3TC#12CU	5 / 2.8	1/3.2
3TC#12CU	2 / 6.8	-
3TC#12CU	2 / 16.0	-
4/C#12CU	1 / 6.8	-
4/C#12CU	2 / 16.0	-
3TC#6AL	1 / 16.0	1/15.5
3TC#6AL	1 / 36.0	1/37.0
3TC#4AL	1 / 36.0	-
3TC#4AL	1 / 53.0	-
3TC#2AL	2 / 60.0	1/50.0
3TC2/OAL	-	1/51.0
3TC 350MCM AL	-	1/151
# of energized cables	23	16
# of unused cables	1	2
actual watts	25.18	12.4
highest temperature	68.8°C	-

TABLE 4

CABLE SIZE	Tray 1A-P20 # of runs / loading (A)	Tray 1AZ-P9 # of runs / loading (A)
3TC#12CU	5 / 0.71	4/0.71
3TC#12CU	5 / 2.8	4 / 2.70
3TC#12CU	2 / 6.8	-
3TC#12CU	2 / 16.0	-
4/C#12CU	1 / 6.8	1/6.4
4/C#12CU	2 / 16.0	-
3TC#6AL	1 / 16.0	-
3TC#6AL	1 / 36.0	-
3TC#4AL	1 / 36.0	-
3TC#4AL	1 / 53.0	1/49.0
3TC#2AL	2 / 60.0	1/60.0
# of energized cables	23	11
# of unused cables	1	0
actual watts	25.18	7.91
highest temperature	68.8°C	-

TABLE 5

CABLE SIZE	Tray 1A-P20 # of runs / loading (A)	Tray 2AI-P2 # of runs / loading (A)
3TC#12CU	5 / 0.71	-
3TC#12CU	5 / 2.8	2/2.0
3TC#12CU	2 / 6.8	-
3TC#12CU	2 / 16.0	1/16.0
4/C#12CU	1 / 6.8	-
4/C#12CU	2 / 16.0	2/16.0
3TC#10CU	-	1/16.0
3TC#6CU	-	1/36.0
3TC#6AL	1 / 16.0	-
3TC#6AL	1 / 36.0	-
3TC#4AL	1 / 36.0	-
3TC#4AL	1 / 53.0	-
3TC#2AL	2 / 60.0	-
# of energized cables	23	7
# of unused cables	1	0
actual watts	25.18	7.82
highest temperature	68.8°C	-

TABLE 6

CABLE SIZE	Tray 1A-P20 # of runs / loading (A)	Tray 2AZ-P3 # of runs / loading (A)
3TC#12CU	5 / 0.71	-
3TC#12CU	5 / 2.8	2 / 1.5
3TC#12CU	2 / 6.8	3 / 3.8
3TC#12CU	2 / 16.0	2 / 18.0
4/C#12CU	1 / 6.8	2 / 7.9
4/C#12CU	2 / 16.0	2 / 16.0
3TC#8CU	-	1 / 13.0
3TC#6AL	1 / 16.0	-
3TC#6AL	1 / 36.0	1 / 36.0
3TC#4AL	1 / 36.0	-
3TC#4AL	1 / 53.0	-
3TC#2AL	2 / 60.0	-
3TC#2CU	-	1 / 73.0
3TC#2CU	-	1 / 1.38
3TC2/OAL	-	1 / 96.4
# of energized cables	23	16
# of unused/control cables	1	4
Actual Watts	25.18	19.89
highest temperature	68.8°C	-

TABLE 7

CABLE SIZE	Tray 1A-P20 # of runs / loading (A)	Tray 2AZ-P10 # of runs / loading (A)
3TC#12CU	5 / 0.71	3/0.8
3TC#12CU	5 / 2.8	4/2.2
3TC#12CU	2 / 6.8	4/3.3
3TC#12CU	2 / 16.0	1/18.0
4/C#12CU	1 / 6.8	-
4/C#12CU	2 / 16.0	-
3TC#6AL	1 / 16.0	-
3TC#6AL	1 / 36.0	-
3TC#4AL	1 / 36.0	-
3TC#4AL	1 / 53.0	1/51.0
3TC#2CU	-	1.38
3TC#2AL	2 / 60.0	2/51.0
3TC2/OAL	-	1/101.0
# of energized cables	23	17
# of unused cables	1	1
actual watts	25.18	16.95
highest temperature	68.8°C	-

TABLE 8