SINGLE 0.69" CABLE

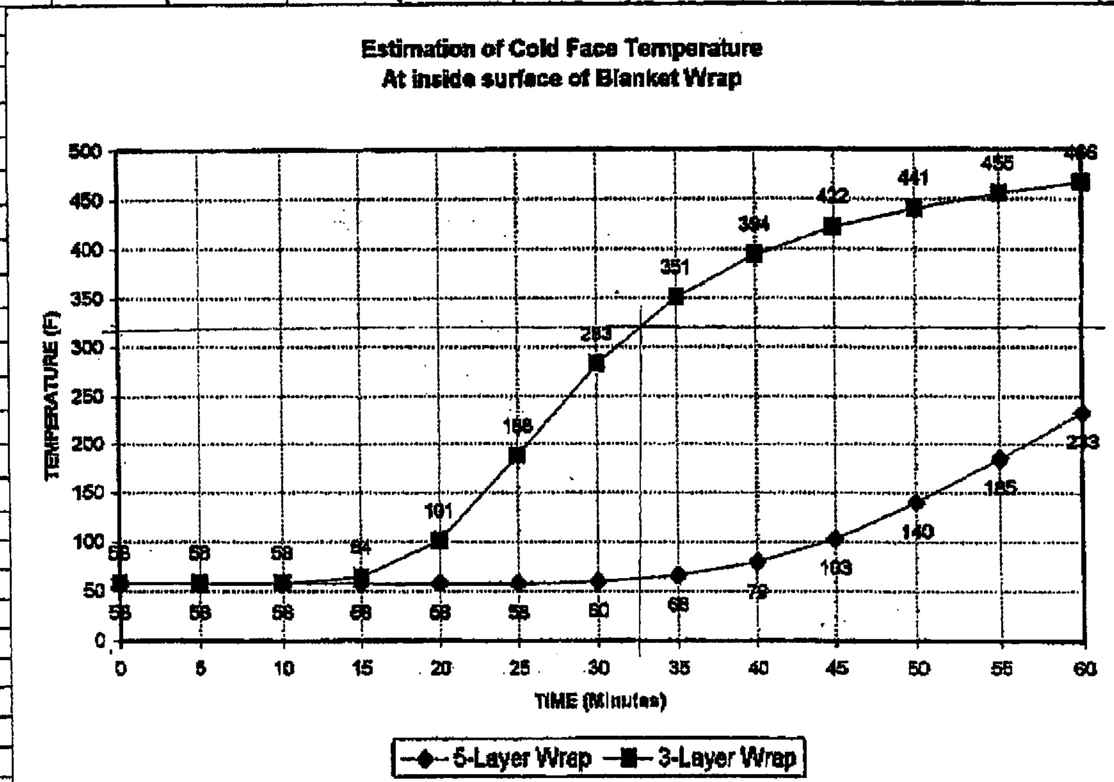
TEMPERATURE ESTIMATION AT INSIDE OF BLANKET WRAP
ASTM E119 SCHEDULE

V. C. SUMMER NUCLEAR STATION

Three & Five Layer Cable Wrap
ASTM E119

No conduit, 0.69" dia. Single cable
Three and Five layers, each 1" Kaowool S, 8 pcf blanket
Estimated cold face temperature (inner surface of blanket wrap)

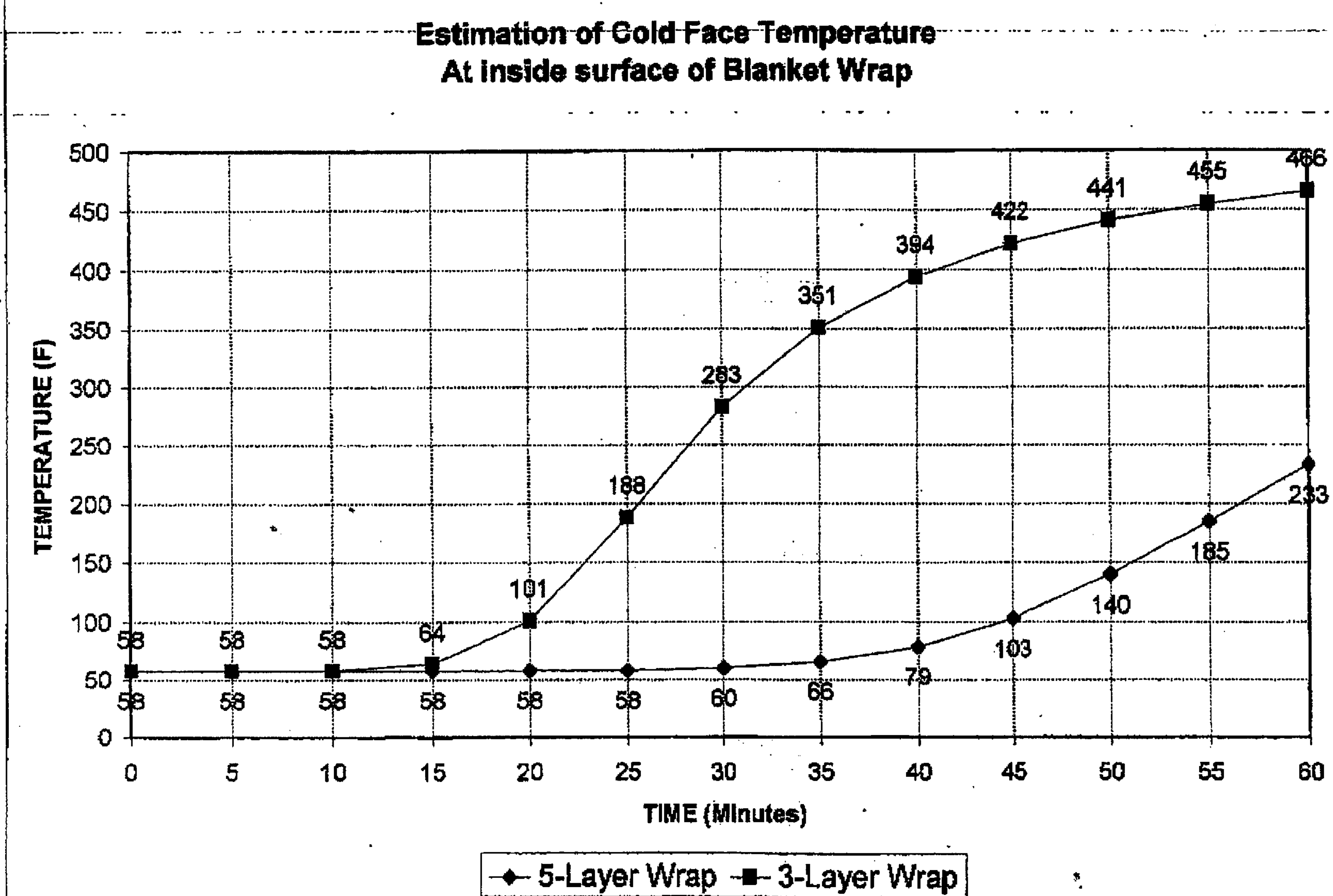
Time (Min.)	5-Layers Temperature (deg. F)	3-Layers Temperature (deg. F)
0	58	58
5	58	58
10	58	58
15	58	64
20	58	101
25	58	188
30	60	283
35	66	351
40	79	394
45	103	422
50	140	441
55	185	455
[redacted]	[redacted]	466



M. T. Johnson
May 9, 2000

FOR COMPARISON PURPOSES ONLY, NOT FOR DESIGN SPECIFICATIONS

V. C. SUMMER NUCLEAR STATION
3 and 5 layers of Kaowool S Blanket
Each layer 1" of 8 pcf blanket over .069" dia. cable



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1.0 PURPOSE

This calculation will document the adequacy of the cable ampacity considerations associated with power cables installed in cable trays that are wrapped with Kaowool blanket material, developed by Babcock and Wilcox.

2.0 SCOPE

This calculation is applicable to the cables installed within the following single lay power cable trays:

Cable Tray 1012
Cable Tray 1034

V.C. summer utilizes three, one-inch (1") thick kaowool blankets (Triple Wrap-TW) at a density of 8 lbs/cu. ft. to provide one (1) hour Appendix R separation of redundant safe shutdown equipment.

When installed over conduit or cable tray, the Kaowool blanket wrap effectively creates a new raceway. It reduces the heat dissipation capability of power cables and the temperature of the cables increases considerably. Conventional ampacity calculations apply derating factors to determine the maximum amount of current the cable system can carry without increasing the temperature to such a point that the cable begins to degrade. Thermal Ceramics, the Manufacturer of Kaowool Blanket Material, has not provided a cable ampacity derating factor.

This calculation will utilize an alternative means of ensuring the adequacy of the size of the cables for the installed configurations. It will analyze the installed cable configurations to ensure that the temperature rise resulting from the required load (adjusted for environmental conditions) does not exceed the allowable temperature for maintaining the cable ampacity – temperatures for which the cable is rated or the cable has demonstrated functionality.

This calculation will consider three (3) cases:

- Appendix R Postulated ASTM E-119 Fire (1700°F, One hour duration) Condition - Since a fire can affect one train of safe shutdown equipment, the Nuclear Regulatory Commission has stipulated that no other failures, such as those resulting from random single failures, accidents or seismic events need to be postulated simultaneously with the fire. (Ref. 6.17)

- Normal Conditions - Service conditions for normal operations that would not result in ambient conditions that exceed the normal operating termperature rating (90°C, 194°F) of the cable (Ref. 6.23)

- Accident Conditions - Service conditions for accident Scenarios that would not result in ambient conditions that exceed the emergency overload termperature rating (130°C, 266°F) of the cable (Ref. 6.23). These service conditions would require different loads to be energized than would be expected during normal plant operations.

The results of this calculation will be documented in Design Calculation DC08500-018, Cable Sizing Criteria Development.

3.0 COMPUTER PROGRAMS

None

4.0 ASSUMPTIONS

4.1 The ampacity of the power cables installed in single lay cable tray is conservatively based on the heat loading for cables in a single lay with no maintained spacing. (Ref. 6.18, Section 3-2). With no maintained spacing between cables installed in a single lay cable tray, heat cannot be carried out of the cable bundle by air flowing through the bundle.

Current-carrying cables in cable trays generate heat in proportion to their individual cross-sectional areas. Convection heat flow is proportional to surface area while conduction heat flow is proportional to cross-sectional area (Ref. 6.5). The basic equation for conductive heat transfer will be utilized to calculate the temperature rise resulting from the installed cable load (Ref. Attachment 1).

4.2 The temperature profile within the cable is linear/finite/constant. The temperature does not change with time. Steady state heat transfer occurs when the temperature at every point within the body is independent of time (Ref. 5.25, Page 2). Each case considered in this calculation (Appendix R Scenario, Normal Condition and Accident Condition) will conservatively assume a worse case constant temperature for the Kaowool barrier internal ambient condition.

4.3

Table 4.3
Equipment Qualification Data
(Ref. 6.25, Sheets 3-86 and 3-135)

Cable Tray	Room	EQ Zone	Normal Oper. Cond. Max. Temp (°F/°C)		Accident Scenario Max. Temp (°F/°C)	
1012	AB 00-02E	AB-80	94	34.4	115	46.1
1034	IB 26-02	IB-04	96	35.6	245	118.3

The Transco Fire Test temperature profile data (Ref. 6.9) at Time=5 minutes (59°F/15°C) will conservatively bound the ambient temperatures in the Kaowool blanket material during Normal and Accident service conditions. This value is conservative in that the 1700°F ASTM-E-119 fire at time T=5 minutes results in 1000°F/538°C ambient temperature outside of the barrier (Ref. Attachment 12.4). This 1000°F/538°C temperature is higher than the maximum temperatures that are postulated given normal and accident conditions. (Refer to Table 4.3.) At five (5) minutes into the ASTM E-119 fire (Time=5 Minutes), the 1000°F/538°C ambient temperature outside of the Kaowool barrier renders a maximum temperature of 59°F/15°C inside of the Kaowool barrier for both the 6x6" Cable Tray and the 6x36" Cable Tray (Ref. Attachments 12.5 and 12.6).

4.4 Cable Tray 1012 is a 4"x12" (Depth x Width) 'B' Train Nuclear Safety Related cable tray. It is located in the Auxiliary Building, Room AB 00-02, Elevation 400 Feet. Approximately five feet (5') of the 1012 Cable Tray is wrapped with three (3), one inch (1") blankets of the Kaowool Ceramic fire barrier material to provide Appendix R protection because the cable tray is within twenty feet (20') of redundant ('A' Train) safe shutdown circuits. (Ref. 6.28, Sheet 5-6, 11-TW). Transco Fire Test Item 5, a 6"x36" steel cable tray that is protected with three (3) one-inch layers of Kaowool ceramic fiber blanket (Ref. 6.9, Page 4), is a representative configuration of the 1012 cable tray (Ref. 6.29).

4.5 Cable Tray 1034 is a 4"x6" (Depth x Width) 'C' Train cable tray that is required to maintain 'C' Train operability. It is located in the Intermediate Building, Room IB 26-02, Elevation 426 Feet. Approximately twenty-eight feet (28') of the 1034 Cable Tray is wrapped with three (3), one inch (1") blankets of the Kaowool Ceramic fire barrier material to maintain twenty feet (20') clearance for redundant safe shutdown circuits. (Ref. 6.28, Sheet 5-26, 45-TW). Transco Fire Test Item 3, a 6"x6" steel cable tray that is protected with three (3) one-inch layers of Kaowool ceramic fiber blanket (Ref. 6.9, Page 4), is a representative configuration of the 1034 cable tray (Ref. 6.29).

4.6 The Transco Fire Test Specification (Ref. 6.9) provides for measurement of internal raceway temperatures by a stranded AWG 8 bare copper conductor routed on the top of the cable tray rungs along the entire length of the cable tray. This temperature is representative of the temperature profile of the cables in the installed cable tray configurations (Ref. 6.29).

5.0 DESIGN INPUTS

5.1 Cable Resistance Data Conversion
Appendix R Scenario
6x36" Cable Tray
(Reference 6.4, Tables 1-3, 1-4 and 1-5)

Conductor Size	DC Resistance @ 25°C (77°F) (Ohms/1000 ft) (Table 1-3)	Temp Corr. Factor 96°C (205°F) (Table 1-4)	AC/DC Resistance Ratio @ 60 Hertz (Table 1-5)	AC Resistance @ 96°C (205°F) (Ohms/1000 ft)
4/0 AWG	0.05	1.274	1.004	0.0640

5.2 Cable Resistance Data Conversion
Appendix R Scenario
6x6" Cable Tray
(Reference 6.4, Tables 1-3, 1-4 and 1-5)

Conductor Size	DC Resistance @ 25°C (77°F) (Ohms/1000 ft) (Table 1-3)	Temp Corr. Factor 124°C (255°F) (Table 1-4)	AC/DC Resistance Ratio @ 60 Hertz (Table 1-5)	AC Resistance @ 124°C (255°F) (Ohms/1000 ft)
4/0 AWG	0.05	1.381	1.004	0.0693

5.3 Cable Resistance Data Conversion
Normal/Accident Scenario
(Reference 6.4, Tables 1-3, 1-4 and 1-5

Conductor Size	DC Resistance @ 25°C 77°F) (Ohms/1000 ft) (Table 1-3)	Temp Corr. Factor 15°C (59°F) (Table 1-4)	AC/DC Resistance Ratio @ 60 Hertz (Table 1-5)	AC Resistance @ 15°C (59°F) (Ohms/1000 ft)
4/0 AWG	0.05	0.961	1.004	0.0482

5.4 The insulation emergency overload temperature rating is for those situations in which load current is higher than normal but is not expected to last more than one hundred (100) hours at any given time or more than a total of five hundred (500) hours in the life of the cable. (Ref. 6.24) This emergency overload temperature is a valid value for the peak acceptable temperature for the accident Scenario. The accident Scenario will require energizing a circuit (Circuit SPM21B, Reactor Building Spray Pump) contained in Cable Tray 1012 that is not required during normal operation. The duration of the accident Scenario load condition does not exceed the stated interval. The accident analysis that demonstrates the Reactor Building's long-term integrity during the design basis accident main steam line break and the worst case Loss Of Cooling Accident (LOCA) makes the conservative assumption that the Reactor Building Spray System is shutdown after twenty-four (24) hours (Ref. 6.16, Sections 6.2.2.2.1.2 and 6.2.1.3.2).

5.5 Per V.C. Summer Cable Sizing Criteria (Ref. 6.13, Table 4.8) **224 Amps** is the Ampacity Rating for 4/0 AWG, 8kV, three (3) conductor cable with a 40°C(104°F) ambient.

5.6 Cable Data

The Cable Data listed in Tables 5.6.1 and 5.6.2 was obtained from the following references:

Column	References
Circuit Number	6.8, 6.19
From Device	6.8, 6.15
To Device	6.8, 6.15
Continuous Load Current	6.15
Cable Type	6.8
Cable Size	6.20, 6.26
Cable Outside Diameter	6.26
Cable Area	6.26

TABLE 5.6.1
Cable Tray 1012 - Cable Data

Cable Number	From Device	To Device	Continuous Load Current	Cable Type	Cable Size	Cable Outside Diameter (Inches)	Cable Area (Square Inches)
CSM11B	XSW1DB, 7.2kV Switchgear Bus 1DB, Unit 15	XPP043B, Charging Injection Pump B	65 FLA	EK-A1E	3/C, 4/0 AWG	2.424	4.6148
CSM42B	XSW1DB, 7.2kV Switchgear Bus 1DB, Unit 14	XET2002C, Transfer Switch for Charging Injection Pump C	65 FLA	EK-A1E	3/C, 4/0 AWG	2.424	4.6148
RCM61XB	XSW1DB, 7.2kV Switchgear Bus 1DB, Unit 5	XTF4102, Pressurizer Htr Pwr XFMR Backup Group 2	43A	EK-A1E	3/C, 4/0 AWG	2.424	4.6148
SPM21B	XSW1DB, 7.2kV Switchgear Bus 1DB, Unit 6	XPP038B, Reactor Bldg Spray Pump B	31 FLA	EK-A1E	3/C, 4/0 AWG	2.424	4.6148

TABLE 5.6.2
Cable Tray 1034- Cable Data

Cable Number	From Device	To Device	Continuous Load Current	Cable Type	Cable Size	Cable Outside Diameter (Inches)	Cable Area (Square Inches)
CCM38C	XES2001C, Speed Switch ForXPP01C	XPP01C, Component Cooling Pump C (High Speed)	45 FLA	EK-A1E	3/C, 4/0 AWG	2.424	4.6148
CCM39C	XES2001C, Speed Switch ForXPP01C	XPP01C, Component Cooling Pump C (Low Speed)	45 FLA	EK-A1E	3/C, 4/0 AWG	2.424	4.6148

5.7 Under the Appendix R postulated ASTM E-119 fire condition, the Nuclear Regulatory Commission has stipulated that no other failures, such as those resulting from random single failures, accidents or seismic events need to be postulated simultaneously with the fire. (Ref. 6.17, Section 2.1)

Table 5.7.1
Cable Tray 1012 Loads

Cable Number	Load Description	Discussion
CSM11B	XPP043B, Charging Injection Pump B	One (1) pump is normally running, one (1) is a non-running pump and the third is a spare with its breaker(s) normally racked out. The third pump, C, can be powered by either bus 1DA or 1DB, depending on the position of the Transfer Switch.(Ref. 6.16, Section 9.3.4.2.5.2) Therefore, circuits CSM11B or CSM42B will be not be energized simulatenously. **Either CSM11B or CSM42B can be energized during the Appendix R Scenario.**
CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C	One (1) pump is normally running, one (1) is a non-running pump and the third is a spare with its breaker(s) normally racked out. The third pump, C, can be powered by either bus 1DA or 1DB, depending on the position of the Transfer Switch.(Ref. 6.16, Section 9.3.4.2.5.2) Therefore, circuits CSM11B or CSM42B will be not be energized simulatenously.. **Either CSM11B or CSM42B can be energized during the Appendix R Scenario.**
RCM61XB	XTF4102, Pressurizer Htr Pwr XFMR Backup Group 2	Only one Backup Heater Group should have disconnects open per SOP-101, Caution 2.0. A minimum of three individual backup heater group Fuse Disconnects should remain closed to ensure compliance with Tech Spec 3.4.3. (Ref. 6.22, Section 2.0) **RCM61XB can be energized during the Appendix R Scenario.**
SPM21B	XPP038B, Reactor Bldg Spray Pump	The Reactor Building Spray System performs its normal operating function only under emergency conditions following a LOCA or a steamline break that results in a major increase in the Reactor Building's internal pressure. **SPM21B will <u>not</u> be energized during the Appendix R Scenario.**

Table 5.7.2
Cable Tray 1034 Loads

Cable Number	Load Description	Discussion
CCM38C	XPP01C, Component Cooling Pump C (High Speed)	The Component Cooling pumps have two (2) speed capability. Operation of the pump at high speed is initiated only by manual operator action and is administratively controlled. One pump operating in the high speed mode satisfies normal shutdown criteria , but the capability of achieving a safe shutdown for normal operation or subsequent to an accident is not contingent upon the availability of the high speed mode. **Either CCM38C or CCM39C can be energized in the Appendix R Scenario.**
CCM39C	XPP01C, Component Cooling Pump C (Low Speed)	The Component Cooling pumps have two (2) speed capability. Operation of the pump at high speed is initiated only by manual operator action and is administratively controlled. One pump operating in the high speed mode satisfies normal shutdown criteria , but the capability of achieving a safe shutdown for normal operation or subsequent to an accident is not contingent upon the availability of the high speed mode. **Either CCM38C or CCM39C can be energized in the Appendix R Scenario.**

5.8 Under Normal conditions the external cable tray will not be exposed to ambient conditions that impose internal raceway temperatures that exceed the cable insulation normal operating 90°C (194°F) temperature rating (Non-Appendix R Conditions). This case will consider the cable load requirement in Normal plant operating conditions.

Table 5.8.1
Cable Tray 1012 Loads

Cable Number	Load Description	Discussion
CSM11B	XPP043B, Charging Injection Pump B	One (1) pump is normally running, one (1) is a non-running pump and the third is a spare with its breaker(s) normally racked out. The third pump, C, can be powered by either bus 1DA or 1DB, depending on the position of the Transfer Switch.(Ref. 6.16, Section 9.3.4.2.5.2) Therefore, circuits CSM11B or CSM42B will be not be energized simulatenously. **Either CSM11B or CSM42B can be energized during the Normal Scenario.**
CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C	One (1) pump is normally running, one (1) is a non-running pump and the third is a spare with its breaker(s) normally racked out. The third pump, C, can be powered by either bus 1DA or 1DB, depending on the position of the Transfer Switch.(Ref. 6.16, Section 9.3.4.2.5.2) Therefore, circuits CSM11B or CSM42B will be not be energized simulatenously. **Either CSM11B or CSM42B can be energized during the Normal Scenario.**
RCM61XB	XTF4102, Pressurizer Htr Pwr XFMR Backup Group 2	Only one Backup Heater Group should have disconnects open per SOP-101, Caution 2.0. A minimum of three individual backup heater group Fuse Disconnects should remain closed to ensure compliance with Tech Spec 3.4.3. (Ref. 6.22, Section 2.0) **RCM61XB can be energized during the Normal Scenario.**
SPM21B	XPP038B, Reactor Bldg Spray Pump	The Reactor Building Spray System performs its normal operating function only under emergency conditions following a LOCA or a steamline break that results in a major increase in the Reactor Building's internal pressure. **SPM21B will <u>not</u> be energized during the Normal Scenario.**

Table 5.8.2
Cable Tray 1034 Loads

Cable Number	Load Description	Discussion
CCM38C	XPP01C, Component Cooling Pump C (High Speed)	The Component Cooling pumps have two (2) speed capability. Operation of the pump at high speed is initiated only by manual operator action and is administratively controlled. One pump operating in the high speed mode satisfies normal shutdown criteria , but the capability of achieving a safe shutdown for normal operation or subsequent to an accident is not contingent upon the availability of the high speed mode. **Either CCM38C or CCM39C can be energized in the Normal Scenario.**
CCM39C	XPP01C, Component Cooling Pump C (Low Speed)	The Component Cooling pumps have two (2) speed capability. Operation of the pump at high speed is initiated only by manual operator action and is administratively controlled. One pump operating in the high speed mode satisfies normal shutdown criteria , but the capability of achieving a safe shutdown for normal operation or subsequent to an accident is not contingent upon the availability of the high speed mode. **Either CCM38C or CCM39C can be energized in the Normal Scenario.**

5.9 Under Accident conditions the external cable tray will not be exposed to ambient conditions that impose internal raceway temperatures that exceed the cable insulation emergency overload 130°C (266°F) temperature rating (Non-Appendix R Conditions). This case will consider the cable load requirement given Accident conditions.

Table 5.9.1
Cable Tray 1012 Loads

Cable Number	Load Description	Discussion
CSM11B	XPP043B, Charging Injection Pump B	One (1) pump is normally running, one (1) is a non-running pump and the third is a spare with its breaker(s) normally racked out. The third pump, C, can be powered by either bus 1DA or 1DB, depending on the position of the Transfer Switch.(Ref. 6.16, Section 9.3.4.2.5.2) Therefore, circuits CSM11B or CSM42B will be not be energized simulatenously. **Either CSM11B or CSM42B can be energized during the Accident Scenario.**
CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C	One (1) pump is normally running, one (1) is a non-running pump and the third is a spare with its breaker(s) normally racked out. The third pump, C, can be powered by either bus 1DA or 1DB, depending on the position of the Transfer Switch.(Ref. 6.16, Section 9.3.4.2.5.2) Therefore, circuits CSM11B or CSM42B will be not be energized simulatenously. **Either CSM11B or CSM42B can be energized during the Accident Scenario.**
RCM61XB	XTF4102, Pressurizer Htr Pwr XFMR Backup Group 2	Only one Backup Heater Group should have disconnects open per SOP-101, Caution 2.0. A minimum of three individual backup heater group Fuse Disconnects should remain closed to ensure compliance with Tech Spec 3.4.3. (Ref. 6.22, Section 2.0) **RCM61XB can be energized during the Accident Scenario.**
SPM21B	XPP038B, Reactor Bldg Spray Pump	The Reactor Building Spray System performs its normal operating function only under emergency conditions following a LOCA or a steamline break that results in a major increase in the Reactor Building's internal pressure. **SPM21B can be energized during the Accident Scenario.**

Table 5.9.2
Cable Tray 1034 Loads

Cable Number	Load Description	Discussion
CCM38C	XPP01C, Component Cooling Pump C (High Speed)	The Component Cooling pumps have two (2) speed capability. Operation of the pump at high speed is initiated only by manual operator action and is administratively controlled. One pump operating in the high speed mode satisfies normal shutdown criteria , but the capability of achieving a safe shutdown for normal operation or subsequent to an accident is not contingent upon the availability of the high speed mode. **Either CCM38C or CCM39C can be energized in the Accident Scenario.**
CCM39C	XPP01C, Component Cooling Pump C (Low Speed)	The Component Cooling pumps have two (2) speed capability. Operation of the pump at high speed is initiated only by manual operator action and is administratively controlled. One pump operating in the high speed mode satisfies normal shutdown criteria , but the capability of achieving a safe shutdown for normal operation or subsequent to an accident is not contingent upon the availability of the high speed mode. **Either CCM38C or CCM39C can be energized in the Accident Scenario.**

5.10 The Okonite Equipment Qualification Report 266 (Ref. 6.6) documents cable operation during a Design Basis Event in which the cable was subjected to Loss Of Coolant Accident (LOCA) conditions. The cables were subjected to temperatures of 171°C (340°F), multiple peak transients of three hours. This ***171°C (340°F)*** temperature will constitute **the *peak acceptable temperature***.

5.11 The Transco Fire Test temperature profile data (Ref. 6.10 and Attachment 12.6) for the 6x36" Cable Tray (Test Item #5) at Time T=60 Minutes, ***96°C (205°F)***, presents the tested profile of the raceway's ***internal ambient temperature*** under ASTM E-119 fire conditions.

5.12 The Transco Fire Test data (Ref. 6.10 and Attachment 12.5) for the 6x6" Cable Tray (Test Item #3) at Time T=60 Minutes, ***124°C (255°F)***, presents the tested profile of the raceway's ***internal ambient temperature*** under ASTM E-119 fire conditions.

5.13 Specification SP-0551 (Ref. 6.23) identifies the insulation temperature rating for 8kV power cable in a Normal service condition. This ***90°C (194°F)*** temperature will constitute the ***peak acceptable temperature***.

5.14 Specification SP-0551 (Ref. 6.23) identifies the insulation temperature rating for 8kV power cable in Transient (Accident) service conditions. This ***130°C (266°F)*** temperature will constitute the ***peak acceptable temperature***.

5.15 The Transco Fire Test temperature profile data (Ref. 6.9 and Attachmenst 12.5 and 12.6) for both the 6x6" and the 6x36" Cable Trays (Test Items #3 and #5, respectively) at Time=5 Minutes, ***15°C(59°F)***, conservatively represents the ***ambient temperature*** inside of the Kaowool blanket material during normal operating conditions and accident conditions. (Ref. Assumption 4.3)

5.16 The thermal resistivity (inverse of thermal conductivity) of Okonite's proprietary Okolon CSPE jacket compound is 400°C-cm/Watt (Ref. Attachment 12.7)

5.17 "A comparison of fire test temperature profiles to existing Equipment Qualification and Loss Of Cooling Accident (LOCA) test results or air oven test results is an acceptable approach to demonstrate cable functionality provided the subject analysis incorproates the anticipated temperature rise due to self heating effects of installed power cables with the fire test results." (Ref. 6.12, Section H-1.3.1, Page 146)

5.18 The AC resistance variable, R, in Stolpe's (Ref. 6.5) development presents the resistance in terms of ohms per a specified unit length (Ohms/Ft).

6.0 REFERENCES

6.1 ICEA Publication No. P-46-426, "Power Cable Ampacities", dated 1962, including cumulative errata of September 1, 1966.

6.2 ICEA-NEMA Standards Publication No. P-54-440, "Ampacities Cables in Open-Top Cable Trays", Second Edition dated August 1979.

6.3 NFPA 70, "National Electrical Code", dated 1993.

6.4 The Okonite Company, Engineering Data for Copper and Aluminum Conductor Electrical Cables, Bulletin EHB-98.

6.5 J. Stolpe, "Ampacities For Cables In Randomly-Filled Trays", IEEE Transactions Power Apparatus and Systems, Volume PAS-90, Part 1, Pages 962-974, 1971.

6.6 Equipment Qualification Documentation, EQDP-CA2-001,Okonite 8kV Power Cable.

6.7 CHAMPS Database

6.8 PC-CKS Database

6.9 Specification SP-0836, Kaowool Triple Wrap Raceway Fire Barrier Test For Conduits And Cable Trays

6.10 Technical Report, TR 07870-001, Kaowool Triple Wrap

6.11 EIR-80196, V.C.Summer Kaowool Triple Wrap Evaluation

6.12 NEI – Draft Regulatory Guied DG-1094, "Fire Protection For Operating Nuclear Power Plants"

6.13 Design Calculation No. DCO 8500-018, Cable Sizing Criteria Development

6.14 Thermal Ceramics Position Paper, "Determine The Heat Rise Of Various Cable Carrying Configurations Wrapped With The Firemaster Blanket Fire Protection System"

6.15 Feeder Loads And Effects Database

6.16 V.C. Summer Nuclear Station Final Safety Analysis Report

6.17 DBD Appendix R

6.18 DBD Cable & Raceway System

6.19 Drawing Series, SS-211, Electrical Block Diagram

6.20 Drawing Series, SS-212, Circuit Schedule, Cable Routing and Termination

6.21 "Heat Transfer", Seventh Edition, Holman, J. P., 1990.

6.22 V.C. Summer Nuclear Station, Station Operating Procedure SOP-101, Reactor Coolant System, Revision

6.23 Specification, SP-551, 8kV Power Cable

6.24 Petty, K. A. EPRI Power Plant Electrical Series, Volume 4, Wire and Cable (Palo Alto: Electric Power Research Institute, 1987).

6.25 Drawing S-021-018, Revision 10, Equipment Qualification Database, Environmental Zone Information.

6.26 Specification, SP-833, Electrical Construction Guide For Cable Installation

6.27 "Theory And Problems Of Heat Transfer", Schaum's Outline Series, Pitts, Donald R. and Sissom, Leighton E., 1977.

6.28 Drawing S-200-951, Fire Barrier Identification List

6.29 M.C. Kammer's TWR, Kaowool Test Item Selection, Dated 02/16/2000

7.0 METHODOLOGY

7.1 Appendix R Postulated ASTM E-119 Fire Condition

Okonite Report 266 (Ref. 6.6, Tab F1) documents the equipment qualification for Bill of Material Cable EK-A1E (Okonite 8kV Power Cable, 3/C, 4/0, 19 Strand). Worst case environmental conditions were imposed by sequential tests for thermal aging, radiation and a simulated Design Basis Event. Representative samples of Okonite 8kV power cable were:

- thermally aged to simulate end-of-life conditions for 504 hours at 150°C (302°F). Note that the cables were not energized while being subjected to the aging oven temperature of 150°C.
- subjected to radiation to a cumulative dosage of 2×10^8 Rad.
- subjected to a 100 day Loss Of Coolant Accident (LOCA) simulation. The LOCA simulation temperature profile includes two, three-hour intervals with peak temperatures of 340°F and a chemical spray is maintained throughout the qualification period. The cables were carrying rated voltage and current while being subjected to the LOCA profile.

The Okonite Equipment Qualification Report 266 (Ref. 6.6) documents cable operation during a Design Basis Event in which the cable was subjected to Loss Of Coolant Accident (LOCA) conditions. The LOCA conditions were simulated in a steam autoclave while being exposed to a chemical spray. The cables were subjected to multiple three hour transients with peak temperatures of 171°C (340°F. This 171°C (340°F) temperature will constitute the *peak acceptable temperature*. The cables were subjected to rated current and voltage under the thermal aging conditions. These conditions are conservative in that the Design Basis simulation test was the third in a sequence of progressively severe conditions that demonstrated the cable's qualification.

Specification SP-0836/Transco Fire Test (Reference 6.10) documents the requirements and results of a one-hour test conducted in accordance with the performance requirements of NRC Generic Letter 86-10, Supplement 1, ASTM E-119 time-temperature curve. The Transco Fire Test (Ref. 6.10) evaluated the ability of Kaowool raceway fire barriers to protect the circuits contained within cable trays and conduits. The tested configurations are representative of those installed at V.C. Summer Nuclear Station. The data at Time T=60 Minutes presents a worse case profile of the raceway ambient temperature under ASTM E-119 fire conditions.

The cables were not subjected to rated current and voltage in the Transco Fire Test (Ref. 6.10). This calculation will document the amount of heat generated by the load of the cables in the installed configurations and the corresponding temperature rise. The ampacity will be adjusted for the ambient air temperatures that the cable will experience inside the Kaowool barrier in conditions modeled by the Transco Fire Test results at Time =60 Minutes. The maximum ambient temperature at Time =60 Minutes for the Appendix R Scenario, 6x36" Cable Tray Case, is 96ºC (205ºF). The maximum ambient temperature at Time =60 Minutes for the Appendix R Scenario, 6x6" Cable Tray Case, is 124ºC (255ºF).

The calculated temperature rise resulting from the installed loads and the Transco Fire Test ambient temperature profile will be compared to the peak acceptable temperature attained from Equipment Qualification documentation.

7.2 Normal Condition

Specification SP-0551 (Ref. 6.23) identifies the insulation temperature rating for 8kV power cable in a normal service condition. This 90°C (194°F) temperature will constitute the *peak acceptable temperature.*

Specification SP-0836/Transco Fire Test (Reference 6.10) documents the requirements and results of a one-hour test conducted in accordance with the performance requirements of NRC Generic Letter 86-10, Supplement 1, ASTM E-119 time-temperature curve. The cables were not subjected to rated current and voltage in the Transco Fire Test (Ref. 6.10). The Transco Fire Test temperature profile data (Ref. 6.9) at Time=5 Minutes accurately represents the ambient temperature inside the Kaowool blanket material during normal operating conditions (Ref. Assumption 4.3).

This calculation will document the amount of heat generated and the corresponding temperature rise for the loads that will be energized under normal operating conditions.. The ampacity will be adjusted for the ambient air temperatures that the cable will experience inside the Kaowool barrier in conditions modeled by the Transco Fire Test results at Time =5 Minutes.

The calculated temperature rise resulting from the loads energized during Normal Operations and the Transco Fire Test ambient temperature profile (Time T=5 Minutes) will be compared to the *peak acceptable temperature* of the cable insulation.

7.3 Accident Condition

Specification SP-0551 (Ref. 6.23) identifies the insulation temperature rating for 8kV power cable in a transient (accident) condition. This 130°C (266°F) temperature will constitute the *peak acceptable temperature.* The insulation emergency overload temperature rating is for those situations in which 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. (Ref. 6.24)

Specification SP-0836/Transco Fire Test (Reference 6.10) documents the requirements and results of a one-hour test conducted in accordance with the performance requirements of NRC Generic Letter 86-10, Supplement 1, ASTM E-119 time-temperature curve. The cables were not subjected to rated current and voltage in the Transco Fire Test (Ref. 6.10). The Transco Fire Test temperature profile data (Ref. 6.9) Time=5 Minutes conservatively bounds the ambient temperature inside of the Kaowool blanket material during accident conditions (Ref. Assumption 4.3).

This calculation will document the amount of heat generated and the corresponding temperature rise for the loads that will be energized under accident conditions. The ampacity will be adjusted for the ambient air temperatures that the cable will experience in the Kaowool barrier, which is conservatively modeled by the Transco Fire Test results (Time =5 Minutes).

The calculated temperature rise resulting from the energized loads and the Transco Fire Test ambient temperature profile (Time T=5 Minutes) will be compared to the *peak acceptable temperature* of the cable insulation.

8.0 ACCEPTANCE CRITERIA

Conventional ampacity analysis ensures that the allowed or rated cable ampacity is equal to or greater than the required cable load as adjusted for environmental conditions. This calculation will ensure that the temperature rise resulting from the required cable load (as adjusted for environmental conditions) does not exceed allowed temperatures – temperatures for which the cable is rated or the cable has demonstrated functionality.

8.1 Appendix R Postulated ASTM E-119 Fire Condition

The raceway temperature including the temperature rise due to the existing cable load (adjusted for the environmental conditions imposed during the December, 1999 Transco Fire Test simulating the ASTM E-119 fire condition) should be less than the 171°C (340°F) Equipment Qualification Design Basis Event test temperature.

$$\text{Temp.}_{\text{EQ Design Basis Event Condition}} \geq \text{Temp.}_{\text{Rise Due To Cable Load}} + \text{Temp.}_{\text{Ambient Resulting From ASTM E-119 Fire}}$$

8.2 Normal Condition

The internal raceway ambient temperature 15°C (59°F) (Ref. Assumption 4.3) plus the calculated temperature rise given Normal Operating Conditions, should be less than the 90°C (194°F) normal operation insulation temperature rating.

$$\text{Temp.}_{\text{90°C Normal Oper. Insulation Rating}} \geq \text{Temp.}_{\text{Rise Due To Cable Load}} + \text{Temp.}_{\text{15°C Ambient Within Kaowool Blanket}}$$

8.3 Accident Condition

The internal raceway ambient temperature 15°C (59°F) (Ref. Assumption 4.3) plus the calculated temperature rise given Normal Operating Conditions, should be less than the 130°C (266°F) emergency overload insulation temperature rating.

$$\text{Temp.}_{\text{130°C Emer. Overload Insulation Rating}} \geq \text{Temp.}_{\text{Rise Due To Cable Load}} + \text{Temp.}_{\text{15°C Amb. Within Kaowool Blanket}}$$

9.0 Analysis

The peak acceptable temperatures and the ambient temperatures for each case (Appendix R Scenario, Normal and Accident Conditions) are identified in the Design Input Section 5.0. The information is tabulated in Section 10, Summary of Results.

This analysis will document the amount of heat generated and the corresponding temperature rise for the loads that are energized for each case (Appendix R Scenario, Normal and Accident Conditions). The information is tabulated in Section 10, Summary of Results.

9.0.1 Determine Q, Heat Generated By Energized Cable

Cable ampacity is defined by J. Stolpe's basic equation number 8 (Reference 6.5) as:

$$I=\sqrt{\frac{QA}{NR}}$$

Rearranging the Variables,

$$Q=\frac{I^2 NR}{A}$$

Where,

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3).

I = Conductor Current (Amps)

N = Number Of Conductors In The Cable

R = AC Resistance (Ohms/Ft) Of The Conductor At The Maximum Ambient Temperature Of The Cable.

A = Cross-Sectional Area Of The N-Conductor Cable (Inches^2)

9.0.2 Calculate Temperature Rise, ΔT, Resulting From Load Current

The energized cable's temperature rise above the surface temperature is defined by the relationship (Ref. 6.27, Equation 2.25):

$$\Delta T = \frac{r^2 Q}{4k}$$

Where,

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = Cable Outside Radius (Inches)

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3)

k = Thermal Conductivity Of The EK-A1E B/M Okolon Jacket/Okoguard Insulation Cable (°C-cm/Watt)

9.1 Appendix R Postulated ASTM E-119 Fire Condition 6x36" Cable Tray (Transco Test Item #5)

9.1.1 Determine Q, Heat Generated By Energized Cable

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.6),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 3

R = 0.0640 Ohms/1000Ft @ 96°C (205°F)

A = 4.6148 Inches^2

$$Q = \frac{I^2 (3)\left(0.0640\Omega / 1000 Ft\right)}{4.6148 Inch^2} \left(\frac{1 Ft}{12 Inch}\right)$$

$$Q = \frac{I^2 (3.467E-6)\Omega}{Inch^3}$$

Table 9.1.1 facilitates substitution of Current (I) Values:

Table 9.1.1
Cable Tray 1012 – Cable Load/Heat Data

Cable Number	Load	Load Summary	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.	65 FLA	0.0146
CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.		
RCM61XB	XTF4102, Pressurizer Htr Pwr XFMR Backup Group 2	RCM61XB can be energized during the Appendix R Scenario	43A	0.0064
SPM21B	XPP038B, Reactor Bldg Spray Pump B	SPM21B will not be energized during the Appendix R Scenario.	31 FLA	

9.1.2 Calculate Temperature Rise, ΔT, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 1.212 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3)

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(1.212\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{57.8324°C - Inch^3}{Watt}\right)Q$$

Table 9.1.2 facilitates substitution of Heat (Q) Values:

Table 9.1.2
Cable Tray 1012 – Heat/Temperature Rise Data

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM11B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.	0.0146	0.8444
CSM42B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.		
RCM61XB	RCM61XB can be energized during the Appendix R Scenario	0.0064	0.3701
SPM21B	SPM21B will not be energized during the Appendix R Scenario.		

9.2 Appendix R Postulated ASTM E-119 Fire Condition 6x6" Cable Tray (Transco Test Item #3)

9.2.1 Determine Q, Heat Generated By Energized Cable

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.2 and 5.6),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 3

R = 0.0693 Ohms/1000Ft @ 124°C (255°F)

A = 4.6148 Inches^2

$$Q = \frac{I^2 (3)\left(0.0693\Omega / 1000Ft\right)}{4.6148 Inch^2}\left(\frac{1Ft}{12Inch}\right)$$

$$Q = \frac{I^2 (3.754E-6)\Omega}{Inch^3}$$

Table 9.2.1 facilitates substitution of Current (I) Values:

Table 9.2.1
Cable Tray 1034- Cable Load/Heat Data

Cable Number	Load	Load Summary	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CCM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CCM38C or CCM39C can be energized in the Appendix R Scenario.	45 FLA	0.0076
CCM39C	XPP01C, Component Cooling Pump C (Low Speed)	Either CCM38C or CCM39C can be energized in the Appendix R Scenario.		

9.2.2 Calculate Temperature Rise, Δ T, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 1.212 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(1.212\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{57.8324°C - Inch^3}{Watt}\right) Q$$

Table 9.2.2 facilitates substitution of Heat (Q) Values:

TABLE 9.2.2
Cable Tray 1034- Heat/Temperature Rise Data

Cable Number	Load Summary	Q, Heat (Watt/Inches ^{3})	ΔT, Change In Temperature (°C)
CCM38C	Either CCM38C or CCM39C can be energized in the Appendix R Scenario.	0.0076	0.4396
CCM39C			

9.3 Normal Case, 6x6" Cable Tray and 6x36" Cable Trays

9.3.1 Determine Q, Heat Generated By Energized Cable

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.3 and 5.6),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 3

R = 0.0482 Ohms/1000Ft @ 15°C (59°F)

A = 4.6148 Inches^2

$$Q = \frac{I^2(3)\left(0.0482\Omega/1000Ft\right)}{4.6148 Inch^2}\left(\frac{1Ft}{12Inch}\right)$$

$$Q = \frac{I^2(2.611E-6)\Omega}{Inch^3}$$

Tables 9.3.1.1 and 9.3.1.2 facilitate substitution of Current (I) Values:

Table 9.3.1.1
Cable Tray 1012 - Cable Load/Heat Data

Cable Number	Load	Load Summary	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Normal Scenario.	65 FLA	0.0110
CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C	Either CSM11B or CSM42B can be energized during the Normal Scenario.		
RCM61XB	XTF4102, Pressurizer Htr Pwr XFMR Backup Group 2	RCM61XB can be energized during the Normal Scenario	43A	0.0048
SPM21B	XPP038B, Reactor Bldg Spray Pump B	SPM21B will <u>not</u> be energized during the Normal Scenario.	31 FLA	

TABLE 9.3.1.2
Cable Tray 1034- Cable Load/Heat Data

Cable Number	Load	Load Summary	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CCM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CCM38C or CCM39C can be energized in the Normal Scenario.	45 FLA	0.0053
CCM39C	XPP01C, Component Cooling Pump C (Low Speed)	Either CCM38C or CCM39C can be energized in the Normal Scenario.		

9.3.2 Calculate Temperature Rise, Δ T, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 1.212 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3)

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(1.212\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{57.8324°C - Inch^3}{Watt}\right)Q$$

Tables 9.3.2.1 and 9.3.2.2 facilitate substitution of Heat (Q) Values:

Table 9.3.2.1

Cable Tray 1012 - Heat/Temperature Rise Data

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM11B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.	0.0110	0.6362
CSM42B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.		
RCM61XB	RCM61XB can be energized during the Appendix R Scenario	0.0048	0.2776
SPM21B	SPM21B will not be energized during the Appendix R Scenario.		

TABLE 9.3.2.2

Cable Tray 1034- Heat/Temperature Rise Data

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CCM38C	Either CCM38C or CCM39C can be energized in the Normal Scenario.	0.0053	0.3065
CCM39C			

9.4 Accident Case, 6x6" Cable Tray and 6x36" Cable Trays

9.4.1 Determine Q, Heat Generated By Energized Cable

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.3 and 5.6),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 3

R = 0.0482 Ohms/1000Ft @ 15°C (59°F)

A = 4.6148 Inches^2

$$Q = \frac{I^2(3)\left(0.0482\Omega/1000Ft\right)}{4.6148 Inch^2}\left(\frac{1Ft}{12Inch}\right)$$

$$Q = \frac{I^2(2.611E-6)\Omega}{Inch^3}$$

Tables 9.4.1.1 and 9.4.1.2 facilitate substitution of Current (I) Values:

Table 9.4.1.1
Cable Tray 1012 - Cable Load/Heat Data

Cable Number	Load	Load Summary	*I*, Continuous Load Current	*Q*, Heat (Watt/Inches^3)
CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Accident Scenario.	65 FLA	0.0110
CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C	Either CSM11B or CSM42B can be energized during the Accident Scenario.		
RCM61XB	XTF4102, Pressurizer Htr Pwr XFMR Backup Group 2	RCM61XB can be energized during the Accident Scenario	43A	0.0048
SPM21B	XPP038B, Reactor Bldg Spray Pump B	SPM21B can be energized during the Accident Scenario.	31 FLA	0.0025

TABLE 9.4.1.2
Cable Tray 1034- Cable Load/Heat Data

Cable Number	Load	Load Summary	*I*, Continuous Load Current	*Q*, Heat (Watt/Inches^3)
CCM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CCM38C or CCM39C can be energized in the Accident Scenario.	45 FLA	0.0053
CCM39C	XPP01C, Component Cooling Pump C (Low Speed)	Either CCM38C or CCM39C can be energized in the Accident Scenario.		

9.4.2 Calculate Temperature Rise, ΔT, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 1.212 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3)

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(1.212\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{57.8324°C - Inch^3}{Watt}\right)Q$$

Tables 9.4.2.1 and 9.4.2.2 facilitate substitution of Heat (Q) Values:

Table 9.4.2.1

Cable Tray 1012 - Heat/Temperature Rise Data

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM11B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.	0.0110	0.6362
CSM42B	Either CSM11B or CSM42B can be energized during the Accident Scenario.		
RCM61XB	RCM61XB can be energized during the Accident Scenario	0.0048	0.2776
SPM21B	SPM21B will not be energized during the Accident Scenario.	0.0025	0.1451

TABLE 9.4.2.2

Cable Tray 1034- Heat/Temperature Rise Data

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CCM38C	Either CCM38C or CCM39C can be energized in the Accident Scenario.	0.0053	0.3065
CCM39C			

10.0 SUMMARY OF RESULTS

10.1 Appendix R Postulated ASTM E-119 Fire Condition 6x36" Cable Tray (Transco Test Item #5)

Table 10.1.1
Tabulation Of Cable Tray 1012 Data

Cable Number	Load	Load Summary	I, Continuous Load Current	Q,' Heat (Watt/Inches³)	ΔT, Change In Temperature (°C)
CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.	65 FLA	0.0146	0.8444
CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.			
RCM61XB	XTF4102, Pressurizer Htr Pwr XFMR Backup Group 2	RCM61XB can be energized during the Appendix R Scenario	43A	0.0064	0.3701
SPM21B	XPP038B, Reactor Bldg Spray Pump B	SPM21B will <u>not</u> be energized during the Appendix R Scenario.	31 FLA		
Total Temperature Rise					1.2145

Cable Tray 1012 Result Summary

Peak Acceptable Temperature (Ref. Design Input 5.10)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.11)
171°C	≥	1.2°C	+	96°C
171°C	≥	97.2°C		

10.2 Appendix R Postulated ASTM E-119 Fire Condition 6x6" Cable Tray (Transco Test Item #3)

Table 10.2.1
Tabulation Of Cable Tray 1034 Data

Cable Number	Load	Load Summary	I, Continuous Load Current	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CCM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CCM38C or CCM39C can be energized in the Appendix R Scenario.	45 FLA	0.0076	0.4396
CCM39C	XPP01C, Component Cooling Pump C (Low Speed)	Either CCM38C or CCM39C can be energized in the Appendix R Scenario.			
Total Temperature Rise					0.4396

Result Summary

Peak Acceptable Temperature (Ref. Design Input 5.10)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.12)
171°C	≥	0.4396°C	+	124°C
171°C	≥	124.4°C		

10.3 Normal Case, 6x36" (Cable Tray 1012) Cable Tray and 6x6" (Cable Tray 1034) Cable Tray

Table 10.3.1
Tabulation Of Cable Tray 1012 Data

Cable Number	Load	Load Summary	I, Continuous Load Current	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Normal Scenario.	65 FLA	0.0110	0.6362
CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C	Either CSM11B or CSM42B can be energized during the Normal Scenario.			
RCM61XB	XTF4102, Pressurizer Htr Pwr XFMR Backup Group 2	RCM61XB can be energized during the Normal Scenario	43A	0.0048	0.2776
SPM21B	XPP038B, Reactor Bldg Spray Pump B	SPM21B will <u>not</u> be energized during the Normal Scenario.	31 FLA		
Total Temperature Rise					0.9138

Cable Tray 1012 Result Summary

Peak Acceptable Temperature (Ref. Design Input 5.13)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.15)
90°C	≥	0.914°C	+	15°C
90°C	≥	15.9°C		

Table 10.3.2
Tabulation Of Cable Tray 1034 Data

Cable Number	Load	Load Summary	Continuous Load Current	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CCM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CCM38C or CCM39C can be energized in the Normal Scenario.	45 FLA	0.0053	0.3058
CCM39C	XPP01C, Component Cooling Pump C (Low Speed)	Either CCM38C or CCM39C can be energized in the Normal Scenario.			
Total Temperature Rise					0.3058

Cable Tray 1034 Results Summary

Peak Acceptable Temperature (Ref. Design Input 5.13)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire
90°C	≥	0.3058°C	+	15°C
90°C	≥	15.3°C		

10.4 Accident Case, 6x36" Cable Tray and 6x6" Cable Tray

Table 10.4.1
Tabulation Of Cable Tray 1012 Data

Cable Number	Load	Load Summary	I, Continuous Load Current	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Accident Scenario.	65 FLA	0.0110	0.6362
CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C	Either CSM11B or CSM42B can be energized during the Accident Scenario.			
RCM61XB	XTF4102, Pressurizer Htr Pwr XFMR Backup Group 2	RCM61XB can be energized during the Accident Scenario	43A	0.0048	0.2776
SPM21B	XPP038B, Reactor Bldg Spray Pump B	SPM21B can be energized during the Accident Scenario.	31 FLA	0.0025	0.1451
Total Temperature Rise					1.0589

Table 10.4.2
Results Summary

Peak Acceptable Temperature (Ref. Design Input 5.13)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.15)
130°C	≥	1.1°C	+	15°C
130°C	≥	16.1°C		

Table 10.4.3
Tabulation Of Cable Tray 1034 Data

Cable Number	Load	Load Summary	Continuous Load Current	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CCM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CCM38C or CCM39C can be energized in the Accident Scenario.	45 FLA	0.0053	0.3065
CCM39C	XPP01C, Component Cooling Pump C (Low Speed)	Either CCM38C or CCM39C can be energized in the Accident Scenario.			
Total Temperature Rise					0.3065

Table 10.4.4
Results Summary

Peak Acceptable Temperature (Ref. Design Input 5.13)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire
130°C	≥	0.3°C	+	15°C
130°C	≥	15.3°C		

11.0 CONCLUSION

All cables installed in power cable trays that are wrapped within Kaowool fire barrier material have been determined to be sized adequately to meet ampacity requirements and satisfy the Acceptance Criteria of Section 8.0.

12.0 ATTACHMENTS

12.1 "Theory And Problems Of Heat Transfer", Schaum's Outline Series, Pitts, Donald R. and Sissom, Leighton E., 1977, Pages 19 – 20 and 36 - 37.

12.2 PC-CKS Database Report, Circuits by Coordinates for Tray 1012

12.3 PC-CKS Database Report, Circuits by Coordinates for Tray 1034

12.4 ASTM E-119 Representative Time-Temperature Curve

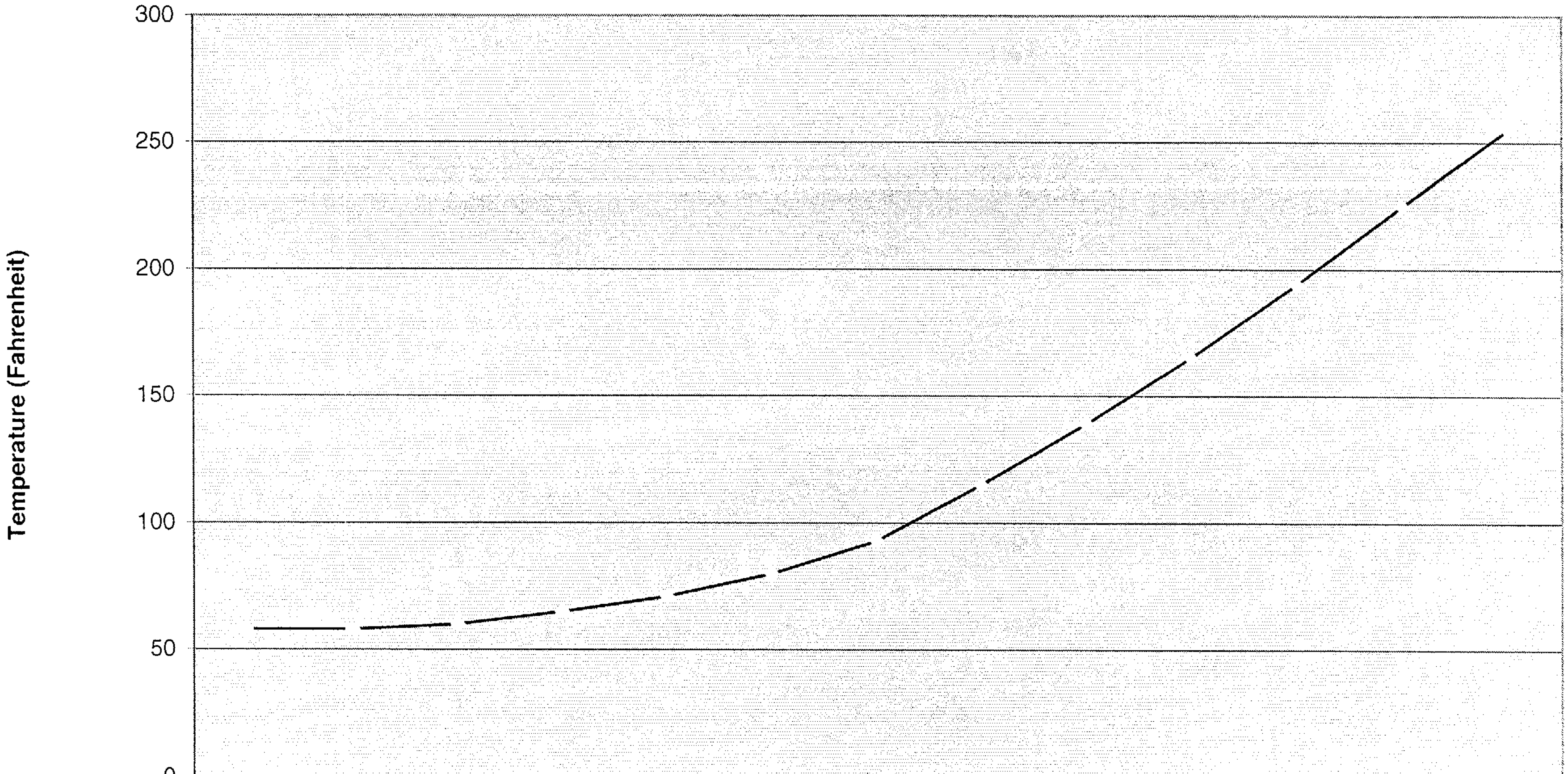
12.5 Technical Report #TR 07870-001, Transco Fire Test Results, Item #3, 6x6" Cable Tray (Reference 6.10)

12.6 Technical Report #TR 07870-001, Transco Fire Test Results, Item #5, 6x36" Cable Tray (Reference 6.10)

12.7 Faxsimile Transmission, Okonite Company, Regional Engineering Office, Bob Finke.

12.8 M.C. Kammer's TWR, Kaowool Test Item Selection, Dated 02/16/2000

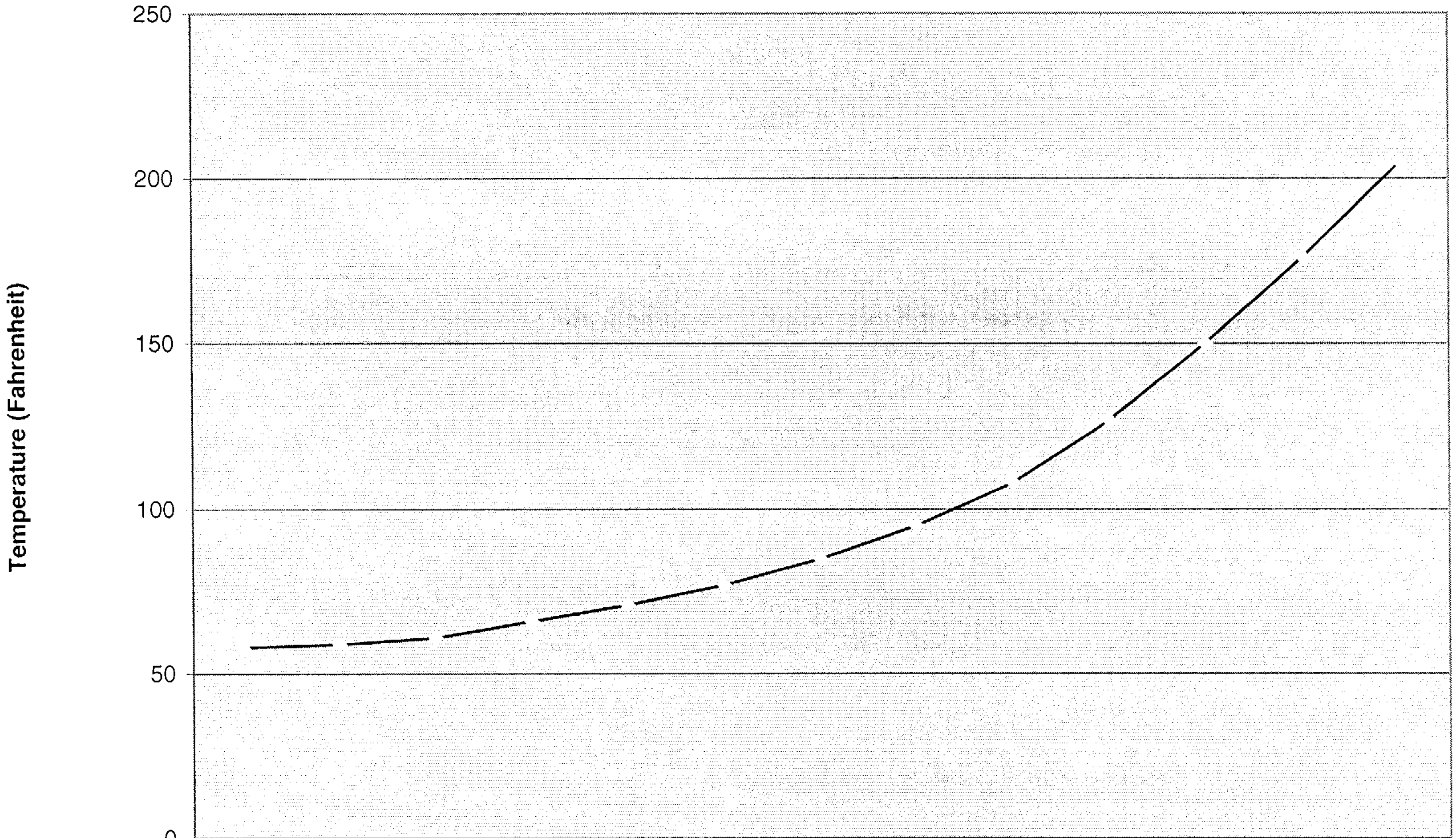
Attachment 12.5
Transco Fire Test Data
Item 3: 6x 6 Cable Tray



	0	5	10	15	20	25	30	35	40	45	50	55	60
— — Bare #8	58	58	60	65	71	80	93	115	139	165	194	225	255

Time (Minutes)

Attachment 12.6
Transco Fire Test Data
Item 5: 6x 36 Cable Tray



	0	5	10	15	20	25	30	35	40	45	50	55	60
— — Bare #8	58	59	61	66	71	77	85	95	108	127	150	176	205

Time (Minutes)

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1.0 PURPOSE

This calculation will document the adequacy of the cable ampacity considerations associated with cables installed in air drops (Fire Barriers 11-TW, 41-TW, 42-TW and 45-TW) and cables routed through junction/pull boxes (Fire Barriers 7-TW, 12-TW, 13-TW, and 51-TW) that were originally wrapped with three (3) one inch thick layers of Kaowool Ceramic blanket material. ECR 50205 proposes modifying several air drop and junction/pull box fire barrier installations to achieve Appendix R-required protection.

2.0 SCOPE

When installed over a raceway - cable, conduit, cable tray or pull boxes, the Kaowool blanket wrap effectively creates a new raceway. It reduces the heat dissipation capability of power cables, considerably increasing the temperature of the cables. Conventional ampacity calculations apply derating factors to determine the maximum amount of current the cable system can carry without increasing the temperature to such a point that the cable begins to degrade.

V.C. summer utilizes three, one-inch (1") thick Kaowool blankets (Triple Wrap-TW) at a density of 8 lbs cu. ft. to provide one (1) hour Appendix R separation of redundant safe shutdown equipment. The Nuclear Regulatory Commission evaluated the fire-resistive capabilities of Kaowool fire barriers and concluded there was no sound technical basis for concluding that Kaowool barriers provide adequate fire protection for equipment that needs to remain functional during and after a nuclear power plant fire. During December,1999, V.C. Summer contracted Transco Products to conduct a full scale fire endurance test at Omega Point Test Laboratory to establish the actual fire resistive performance of the installed Kaowool configurations. When subjected to the ASTM E-119 fire test, some of the cables did not successfully meet the acceptance criteria of Generic Letter (GL) 86-10, Supplement 1. V.C. Summer Station is requesting exemptions from 10CFR50 Appendix R to qualify the previous one (1) hour triple wrap (TW) fire barriers for a forty-five (45) minute rating (Ref. 6.38).

ECR 50205 proposes the application of two (2) additional 1" layers of the Kaowool blanket material to achieve an adequate level of fire protection for post-fire safe shutdown capability. The two (2) additional layers will be installed over the existing triple wrap for the air drop cables in barriers (11-TW, 41-TW, 42-TW and 45-TW) and the junction/pull boxes in barriers (7-TW, 12-TW, 13-TW and 51-TW) containing a smaller thermal mass than those tested by Transco Corporation at Omega Point Test Laboratories. Additionally, ECR 50205 proposes installing un-energized cables within the Air Drop fire barriers (11-TW, 41-TW, 42-TW and 45-TW) to increase the thermal mass, improving the heat dissipation, therefore decreasing the temperature within the barrier.

This calculation will ensure the adequacy of the size of the cables for the proposed five (5) inch layer installation. It will analyze the proposed cable configurations to ensure that the temperature rise resulting from the required electrical load (adjusted for environmental conditions) does not exceed the allowable temperature for maintaining the cable ampacity – temperatures for which the cable is rated or the cable has demonstrated functionality.

This calculation is applicable to the raceways in which two (2) additional layers of Kaowool Ceramic Fiber Blanket material will be installed per ECR 50205.

Table 2.0-1 identifies the cable air drops.

Table 2.0-1
Cable Air Drops

Fire Barrier	Circuit Number	Cable Number	Cable Type	Conductor Description
11-TW	CSM11B		EK-A1E	3/C, 4/0 AWG
	CSM42B		EK-A1E	3/C, 4/0 AWG
41-TW	CCE21A		EK-A3B	2/C, 6 AWG
	XX-3116X	BIJ46XA	EK-B1G	2/C, 12 AWG
		CCM16A	EK-B1G	2/C, 12 AWG
42-TW	CCM44B		EK-B1K	5/C, 12 AWG
	XX-3115B	BIJ56XA	EK-B1G	2/C, 12 AWG
		CCM26A	EK-B1G	2/C, 12 AWG
45-TW	CCM38C		EK-A1E	3/C, 4/0 AWG
	CCM39C		EK-A1E	3/C, 4/0 AWG

Table 2.0-2 identifies the cable routed through pull boxes onto which two (2) additional layers of Kaowool Ceramic Fiber Blanket material will be installed.

Table 2.0-2
Cables In Pull Boxes

Fire Barrier	Raceway Identification	Cable Number	Circuit Number	Cable Type	Conductor Description
7-TW	PB-CS10 (18"x2"x2")	CSM1A		EK-A1E	3/C, 4/0 AWG
12-TW	PB-CS117 (30"x4"x4")	XX-2048C	YY-36C		
			CSC264XC	EK-B1L	7/C, 12 AWG
			VLC12C	EK-B1L	7/C, 12 AWG
		XX-2511C	YY-36C		
			CSC264XC	EK-B1L	7/C, 12 AWG
			VLC12C	EK-B1L	7/C, 12 AWG
13-TW	PB-CS112 (30"x4"x4")	XX-3153C	CSC264XC	EK-B1L	7/C, 12 AWG
			VLC12C	EK-B1L	7/C, 12 AWG
	PB-CS118 (30"x4"x4")	XX-2511C	YY-36C		
			CSC264XC	EK-B1L	7/C, 12 AWG
			VLC12C	EK-B1L	7/C, 12 AWG
		XX-2512C	YY-36C		
			CSC264XC	EK-B1L	7/C, 12 AWG
			VLC12C	EK-B1L	7/C, 12 AWG
51-TW	PB-VL30 (20"x3"x3")	VLC44B		EK-A3G	3/C, 6 AWG
	PB-VL31 (20"x3"x3")				

This calculation will consider three (3) cases:

- Appendix R Postulated ASTM E-119 Fire Condition (1640°F, Forty-five Minutes)
- Normal Conditions - Service conditions for normal operations that would not result in ambient conditions that exceed the normal operating termperature rating (90°C, 194°F) of the cable (Ref. 6.23)
- Accident Conditions - Service conditions for accident Scenarios that would not result in ambient conditions that exceed the emergency overload termperature rating (130°C, 266°F) of the cable (Ref. 6.23). These service conditions would require different loads to be energized than would be expected during normal plant operations.

3.0 COMPUTER PROGRAMS

None

4.0 ASSUMPTIONS

4.1 Current-carrying cables generate heat in proportion to the load and their individual cross-sectional areas. Convection heat flow is proportional to surface area while conduction heat flow is proportional to cross-sectional area (Ref. 6.5). The basic equation for conductive heat transfer will be utilized to calculate the temperature rise resulting from the installed cable load (Ref. Attachment 12.1). The heat contribution from convective and radiative heat transfer is assumed to be negligible.

4.2 A Fire Endurance test conducted by Transco Products Inc. and performed at Omega Point Test Labs documented the temperature profile of three (3) inches of Kaowool barrier material (Ref. 6.10). Documentation of the temperature profile utilizing five (5) inches of the Kaowool brand of ceramic fire barrier material, as proposed by ECR 50205, was not attainable. However, Attachments 12.5 and 12.6 present an estimated temperature profile provided by Kaowool Manufacturer, Thermal Ceramics, for three (3) and five (5) layers. This information was calculated by Thermal Ceramics' Engineering Department (Ref. Attachment 12.7) and is included for comparison of the insulation properties of three (3) layers versus five (5) layers of the barrier material.

4.3 Table 4.3
Equipment Qualification Data
(Ref. 6.25, Sheets 3-24, 3-40, 3-41, 3-86, 3-135, 3-136, 3-139 and 3-140)

Fire Barrier	Room	EQ Zone	Normal Oper. Cond. Max. Room/Zone Temp (°F/°C)		Accident Scenario Max. Room/Zone Temp (°F/°C)	
7-TW	AB 00-02E	AB-80	94	34.4	115	46.1
11-TW	AB 00-02E	AB-80	94	34.4	115	46.1
12-TW	AB 12-28	AB-22	92	33.3	96	35.6
13-TW	AB 36-18	AB-38	104	40	115	46.1
41-TW	IB 26-01	IB-04	96	35.6	245	118.3
42-TW	IB 26-01	IB-04	96	35.6	245	118.3
45-TW	IB 26-01	IB-04	96	35.6	245	118.3
51-TW	IB 51-01 & IB 51-02	IB-06	88	31.3	90	32.2

4.4 The Transco Test configuration (Ref. 6.10) included only three (3) 1" wraps of the barrier material. No test documentation is available to demonstrate the time temperature profile with five (5) 1" wraps. Attachment 12.5 presents a graphical comparison of the temperature profiles of a cable air drop wrapped in the Transco-tested three (3) layer configuration and an estimation of internal temperature by Thermal Ceramics (Ref. 6.30) given a cable air drop wrapped in three (3) and five (5) layers of Kaowool. The Transco Test (three 1" wraps) information is the most conservative (highest) temperature profile. Therefore, the Transco Test temperature data will represent the barrier internal temperature.

4.5 Attachment 12.5 is a graphical comparison of the cable air drop temperature profiles inside of the blanket material at various intervals. The temperature at Time=5 minutes (63°F/17.2°C) will conservatively bound the ambient temperature for the cables in air drops during Normal and Accident service conditions. This value is conservative in that the ASTM-E-119 fire at time T=5 minutes results in 1000°F/538°C ambient temperature outside of the barrier (Ref. Attachment 12.2). This 1000°F/538°C temperature is higher than the maximum temperatures that are postulated given normal and accident conditions. (Refer to Table 4.3.) At five (5) minutes into the ASTM E-119 fire (Time=5 Minutes), the 1000°F/538°C ambient temperature outside of the Kaowool barrier renders a maximum temperature of 145.4°F/63°C inside of the Kaowool barrier given *Normal and Accident* service conditons.

4.6 Attachment 12.5 is a graphical comparison of the cable air drop temperature profiles inside of the blanket material at various intervals. Although the Transco Test configuration included only three (3) 1" wraps of the barrier material, no test documentation is available to demonstrate the time temperature profile with five (5) 1" wraps. Therefore, the Transco Test (three 1" wraps) information renders the most conservative temperature profile. The maximum temperature 370°C (698°F) at time T=45 minutes will constitute the ambient temperature for the cables in air drops subjected to the *Appendix R* ASTM E-119 fire scenerio.

4.7 The Transco test item #8 (Ref. 6.10) included a 12"x12"x6" junction box, a much larger specimen than would render a conservative relationship to those pull boxes installed in barriers (7-TW, 12-TW, 13-TW and 51-TW). The barriers considered in this calculation (7-TW, 12-TW, 13-TW and 51-TW) contain a smaller thermal mass and have smaller dimensions than the box that was tested by Transco Coroporation at Omega Point Test Lab. Table 2.0-2 identifies the sizes of the pull boxes that are installed in raceways that are wrapped with three 1" layers of Kaowool fire barrier material. This population includes those that contain a smaller thermal mass than the 12"x12"x6" junction box that was previously tested in the Transco Fire Test. The sizes of the boxes within barriers considered in this calculation (7-TW, 12-TW, 13-TW and 51-TW) range from 2"x2" to 4"x4".

The area contained within the pull boxes of fire barriers 12-TW and 13-TW is 16 Inch^2. The area contained within the 4" conduit (πr^2) is 12.6Inch^2. The temperature profile of the tested 4" conduit (Attachment 12.4) will conservatively approximate the temperature profile of the smaller pull box configurations (12-TW and 13-TW).

The area contained within the pull boxes of fire barriers 7-TW and 51-TW ranges from 4 Inch^2 (7-TW) to 9 Inch^2 (51-TW). The area contained within the 1" conduit (πr^2) is 3.1 Inch^2. The temperature profile of the tested 1" conduit (Attachment 12.7) will conservatively approximate the temperature profile of the smaller pull box configurations (7-TW and 51-TW).

4.8 Attachment 12.4 is a graphical comparison of the Open Air and Surface Mounted 4" conduit temperature profiles inside of the blanket material at various intervals. The Transco Test configuration included only three 1" wraps of the barrier material, no test documentation is available to demonstrate the time temperature profile with five 1" wraps. The Open Air 4" Conduit (three 1" wraps) information renders the most conservative temperature profile.

4.9 Attachment 12.6 presents a graphical comparison of the temperature profiles of 4" Open Air conduit wrapped in the Transco-tested three (3) layer configuration and an estimation of internal temperature by Thermal Ceramics given 4" conduit wrapped in three (3) and five (5) layers of Kaowool. Although the Transco Test configuration included only three 1" wraps of the barrier material, no test documentation is available to demonstrate the time temperature profile with five 1" wraps. Therefore, the Transco Test (three 1" wraps) information is the most conservative temperature profile.

4.10 Attachment 12.6 presents a graphical comparison of the temperature profiles of 4"Open Air conduit wrapped in the Transco-tested three (3) layer configuration and an estimation of internal temperature by Thermal Ceramics given 4" conduit wrapped in three (3) and five (5) layers of Kaowool. The temperature at Time=5 minutes (16.1°C/61°F) will conservatively bound the ambient temperature for the cables in air drops during Normal and Accident service conditions. This value is conservative in that the ASTM-E-119 fire at time T=5 minutes results in 1000°F/538°C ambient temperature outside of the barrier (Ref. Attachment 12.2). This 1000°F/538°C temperature is higher than the maximum temperatures that are postulated given normal and accident conditions. (Refer to Table 4.3.) At five (5) minutes into the ASTM E-119 fire (Time=5 Minutes), the 1000°F/538°C ambient temperature outside of the Kaowool barrier renders a maximum temperature of 16.1°C/61°F inside of the Kaowool barrier given *Normal and Accident* conditions.

4.11 Attachment 12.6 presents a graphical comparison of the temperature profiles of 4"Open Air conduit wrapped in the Transco-tested three (3) layer configuration and an estimation of internal temperature by Thermal Ceramics given 4" conduit wrapped in three (3) and five (5) layers of Kaowool. The maximum temperature 99.4°C (211°F) at time T=45 minutes will constitute the *ambient temperature* for the Fire Barrier 12-TW and 13-TW cables in pull/junction boxes subjected to the *Appendix R* ASTM E-119 fire scenerio.

4.12 The normal and accident operating conditions are considered in the scope of this calculation. Since the maximum allowable Normal operating temperature is considerably less than the Accident/Transient allowable temperature, the normal operating temperature will conservatively represent the peak acceptable temperature for both the Normal and Accident Conditions.

4.13 The temperature profile within the cable is linear/finite/constant. The temperature does not change with time. Steady state heat transfer occurs when the temperature at every point within the body is independent of time (Ref. 5.25, Page 2). Each case considered in this calculation (Appendix R Scenario, Normal Condition and Accident Condition) will conservatively assume a worse case constant temperature for the Kaowool barrier internal ambient condition.

4.14 The operating temperature for power cables must take into account the temperature rise due to cable I^2R losses. The use of fire barriers or wraps may affect the qualified life of a cable by inhibiting the transfer of heat from the cable.

No ampacity derating factors are applied to control and instrument cables due to the type of service and low current levels. Due to the small or negligible currents, or their intermittent operation, there is no heat rise from I^2R losses attributable to control or instrumentation cables. Therefore fire wraps around control or instrumentation cables do not affect their qualified lives.

Although several of the circuits in the subject fire barriers are control cables with small currents and/or intermittnet loads, the loads will conservatively be included in this calculation.

4.15 Attachments 12.11 and 12.12 present the options for installation of the additional thermal mass cables around the existing raceway cables within the Cable Air Drop raceways (Ref. Assumption 4.15). The installation option identified in Attachment 12.11 is the ECR 50205 conservative configuration. In the event that as-installed conditions do not facilitate installation of the three (3) thermal mass cables around existing raceway cables Attachment 12.12 permits installation of the three (3) thermal mass cables around each raceway cable. The Attachment 12.11 configuration, assumed in this calculation, will render a more conservative (less) thermal mass condition than the Attachment 12.12 condition.

Additionally, this calculation computes the heat generated prior to and subsequent to the ECR 50205 installation of the thermal mass cables for the cable air drop cases. For the purpose of computation, the effect of the thermal mass cables will be applied to a power cable (Ref. Assumption 4.14) in cases in which power and control/instrumentation cable reside in the same raceway.

4.16 The contribution of the thermal mass of the spared (YY Circuits) and voided circuits will not be considered in this calculation. This assumption adds conservatism to those raceways (junction/pull boxes) whose size is approximated by a 4" open air conduit (Fire Barriers 12-TW and 13-TW, Ref. Assumption 4.8) because this calculation does not take credit for the effect of the thermal mass of the spared and voided cable(s).

4.17 The contribution of the thermal mass of cables that are installed in a raceway and are un-energized will only be considered in the computations of heat generated in cable air drop cases given the Appendix R scenerio. Due to the elevated values that establish the internal temperature of the raceway (Ref. 6.10), the available margin in the cable air drop cases, Appendix R scenerio, takes credit for all of the thermal mass that is available within the barrier. Specifically, the calculation computes the heat generated within the air drop barriers prior to, and subsequent to, the ECR 50205 upgrade that will install the additional thermal mass cables. This assumption adds conservatism to the junction/pull box cases in which considerable margin exists without taking credit for the thermal mass of the existing raceway cables.

5.0 DESIGN INPUTS

5.1 Cable Resistance Data Conversion - Appendix R Scenario

Cables In Air Drops

The dc resistance at some other temperature is determined by the relationship:

$R_{370°C} = R_{25} [1 + \propto_{t25°C} (t_{370°C} - t_{25°C})]$ (Ref. 6.35, Page 4.8 – 4.9)

$\propto_{t25°C} = 0.00385$ (Ref. 6.35, Page 4.9, Table 4-3)

$R_{370} = R_{25} [1 + 0.00385(370°C - 25°C]$

$R_{370} = R_{25} [2.3283]$

Conductor Size	DC Resistance @ 25°C (77°F) (Ohms/1000 ft) (Table 1-3)	DC Resistance @ 370°C (698°F) (Ohms/1000 ft) (Equation)	AC/DC Resistance Ratio @ 60 Hertz (Table 1-5)	AC Resistance @ 370°C (698°F) (Ohms/1000 ft)
12 AWG	1.62	3.7718	1.000	3.7718
6 AWG	0.403	0.9383	1.000	0.9383
4/0 AWG	0.05	0.1164	1.004	0.1169

5.2 Cable Resistance Data Conversion - Appendix R Scenario Open Air 4" Conduit

Conductor Size	DC Resistance @ 25°C (77°F) (Ohms/1000 ft) (Table 1-3)	Temp Corr. Factor @ 100°C (211°F)* (Table 1.4)	AC/DC Resistance Ratio @ 60 Hertz (Table 1-5)	AC Resistance @ 100°C (211°F)* (Ohms/1000 ft)
12 AWG	1.62	1.289	1.000	2.0881
6 AWG	0.403	1.289	1.000	0.5195
4/0 AWG	0.05	1.289	1.004	0.0647

- 211°F converts to 99.4°C. However, 100°C will conservatively be utilized to facilitate use of the tabular resistance values.

(Reference 6.4, Tables 1-3, 1-4 and 1-5)

Open Air 1" Conduit

The dc resistance at some other temperature is determined by the relationship:

326°F converts to 163.3°C. However, 164°C will conservatively be utilized to facilitate use of the tabular resistance values.

$R_{164°C} = R_{25°C}\,[1 + \propto_{t25°C}\,(t_{164°C} - t_{25°C})]$ (Ref. 6.35, Page 4.8 – 4.9)

$\propto_{t25°C} = 0.00385$ (Ref. 6.35, Page 4.9, Table 4-3)

$R_{164°C} = R_{25°C}\,[1 + 0.00385(164°C - 25°C]$

$R_{164°C} = R_{25°C}\,[1.5352]$

Conductor Size	DC Resistance @ 25°C (77°F) (Ohms/1000 ft) (Table 1-3)	DC Resistance @ 164°C (326°F) (Ohms/1000 ft) (Equation)	AC/DC Resistance Ratio @ 60 Hertz (Table 1-5)	AC Resistance @ 164°C (326°F) (Ohms/1000 ft)
12 AWG	1.62	2.4869	1.000	2.4869
6 AWG	0.403	0.6187	1.000	0.6187
4/0 AWG	0.05	0.0768	1.004	0.0771

5.3 Cable Resistance Data Conversion - Normal/Accident Scenario
Cables In Air Drops

Conductor Size	DC Resistance @ 25°C (77°F) (Ohms/1000 ft) (Table 1-3)	Temp Corr. Factor @ 18°C (63°F) * (Table 1.4)	AC/DC Resistance Ratio @ 60 Hertz (Table 1-5)	AC Resistance @ 18°C (63°F)* (Ohms/1000 ft)
12 AWG	1.62	0.973	1.000	1.5763
6 AWG	0.403	0.973	1.000	0.3921
4/0 AWG	0.05	0.973	1.004	0.0488

- 63°F converts to 17.2°C. However, 18°C will conservatively be utilized to facilitate use of the tabular resistance values.

(Reference 6.4, Tables 1-3, 1-4 and 1-5)

5.4 Cable Resistance Data Conversion - Normal/Accident Scenario
Open Air 4" Conduit

Conductor Size	DC Resistance @ 25°C (77°F) (Ohms/1000 ft) (Table 1-3)	Temp Corr. Factor @ 17°C (61°F)* (Table 1.4)	AC/DC Resistance Ratio @ 60 Hertz (Table 1-5)	AC Resistance @ 17°C (61°F) (Ohms/1000 ft)
12 AWG	1.62	0.969	1.000	1.5698
6 AWG	0.403	0.969	1.000	0.3905
4/0 AWG	0.05	0.969	1.004	0.0486

- 61 F converts to 16.1°C. However, 17°C will conservatively be utilized to facilitate use of the tabular resistance values.

Open Air 1" Conduit

Conductor Size	DC Resistance @ 25°C (77°F) (Ohms/1000 ft) (Table 1-3)	Temp Corr. Factor @ 15°C (58°F)* (Table 1.4)	AC/DC Resistance Ratio @ 60 Hertz (Table 1-5)	AC Resistance @ 15°C (58°F)* (Ohms/1000 ft)
12 AWG	1.62	0.961	1.000	1.5568
6 AWG	0.403	0.961	1.000	0.3873
4/0 AWG	0.05	0.961	1.004	0.0482

- 58 F converts to 14.4°C. However, 15°C will conservatively be utilized to facilitate use of the tabular resistance values.

(Reference 6.4, Tables 1-3, 1-4 and 1-5)

5.5 The insulation emergency overload temperature rating is for those situations in which load current is higher than normal but is not expected to last more than one hundred (100) hours at any given time or more than a total of five hundred (500) hours in the life of the cable. (Ref. 6.24) This emergency overload temperature is a valid value for the peak acceptable temperature for the accident Scenario.

5.6 Circuits identified in Table 5.6.1 and 5.6.2 with 5 Amp loads (Cable Type EK-B1) are 120VAC or 125VDC control circuits. This 5 Amp maximum load is conservatively assumed based on the V.C. Summer Electrical criteria for classifying the circuit as a control circuit.

Circuits larger than #10AWG or carrying greater than five (5) Amps continuous load should not be run in control tray (Ref. 6.31, Note 5). The Cable And Raceway Design Basis Document (Ref. 6.18, Section 3.2) describes the cable tray systems, "The 480V Control Cable Tray system contains control cables, small 480V power cables (No. 10 AWG and smaller) and small DC power feeds (No. 10 AWG and smaller). All of these cables carry 5 Amps or less. Single phase, 120V ac circuits (No. 10 AWG and smaller) carrying 5 Amps or less are also run in the control trays."

5.7 Cable Data

The Cable Data listed in Tables 5.7.1 and 5.7.2 was obtained from the following references:

Column	References
Circuit Number	6.8, 6.19
From Device	6.8, 6.15
To Device	6.8, 6.15
Continuous Load Current	6.15
Cable Type	6.8
Cable Size	6.20, 6.26
Cable Outside Diameter	6.26
Cable Area	6.26

TABLE 5.7.1
Cable Air Drop - Cable Data

Fire Barrier	Cable Number	From Device	To Device	Continuous Load Current	Cable Type/Size	Cable Outside Diameter (Inches)	Cable Area (Square Inches)
11-TW	CSM11B	XSW1DB, 7.2kV Switchgear Bus 1DB, Unit 15	XPP043B, Charging Injection Pump B	65 FLA	EK-A1E 3/C, 4/0 AWG	2.424	4.6148
11-TW	CSM42B	XSW1DB, 7.2kV Switchgear Bus 1DB, Unit 14	XET2002C, Transfer Switch for Charging Injection Pump C	65 FLA	EK-A1E 3/C, 4/0 AWG	2.424	4.6148
41-TW	CCE21A	DPN1HA1, DC DIST. PANEL 1HA1	XET2001C, Transfer Switch for Comp. Cooling Pump C	15 A (125Vdc)	EK-A3B 2/C, 6 AWG	0.82	0.5281
41-TW	BIJ46XA	XSW1DA, 7.2kV Switchgear Bus 1DA, Unit 7	XET2001C, Transfer Switch for Comp. Cooling Pump C	5A (125Vdc)	EK-B1G 2/C, 12 AWG	0.61	0.2922
41-TW	CCM16A	XSW1DA, 7.2kV Switchgear Bus 1DA, Unit 8	XET2001C, Transfer Switch for Comp. Cooling Pump C	5A (125Vdc)	EK-B1G 2/C, 12 AWG	0.61	0.2922
42-TW	CCM44B	XSW1DB, 7.2kV Switchgear Bus 1DB, Unit 11	XES2001C, Speed Switch for Comp. Cooling Pump C	5A (125Vdc)	EK-B1K 5/C, 12 AWG	0.74	0.4301
42-TW	BIJ56XB	XSW1DB, 7.2kV Switchgear Bus 1DB, Unit 11	XET2001C, Transfer Switch for Comp. Cooling Pump C	5A (125Vdc)	EK-B1G 2/C, 12 AWG	0.61	0.2922
42-TW	CCM26B	XSW1DB, 7.2kV Switchgear Bus 1DB, Unit 13	XES2001C, Speed Switch for Comp. Cooling Pump C	5A (125Vdc)	EK-B1G 2/C, 12 AWG	0.61	0.2922

TABLE 5.7.1, Continued
Cable Air Drop - Cable Data

Fire Barrier	Cable Number	From Device	To Device	Continuous Load Current	Cable Type/Size	Cable Outside Diameter (Inches)	Cable Area (Square Inches)
45-TW	CCM38C	XES2001C, Speed Switch For Comp. Cooling Pump C	XPP01C, Component Cooling Pump C (High Speed)	45 FLA	EK-A1E 3/C, 4/0 AWG	2.424	4.6148
	CCM34C	XES2001C, Speed Switch For Comp. Cooling Pump	XPP01C, Component Cooling Pump C (Low Speed)	45 FLA	EK-A1E 3/C, 4/0 AWG	2.424	4.6148

Table 5.7.2
Cables In Pull Boxes - Cable Data

Fire Barrier	Cable Number	From Device	To Device	Continuous Load Current	Cable Size	Cable Outside Diameter (Inches)	Cable Area (Square Inches)
7-TW	CSM1A	XSW1DA, 7.2kV Switchgear Bus 1DA, Unit 5	XPP043A, Charging Injection Pump A	65 FLA	EK-A1E 3/C, 4/0 AWG	2.424	4.6148
12-TW	CSC264XC			CIRCUIT VOID			
	VLC12C	Charging Pump Accessories Equipment Cabinet	Term Box TB-CS102 For 120V Control Of XFN47	5 A	EK-B1L 7/C, 12 AWG	0.80	0.5207
13-TW	CSC264XC			CIRCUIT VOID			
	VLC12C	Charging Pump Accessories Equipment Cabinet	Term Box TB-CS102 For 120V Control Of XFN47	5 A	EK-B1L 7/C, 12 AWG	0.80	0.5207
51-TW	VLC44B	ESF Motor Control Center 1DB2X, Unit 4IJ	XFN76-XL, ESF Swgr 1DB Cooling Unit	19.5 A	EK-A3G 3/C, 6 AWG	0.87	0.5945

5.8 Under Normal and Accident conditions the raceways will not be exposed to ambient conditions that impose internal raceway temperatures that exceed the cable insulation normal operating 90°C (194°F) temperature rating or emergency overload 130°C (266°F) temperature rating (Non-Appendix R Conditions).

Under the Appendix R postulated ASTM E-119 fire condition, the Nuclear Regulatory Commission has stipulated that no other failures, such as those resulting from random single failures, accidents or seismic events need to be postulated simultaneously with the fire. (Ref. 6.17, Section 2.1)

The Section 5.7 Tables include a discussion of the cable loads.

Table 5.8.1
Fire Barrier 11-TW Loads

Cable Number	Load Description	Discussion
CSM11B	XPP043B, Charging Injection Pump B	One (1) pump is normally running, one (1) is a non-running pump and the third is a spare with its breaker(s) normally racked out. The third pump, C, can be powered by either bus 1DA or 1DB, depending on the position of the Transfer Switch.(Ref. 6.16, Section 9.3.4.2.5.2) Therefore, circuits CSM11B or CSM42B will be not be energized simulatenously. **Either CSM11B or CSM42B can be energized during the Appendix R, Normal and Accident Scenarios.**
CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C	One (1) pump is normally running, one (1) is a non-running pump and the third is a spare with its breaker(s) normally racked out. The third pump, C, can be powered by either bus 1DA or 1DB, depending on the position of the Transfer Switch.(Ref. 6.16, Section 9.3.4.2.5.2) Therefore, circuits CSM11B or CSM42B will be not be energized simulatenously.. **Either CSM11B or CSM42B can be energized during the Appendix R, Normal and Accident Scenarios.**

Table 5.8.2
Fire Barrier 41-TW Loads

Cable Number	Load Description	Discussion
CCE21A	XET2001C, Transfer Switch for Comp. Cooling Pump C	'A' Train 125Vdc Power To Comp. Cooling Pump C Transfer Switch for control relays and pilot lights. **CCE21A can be energized in the Appendix R, Normal and Accident Scenarios.**
BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	BISI input, "CC Pump C Transfer Switch Aligned to Channel B". **BIJ46XA can be energized in the Appendix R, Normal and Accident Scenarios.**
CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	125Vdc relay contact circuit ('C' Pump Aligned to 'B' Channel). **CCM16A can be energized in the Appendix R, Normal and Accident Scenarios.**

Table 5.8.3
Fire Barrier 42-TW Loads

Cable Number	Load Description	Discussion
CCM44B	XES2001C, Speed Switch for Comp. Cooling Pump C	'A' Train 125Vdc Power To Comp. Cooling Pump C Transfer Switch for control relays and pilot lights. **CCM44B can be energized in the Appendix R, Normal and Accident Scenarios.**
BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	BISI input, "CC Pump C Transfer Switch Aligned to Channel A". **BIJ56XB can be energized in the Appendix R, Normal and Accident Scenarios.**
CCM26B	XES2001C, Speed Switch for Comp. Cooling Pump C	125Vdc relay contact circuit ('C' Pump Aligned to 'A' Channel). **CCM26B can be energized in the Appendix R, Normal and Accident Scenarios.**

Table 5.8.4
Fire Barrier 45-TW Loads

Cable Number	Load Description	Discussion
CCM38C	XPP01C, Component Cooling Pump C (High Speed)	The Component Cooling pumps have two (2) speed capability. Operation of the pump at high speed is initiated only by manual operator action and is administratively controlled. One pump operating in the high speed mode satisfies normal shutdown criteria , but the capability of achieving a safe shutdown for normal operation or subsequent to an accident is not contingent upon the availability of the high speed mode. **Either CCM38C or CCM39C can be energized in the Appendix R, Normal and Accident Scenarios.**
CCM39C	XPP01C, Component Cooling Pump C (Low Speed)	The Component Cooling pumps have two (2) speed capability. Operation of the pump at high speed is initiated only by manual operator action and is administratively controlled. One pump operating in the high speed mode satisfies normal shutdown criteria , but the capability of achieving a safe shutdown for normal operation or subsequent to an accident is not contingent upon the availability of the high speed mode. **Either CCM38C or CCM39C can be energized in the Appendix R, Normal and Accident Scenarios.**

Table 5.8.5
Fire Barrier 7-TW Loads

Cable Number	Load Description	Discussion
CSM1A	XPP043A, Charging Injection Pump B	One (1) pump is normally running, one (1) is a non-running pump and the third is a spare with its breaker(s) normally racked out. The third pump, C, can be powered by either bus 1DA or 1DB, depending on the position of the Transfer Switch.(Ref. 6.16, Section 9.3.4.2.5.2) Therefore, circuits CSM11B or CSM42B will be not be energized simulatenously. **CSM1A can be energized during the Appendix R, Normal and Accident Scenarios.**

Table 5.8.6
Fire Barrier 12-TW Loads/13-TW Loads

Cable Number	Load Description	Discussion
CSC264XC	Circuit Void	
VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	120V control circuit for control relay contacts. **VLC12C can be energized in the Appendix R, Normal and Accident Scenarios.**

Table 5.8.7
Fire Barrier 51-TW Loads

Cable Number	Load Description	Discussion
VLC44B	XFN76-XL, ESF Swgr 1DB Cooling Unit	480V power circuit.. **VLC44B can be energized in the Appendix R, Normal and Accident Scenarios.**

5.9 The cables wrapped in the blanket material are all qualified cable per IEEE-383. (Refs. 6.23, Section 2:04.8; 6.36, Section 2:04.8; and 6.37, Section 2:04.3.g). IEEE-383 qualified cable has a damage threshold temperature of 371.1°C (700°F) (Ref.6.34). This temperature, ***371.1°C (700°F),*** will constitute the ***peak acceptable temperature*** for the Appendix R Fire Condition given cables in <u>air drops</u>.

5.10 Equipment Qualification Reports (Tab F of Refs. 6.1, 6.2 and 6.6) document the equipment qualification of subject cables identified in Tables 2.0-1 and 2.0-2. Worst case environmental conditions were imposed by sequential tests for thermal aging, radiation and a simulated Design Basis Event. The cables were subjected to temperatures of 171°C (340°F), multiple peak transients of three hours. This ***171°C (340°F)*** temperature, at which the cables demonstrated functionality, will constitute **the *peak acceptable temperature*** for the Appendix R Fire Condition given cables in <u>pull boxes</u>. Table 5.10 presents a summary of the Equipment Qualification test conditions:

5.11 The Transco Fire test temperature profile data for 4" open air conduit (Ref. 6.30 and Attachment 12.6) at Time T=45 Minutes, ***99.4°C (211°F),*** represents the ***ambient temperature*** of the 12-TW and 13-TW <u>pull box</u> raceways under ASTM E-119 fire conditions. (Refer to Assumption 4.11).

The Transco Fire test temperature profile data for 1" open air conduit (Ref. 6.30 and Attachment 12.7) at Time T=45 Minutes, ***163.3°C (326°F)***, represents the ***ambient temperature*** of the 7-TW and 51-TW <u>pull box</u> raceways under ASTM E-119 fire conditions. (Refer to Assumption 4.7).

5.12 The Transco Fire Test temperature profile data (Ref. 6.10 and Attachment 12.5) is the most conservative for Cable Air Drops subjected to ASTM E-119 fire conditions. At Time T=45 Minutes, ***370°C (698°F)***, represents the raceway's ***ambient temperature*** under ASTM E-119 fire conditions (Refer to Assumption 4.6).

5.13 The respective Cable Specifications SP-0551 (8kV Power Cable), SP-0553 (600V Power Cable), and SP 0554 (600V Control Cable) identify the insulation temperature rating for the subject cables in a Normal service condition. This ***90°C (194°F)*** temperature will constitute the ***peak acceptable temperature*** for the normal and accident conditons. (Ref. Assumption 4.12)

5.14 The respective Cable Specifications SP-0551 (8kV Power Cable), SP-0553 (600V Power Cable), and SP 0554 (600V Control Cable) (Refs. 6.23, Section 2:06.2.2; 6.36, Section 2:06.2.2; and 6.37, Section 2:06.2.2.b) identify the insulation temperature rating for the subject cables in Transient (Accident) service conditions.

5.15 The Transco Fire test temperature profile data (Ref. 6.30 and Attachment 12.5) at Time=5 Minutes presents the tested profile of the raceway. ***17.2°C (63°F)***, conservatively represents the ***ambient temperature*** inside of the Kaowool blanket material during normal operating conditions and accident conditions for the cable air drop configuration. (Ref. Assumption 4.5)

5.16 The Transco Fire test temperature profile data (Ref. 6.30 and Attachment and 12.6) at Time=5 Minutes presents the tested profile of the raceway. ***16.1°C (61°F)***, conservatively represents the ***ambient temperature*** inside of the Kaowool blanket material during normal operating conditions and accident conditions for the cables in pull box in Fire Barriers 12-TW and 13-TW (bounded by 4" conduit) configuration. (Ref. Assumption 4.10)

The Transco Fire test temperature profile data (Ref. 6.30 and Attachment and 12.7) at Time=5 Minutes presents the tested profile of the raceway. ***14.4°C (58°F)***, conservatively represents the ***ambient temperature*** inside of the Kaowool blanket material during normal operating conditions and accident conditions for the cables in pull box in Fire Barriers 7-TW and 51-TW (bounded by 1" conduit) configuration. (Ref. Assumption 4.7)

5.17 Due to the lower temperatures resulting from the time-temperature profiles given the pull/junction box configurations in the Transco Fire Test (Ref. 6.10) a more conservative acceptance criteria will be applied. Design Inputs 5.9 and 5.10 identify the peak acceptable temperatures for the Appendix R Fire Condition given the air drop and pull box configurations, respectively. All of the subject cables, regardless of the configuration, are IEEE-383 qualified cables. IEEE-383 qualified cable has a damage threshold temperature of 371.1°C (700°F) (Ref.6.34). Although this acceptance limit is applicable to all configurations (air drops and pull/junction boxes) and operating conditions (Normal/Accident and Appendix R scenerios), more conservative acceptance limits are utilized for the various configurations and conditions.

Table 5.10
Equipment Qualification Summary Table

EQ Test Report	Relevant B/M	Thermal Aging Conditions	Radiation Exposure	Design Basis Accident Simulation
EQDP-CA1-K03-1	EK-B1	Combined Thermal and Radiation Aging simulation - subjected to a radiation to a cumulative dosage of 5 x 10^7 Rad and 7 day exposure to environmental temperatures of **50°C (122°F)**. Cables electrically energized with 600V potential and 12A current.		Subjected to a 100 day Loss Of Coolant Accident (LOCA) simulation. The LOCA simulation temperature profile includes two, three-hour intervals with peak temperatures of **340°F (171°C)** and a chemical spray is maintained throughout the qualification period. The cables were carrying rated voltage and current while being subjected to the LOCA profile.
EQDP-CA1-K03-2	EK-A3	168 hours at **143°C (289.4°F)**	Subjected to radiation to a cumulative dosage of 2 x 10^8 Rad	Subjected to 30 day and 100 day exposure cycles during Loss Of Coolant Accident (LOCA) simulation. The LOCA simulation temperature profile includes two, three-hour intervals with peak temperatures of **340°F (171°C)** and a chemical spray is maintained throughout the qualification period. The cables were energized at 600V, with #12AWG cables carrying a minimum of 12A while being subjected to the LOCA profile.
EQDP-CA2-001	EK-A1	504 hours at **150°C (302°F)**. Note that the cables were not energized while being subjected to the aging oven temperature of 150°C.	Subjected to radiation to a cumulative dosage of 2 x 10^8 Rad	Subjected to a 100 day Loss Of Coolant Accident (LOCA) simulation. The LOCA simulation temperature profile includes two, three-hour intervals with peak temperatures of **340°F (171°C)** and a chemical spray is maintained throughout the qualification period. The cables were carrying rated voltage and current while being subjected to the LOCA profile

5.17 Table 5.17 provides a summary of the peak acceptable and ambient temperatures for the various operating conditions:

Table 5.17

Temperature Summary

Installation Configuration		Operating Condition	Internal Raceway Ambient Temperature	Peak Acceptable Temperature	Design Input (Ambient/Peak)
Cable Air Drop		Appendix R	370°C (698°F)	371.1°C (700°F)	5.12/5.9
		Normal/Accident	17.2°C (63°F)	90°C (194°F)	5.15/5.13
Pull Box	Fire Barriers 12-TW and 13-TW	Appendix R	99.4°C (211°F)	171°C (340°F)	5.11/5.10
		Normal/Accident	16.1°C (61°F)	90°C (194°F)	5.16/5.13
	Fire Barriers 7-TW and 51-TW	Appendix R	163.3°C (326°F)	171°C (340°F)	5.11/5.10
		Normal/Accident	14.4°C (58°F)	90°C (194°F)	5.16/5.13

5.18 The thermal resistivity (inverse of thermal conductivity) of ethylene-propylene polymer insulation/jacket compound is 400°C-cm/Watt (Refs. 6.23, Section 2:06.2.2; 6.36, Section 2:06.2.2; 6.37, Section 2:06.2.2.b and Attachment 12.9)

5.19 "A comparison of fire test temperature profiles to existing Equipment Qualification and Loss Of Cooling Accident (LOCA) test results or air oven test results is an acceptable approach to demonstrate cable functionality provided the subject analysis incorproates the anticipated temperature rise due to self heating effects of installed power cables with the fire test results." (Ref. 6.12, Section H-1.3.1, Page 146)

5.20 The AC resistance variable, R, in Stolpe's (Ref. 6.5) development presents the resistance in terms of ohms per a specified unit length (Ohms/Ft).

6.0 REFERENCES

6.1 Equipment Qualification Documentation, EQDP-CA2-KO3-1, Kerite 600V Control Cable.

6.2 Equipment Qualification Documentation, EQDP-CA2-KO3-2, Kerite Power And Control Cable.

6.3 NFPA 70, "National Electrical Code", dated 1993.

6.4 The Okonite Company, Engineering Data for Copper and Aluminum Conductor Electrical Cables. Bulletin EHB-98.

6.5 J. Stolpe, "Ampacities For Cables In Randomly-Filled Trays", IEEE Transactions Power Apparatus and Systems, Volume PAS-90, Part 1, Pages 962-974, 1971.

6.6 Equipment Qualification Documentation, EQDP-CA2-001,Okonite 8kV Power Cable.

6.7 CHAMPS Database

6.8 PC-CKS Database

6.9 Specification SP-0836, Kaowool Triple Wrap Raceway Fire Barrier Test For Conduits And Cable Trays

6.10 Technical Report, TR 07870-001, Kaowool Triple Wrap

6.11 EIR-80196, V.C.Summer Kaowool Triple Wrap Evaluation

6.12 NEI – Draft Regulatory Guide DG-1094, "Fire Protection For Operating Nuclear Power Plants"

6.13 Design Calculation No. DC0 8500-018, Cable Sizing Criteria Development

6.14 Thermal Ceramics Position Paper, "Determine The Heat Rise Of Various Cable Carrying Configurations Wrapped With The Firemaster Blanket Fire Protection System"

6.15 Feeder Loads And Effects Database

6.16 V.C. Summer Nuclear Station Final Safety Analysis Report

6.17 DBD Appendix R

6.18 DBD Cable & Raceway System

6.19 Drawing Series, SS-211, Electrical Block Diagram

6.20 Drawing Series, SS-212, Circuit Schedule, Cable Routing and Termination

6.21 "Heat Transfer", Seventh Edition, Holman, J. P., 1990.

6.22 Design Calculation No. DC0 8500-018, Thermal Mass Of Kaowool Fire Barriers

6.23 Specification, SP-551, 8kV Power Cable

6.24 Petty, K. A. EPRI Power Plant Electrical Series, Volume 4, Wire and Cable (Palo Alto: Electric Power Research Institute, 1987).

6.25 Drawing S-021-018, Revision 10, Equipment Qualification Database, Environmental Zone Information.

6.26 Specification, SP-833, Electrical Construction Guide For Cable Installation

6.27 "Theory And Problems Of Heat Transfer", Schaum's Outline Series, Pitts, Donald R. and Sissom, Leighton E., 1977.

6.28 Drawing S-200-951, Fire Barrier Identification List

6.29 Engineering Change Request ECR 50205, Kaowool Triple Wrap Change.

6.30 Faxsimile Transmissions, Thermal Ceramics Corporation, Michael Johnson, Senior Fire Protection Engineer, Dated May 8, 2000 and May 9, 2000.

6.31 Drawing D-224-521, Electrical Nature of Circuit and Circuit Separation Identification

6.32 Kaowool Ceramic Fiber Product Catalog

6.33 Kaowool Ceramic Fiber Blanket Product Data, Thermal Ceramics, Catalog Number 5 14-209, Dated December, 1997.

6.34 Fire PRA Implementation Guide, EPRI TR-105928, December 1995.

6.35 Standard Handbook For Electrical Engineers, Twelth Edition, Fink, Donald G. and Beaty, H. Wayne.

6.36 Specification 553, 600V Power Cable.

6.37 Specification 554, 600V Control Cable.

6.38 Kaowool Fire Barrier Deviation Requests, Request For Deviation To Section III.G.2 of Appendix R to 10CFR Part 50, Operating License #NPF-12.

7.0 METHODOLOGY

7.1 Appendix R Postulated ASTM E-119 Fire Condition

7.1.1 Cables In Air Drops – Fire Barriers 11-TW, 41-TW, 42-TW and 45-TW

The cables wrapped in the blanket material are all qualified cable per IEEE-383. (Refs. 6.23, Section 2:04.8; 6.36, Section 2:04.8; and 6.37, Section 2:04.3.g). IEEE-383 qualified cable has a damage threshold temperature of 371.1°C (700°F) (Ref. 6.34).

The maximum temperature 370°C (698°F) at time T=45 minutes will constitute the *ambient temperature* for the cables in air drops subjected to the Appendix R ASTM E-119 fire scenerio (Ref. Assumption 4.6). Attachment 12.6 presents that this temperature profile will conservatively bound the ambient temperatures in the ECR 50205 proposed additional layers of Kaowool blanket material during Appendix R service conditions. The Attachment 12.6 comparison data presents that the barrier internal temperature of the five (5) layer configuration will be less than that of the three (3) layer configuration.

This calculation will document the amount of heat generated by the load of the cables in the installed configurations and the corresponding temperature rise. The ampacity will be adjusted for the ambient air temperatures that the cable will experience inside the Kaowool barrier at conditions modeled by the Transco Test Temperature Profile at Time =45 Minutes (Attachment 12.5). The maximum ambient temperature at Time =45 Minutes for the Appendix R Scenario is 370°C (698°F) (Design Input 5.12).

The cable air drop cases in which there is minimal temperature margin in the Appendix R condition have been re-evaluated considering the impact of the additional cable mass. The heat generated inside of the three (3) layer barrier at the given internal raceway temperature approaches the peak acceptable temperature. The consideration of the thermal mass resulting from the ECR 50205 installation of three (3) additional un-energized cables will modify the configuration such that the internal barrier temperature is reduced. The increased thermal mass results in decreased internal raceway temperatures.

The calculated temperature rise resulting from the installed loads and the Transco Test Temperature Profile at ambient conditions 370°C (698°F) will be compared to the peak acceptable temperature 371.1°C (700°F) (Design Input 12.9).

7.1.2 Cables Routed In Pull Boxes – Fire Barriers 7-TW, 12-TW, 13-TW and 51-TW

Equipment Qualification Reports (Tab F of Refs. 6.1, 6.2 and 6.6) document the equipment qualification of subject cables identified in Tables 2.0-1 and 2.0-2. Worst case environmental conditions were imposed by sequential tests for thermal aging, radiation and a simulated Design Basis Event.

Equipment Qualification Reports (Tab F of Refs. 6.1, 6.2 and 6.6) document cable operation during a Design Basis Event in which the cable was subjected to Loss Of Coolant Accident (LOCA) conditions. The LOCA conditions were simulated in a steam autoclave while being exposed to a chemical spray. The cables were subjected to multiple three hour transients with peak temperatures of 171°C (340°F). This 171°C (340°F) temperature will constitute the *peak acceptable temperature* for the cables in pull boxes subjected to the Appendix R ASTM E-119 fire scenerio. The cables were subjected to rated current and voltage under the thermal aging conditions. These conditions are conservative in that the Design Basis simulation test was the third in a sequence of progressively severe conditions that demonstrated the cable's qualification.

This calculation will document the amount of heat generated by the load of the cables in the installed configurations and the corresponding temperature rise. The ampacity will be adjusted for the ambient air temperatures that the cable will experience inside the Kaowool barrier at conditions documented in the Transco Test Temperature Profile at Time =45 Minutes (Ref. 6.10 and Attachments 12.3 and 12.4). The maximum ambient temperature at Time =45 Minutes for Fire Barriers 12-TW and 13-TW given the Appendix R Scenario is 99.4°C (211°F). The maximum ambient temperature at Time =45 Minutes for Fire Barriers 7-TW and 51-TW given the Appendix R Scenario is 163.3°C (326°F).

The calculated temperature rise resulting from the installed loads and the Transco Temperature Profile at ambient conditions, 99.4°C (211°F) for Fire Barriers 12-TW and 13-TW and 163.3°C (326°F) for Fire Barriers 7-TW and 51-TW, will be compared to the peak acceptable temperature attained from Equipment Qualification documentation 171°C (340°F).

7.2 Normal/Accident Condition

The respective Cable Specifications SP-0551 (8kV Power Cable), SP-0553 (600V Power Cable), and SP 0554 (600V Control Cable) (Refs. 6.23, Section 2:06.2.2; 6.36, Section 2:06.2.2; and 6.37, Section 2:06.2.2.b) identify the insulation temperature rating for the subject cable in normal and accident service conditions.

Service conditions for normal operations are those that would not result in ambient conditions that exceed the normal operating termperature rating (90°C, 194°F) of the cable (Ref. 6.23)

The insulation emergency overload temperature rating is for those situations in which 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. (Ref. 6.24)

90°C (194°F) temperature will constitute the *peak acceptable temperature*. (Refer to Assumption 4.9)

The Transco Test Temperature Profile data at Time=5 Minutes (Ref. 6.10 and Attachments 12.3, 12.4 and 12.7) conservatively bounds the ambient temperature inside the Kaowool blanket material during normal operating conditions (Ref. Assumption 4.3).

This calculation will document the amount of heat generated and the corresponding temperature rise for the loads that will be energized under normal and accident operating conditions.. The ampacity will be adjusted for the ambient air temperatures that the cable will experience inside the Kaowool barrier at temperatures presented in the Transco Test Temperature Profile at Time =5 Minutes (Ref. 6.10 and Attachments 12.3 and 12.4).

The calculated temperature rise resulting from the loads energized during Normal and Accident Operating Conditions and the Ambient Temperature (Time T=5 Minutes) will be compared to the *peak acceptable temperature* of the cable insulation.

7.3 The Transco Test configuration modeled the installed triple wrap installation (three 1" layers of the Kaowool blanket material). The comparison graphs in Attachments 12.5 and 12.6 present the temperature profiles from the Transco test configuration (three 1" layers of the Kaowool blanket material) and the temperature profiles from a Thermal Ceramics (Manufacturer of the Kaowool bire barrier material) model of the configurations with five 1" layers of the Kaowool blanket material (Ref. 6.30). These graphs present the Transco tested temperatures as the most conservative (highest) values of the internal temperatures within the barriers. Therefore, these values were utilized in this calculation. The Thermal Ceramics temperature data (Ref. 6.30), derived from modeling the five (5) layer configuration, presents that the temperatures would be significantly lower with the ECR 50205 proposed installation of two additional layers of the barrier material.

7.4 ECR 50205 proposes the installation of three additional un-energized EK-A1E B/M cables to increase the thermal mass (improve the heat dissipation) within the air drop fire barriers (11-TW, 41-TW, 42-TW and 45-TW). This aspect of the barrier upgrade is supported by the analysis documented in Design Calculation DC07870-002, Thermal Mass Of Kaowool Fire Barriers (Ref. 6.38). Attachments 12.11 and 12.12 present the options for installation of the additional thermal mass cables within the Cable Air Drop raceways (Ref. Assumption 4.15).

8.0 ACCEPTANCE CRITERIA

Conventional ampacity analysis ensures that the allowed or rated cable ampacity is equal to or greater than the required cable load as adjusted for environmental conditions. This calculation will ensure that the temperature rise resulting from the required cable load (as adjusted for environmental conditions) does not exceed allowed temperatures – temperatures for which the cable is rated or the cable has demonstrated functionality.

8.1 Appendix R Postulated ASTM E-119 Fire Condition – Cable Air Drops

The raceway temperature including the temperature rise due to the existing cable load (adjusted for the environmental conditions given the Transco Test Temperature Profile Data, Ref. 6.10 and Attachments 12.3 and 12.4) should be less than the IEEE-383 qualified cable damage threshold temperature of 371.1°C (700°F). Refer to Design Input 5.17.

$$\text{Temp.}_{\text{Cable Damage Threshold Temp.}} \geq \text{Temp.}_{\text{Rise Due To Cable Load}} + \text{Temp.}_{\text{Ambient Resulting From ASTM E-119 Fire}}$$

8.2 Appendix R Postulated ASTM E-119 Fire Condition – Cables In Pull Boxes

The raceway temperature including the temperature rise due to the existing cable load (adjusted for the environmental conditions given the Transco Test Temperature Profile Data, Ref. 6.10 and Attachments 12.3 and 12.4) should be less than the 171°C (340°F) Equipment Qualification Design Basis Event test temperature. Refer to Design Input 5.17.

$$\text{Temp.}_{\text{EQ Design Basis Event Condition}} \geq \text{Temp.}_{\text{Rise Due To Cable Load}} + \text{Temp.}_{\text{Ambient Resulting From ASTM E-119 Fire}}$$

8.3 Normal/Accident Condition

The internal raceway ambient temperature 58°C (136°F) (Ref. Assumption 4.3) plus the calculated temperature rise given Normal Operating Conditions, should be less than the 90°C (194°F) normal operation insulation temperature rating.

$$\text{Temp.}_{\text{90°C Normal/Accident Cond.}} \geq \text{Temp.}_{\text{Rise Due To Cable Load}} + \text{Temp.}_{\text{Ambient Within Kaowool Blanket}}$$

8.4 This calculation conservatively utilizes internal barrier temperatures given three layers of the barrier material. Attachments 12.5 and 12.6 present graphical comparisions of the internal temperature given configurations with three (3) and five (5) layers of Kaowool. This data presents that the barrier internal temperatures are considerably less with the five (5) layer configuration.

9.0 ANALYSIS

The peak acceptable temperatures and the ambient temperatures for each case (Appendix R Scenario, Normal/Accident Conditions) are identified in the Design Input Section, Table 5.17.

This analysis will document the amount of heat generated and the corresponding temperature rise for the loads that are energized for each case (Appendix R Scenario and Normal/Accident Conditions). The information is tabulated in Section 10, Summary of Results.

9.0.1 Determine Q, Heat Generated By Energized Cable

Cable ampacity is defined by J. Stolpe's basic equation number 8 (Reference 6.5) as:

$$I=\sqrt{\frac{QA}{NR}}$$

Rearranging the Variables,

$$Q=\frac{I^2 NR}{A}$$

Where,

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3).

I = Conductor Current (Amps)

N = Number Of Energized Conductors In The Cable

R = AC Resistance (Ohms/Ft) Of The Conductor At The Maximum Ambient Temperature Of The Cable.

A = Cross-Sectional Area Of The N-Conductor Cable (Inches^2)

9.0.2 Calculate Temperature Rise, ΔT, Resulting From Load Current

The energized cable's temperature rise above the surface temperature is defined by the relationship (Ref. 6.27, Equation 2.25):

$$\Delta T = \frac{r^2 Q}{4k}$$

Where,

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = Cable Outside Radius (Inches)

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3)

k = Thermal Conductivity Of Cable (°C-cm/Watt)

9.1 Appendix R Postulated ASTM E-119 Fire Condition – Fire Barrier 11-TW

9.1.1 Determine Q, Heat Generated By Energized Circuits CSM11B/CSM42B Installation Configuration Prior To ECR 50205

$$Q=\frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

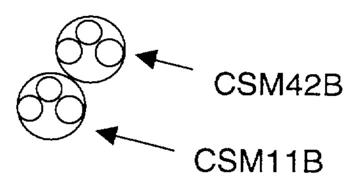
I = Conductor Current (Amps)

N = 3

R = 0.1169 Ohms/1000Ft @ 370°C (698°F)

A = 2 B/M EK-A1E Cables ($Area_{EK\text{-}A1E\ Cable}$)
A = 2 (4.6148 Inches^2)

$$Q=\frac{I^2(3)\left(0.1169/1000Ft\right)}{(2)4.6148Inch^2}\ \frac{1Ft}{12Inch}$$



$$Q=\frac{I^2(3.1665E\text{-}6)\Omega}{Inch^3}$$

Table 9.1-1 facilitates substitution of Current (I) Values:

Table 9.1-1
Fire Barrier 11-TW – Cable Load/Heat Data– Appendix R Fire Condition

<table>
<tr><th>Cable Number</th><th>Load</th><th>Load Summary</th><th>I, Continuous Load Current</th><th>Q, Heat (Watt/Inches³)</th></tr>
<tr><td>CSM11B</td><td>XPP043B, Charging Injection Pump B</td><td>Either CSM11B or CSM42B can be energized during the Appendix R Scenario.</td><td rowspan="2">65 FLA</td><td rowspan="2">0.0134</td></tr>
<tr><td>CSM42B</td><td>XET2002C, Transfer Switch for Charging Injection Pump C</td><td>Either CSM11B or CSM42B can be energized during the Appendix R Scenario.</td></tr>
</table>

9.1.2 Calculate Temperature Rise, ΔT, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 1.212 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(1.212\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{57.8324°C - Inch^3}{Watt}\right)Q$$

Table 9.1-2 facilitates substitution of Heat (Q) Values:

Table 9.1-2
Fire Barrier 11-TW – Heat/Temperature Rise Data – Appendix R Fire Condition

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM11B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.	0.0134	0.7750
CSM42B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.		

There is a minimal temperature margin in the Appendix R condition for Fire Barrier 11-TW (CSM11B/CSM42B) cable air drop case. The heat generated inside of the three (3) layer barrier at the maximum Appendix R internal raceway temperature approaches the peak acceptable temperature. This case is re-evaluated in Analysis Sections 9.1.3 and 9.1.4 considering the impact of the ECR 50205-installed additional cable mass (Ref. Attachments 12.11 and 12.12). The consideration of the thermal mass resulting from the ECR 50205 installation of three (3) additional un-energized cables will modify the configuration such that the internal barrier temperature is reduced. The increased thermal mass results in decreased internal raceway temperatures.

9.1.3 Determine Q, Heat Generated By Energized Circuits CSM11B/CSM42B

Installation Configuration Subsequent To ECR 50205 (Three Additional B/M EK-A1E Cables)

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 3

R = 0.1169 Ohms/1000Ft @ 370°C (698°F)

A = 5 B/M EK-A1E Cables ($Area_{EK\text{-}A1E\ Cable}$) (Ref. Assumption 4.15)
A = 5 (4.6148 Inches^2)
A = 23.074 Inches^2

$$Q = \frac{I^2 (3)\left(0.1169 / 1000Ft\right)}{23.074 Inch^2} \frac{1Ft}{12 Inch}$$

$$Q = \frac{I^2 (1.267E-6)\Omega}{Inch^3}$$

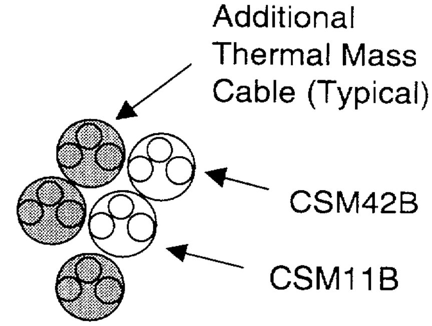


Table 9.1-3 facilitates substitution of Current (I) Values:

Table 9.1-3
Fire Barrier 11-TW – Cable Load/Heat Data– Appendix R Fire Condition

Cable Number	Load	Load Summary	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.	65 FLA	0.0054
CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.		

9.1.4 Calculate Temperature Rise, ΔT, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 1.212 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(1.212\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{57.8324°C - Inch^3}{Watt}\right)Q$$

Table 9.1-4 facilitates substitution of Heat (Q) Values:

Table 9.1-4
Fire Barrier 11-TW – Heat/Temperature Rise Data – Appendix R Fire Condition

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM11B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.	0.0054	0.3123
CSM42B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.		

9.2 Normal/Accident Condition – Fire Barrier 11-TW

9.2.1 Determine Q, Heat Generated By Energized Circuits CSM11B/CSM42B

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.3 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 3

R = 0.0488 Ohms/1000Ft @ 18°C (63°F)

A = 4.6148 Inches^2

$$Q = \frac{I^2 (3)\left(0.0488 / 1000Ft\right)}{4.6148 Inch^2} \frac{1Ft}{12Inch}$$

$$Q = \frac{I^2 (2.644E-6)\Omega}{Inch^3}$$

Table 9.2-1 facilitates substitution of Current (I) Values:

Table 9.2-1
Fire Barrier 11-TW – Cable Load/Heat Data – Normal/Accident Condition

Cable Number	Load	Load Summary	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.	65 FLA	0.0112
CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.		

9.2.2 Calculate Temperature Rise, ΔT, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 1.212 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3)

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(1.212\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{57.8324°C - Inch^3}{Watt}\right) Q$$

Table 9.1-2 facilitates substitution of Heat (Q) Values:

Table 9.2-2
Fire Barrier 11-TW – Heat/Temperature Rise Data – Normal/Accident Condition

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM11B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.	0.0112	0.6477
CSM42B	Either CSM11B or CSM42B can be energized during the Appendix R Scenario.		

9.3 Appendix R Postulated ASTM E-119 Fire – Fire Barrier 41-TW

9.3.1 Determine Q, Heat Generated By Energized Cable Installation Configuration Prior To ECR 50205

9.3.1.1 Determine Q, Heat Generated By Energized Cable – CCE21A

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

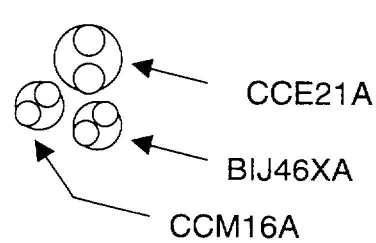
N = 2

R = 0.9383 Ohms/1000Ft @ 370°C (698°F)

A = 0.5281 Inches^2

$$Q = \frac{I^2 (2)\left(0.9383\Omega / 1000Ft\right)}{0.5281 Inch^2}\left(\frac{1Ft}{12Inch}\right)$$

$$Q = \frac{I^2 (2.9612E-4)\Omega}{Inch^3}$$



9.3.1.2 Determine Q, Heat Generated By Energized Cable – BIJ46XA/CCM16A

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 2

R = 3.7718 Ohms/1000Ft @ 370°C (698°F)

A = 2 B/M EK-B1G Cables ($Area_{EK\text{-}BIG\ Cable}$)
A = 2 (0.2922 Inches^2)

$$Q = \frac{I^2(2)\left(3.7718\Omega / 1000Ft\right)}{(2)0.2922Inch^2} \frac{1Ft}{12Inch}$$

$$Q = \frac{I^2(1.0757E-3)\Omega}{Inch^3}$$

Table 9.3-1 facilitates substitution of Current (I) Values:

Table 9.3-1
Fire Barrier 41-TW - Cable Load/Heat Data – Appendix R Fire Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CCE21A	XET2001C, Transfer Switch for Comp. Cooling Pump C	15 FLA	0.0666
BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0269
CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0269

9.3.2 Calculate Temperature Rise, Δ T, Resulting From Load Current

9.3.2.1 Calculate Temp. Rise, Δ T, Resulting From Load Current – CCE21A

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.41 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.41\,Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{6.6181\,°C - Inch^3}{Watt}\right) Q$$

9.3.2.2 Calculate Temp. Rise, ΔT, From Load Current – BIJ46XA/CCM16A

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.31 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3)

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.31\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \frac{3.7835°C\ \ Inch^3}{Watt}\ Q$$

Table 9.3-2 facilitates substitution of Heat (Q) Values:

Table 9.3-2
Fire Barrier 41-TW – Heat/Temperature Rise Data – Appendix R Fire Condition

Cable Number	Load	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CCE21A	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0666	0.4408
BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0269	0.1018
CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0269	0.1018

There is a minimal temperature margin in the Appendix R condition for Fire Barrier 41-TW (CCE21A/BIJ46XA/CCM16A) cable air drop case. The heat generated inside of the three (3) layer barrier at the maximum Appendix R internal raceway temperature approaches the peak acceptable temperature. This case is re-evaluated in Analysis Sections 9.3.3 and 9.3.4 considering the impact of the ECR 50205-installed additional cable mass (Ref. Attachments 12.11 and 12.12). The consideration of the thermal mass resulting from the ECR 50205 installation of three (3) additional un-energized cables will modify the configuration such that the internal barrier temperature is reduced. The increased thermal mass results in decreased internal raceway temperatures.

9.3.3 Determine Q, Heat Generated By Energized Cable Installation Configuration Subsequent To ECR 50205

9.3.3.1 Determine Q, Heat Generated By Energized Cable – CCE21A

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

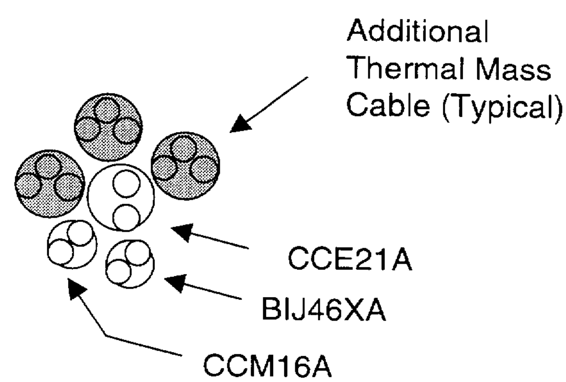
N = 2

R = 0.9383 Ohms/1000Ft @ 370°C (698°F)

A = 3 (Area$_{\text{EK-A1E Cable}}$) + Area$_{\text{EK-A3B Cable}}$
A = 3 (4.6148 Inches^2) + 0.5281 Inches^2
A = 14.3725 Inches^2

$$Q = \frac{I^2 (2)\left(0.9383\Omega / 1000Ft\right)}{14.3725 Inch^2} \cdot \frac{1Ft}{12Inch}$$

$$Q = \frac{I^2 (1.0081E-5)\Omega}{Inch^3}$$



9.3.3.2 Determine Q, Heat Generated By Energized Cable – BIJ46XA/CCM16A

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 2

R = 3.7718 Ohms/1000Ft @ 370°C (698°F)

A = 2 ($Area_{EK\text{-}BIG\ Cable}$)
A = 2 (0.2922 Inches^2)

$$Q = \frac{I^2(2)\left(3.7718\Omega / 1000Ft\right)}{(2)0.2922Inch^2} \; \frac{1Ft}{12Inch}$$

$$Q = \frac{I^2(1.0757E-3)\Omega}{Inch^3}$$

Table 9.3-3 facilitates substitution of Current (I) Values:

Table 9.3-3
Fire Barrier 41-TW - Cable Load/Heat Data – Appendix R Fire Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CCE21A	XET2001C, Transfer Switch for Comp. Cooling Pump C	15 FLA	0.0024
BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0269
CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0269

9.3.4 Calculate Temperature Rise, Δ T, Resulting From Load Current

9.3.4.1 Calculate Temp. Rise, Δ T, Resulting From Load Current – CCE21A

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.41 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.41\,Inch)^2 Q}{4(0.0025\,Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{6.6181\,°C - Inch^3}{Watt}\right) Q$$

9.3.4.2 Calculate Temp. Rise, ΔT, From Load Current – BIJ46XA/CCM16A

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.31 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3)

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.31\ Inch)^2 Q}{4(0.0025\ Watt/°C-cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \frac{3.7835°C\ \ Inch^3}{Watt}\ Q$$

Table 9.3-4 facilitates substitution of Heat (Q) Values:

Table 9.3-4
Fire Barrier 41-TW – Heat/Temperature Rise Data – Appendix R Fire Condition

Cable Number	Load	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CCE21A	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0024	0.0159
BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0269	0.1018
CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0269	0.1018

9.4 Normal/Accident Condition – Fire Barrier 41-TW

9.4.1 Determine Q, Heat Generated By Energized Cable

9.4.1.1 Determine Q, Heat Generated By Energized Cable – CCE21A

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.3 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 2

R = 0.3921 Ohms/1000Ft @ 18°C (63°F)

A = 0.5281 Inches^2

$$Q = \frac{I^2 (2)\left(0.3921\,\Omega / 1000\text{Ft}\right)}{0.5281\text{Inch}^2} \; \frac{1\text{Ft}}{12\text{Inch}}$$

$$Q = \frac{I^2 (1.2375\text{E} - 4)\Omega}{\text{Inch}^3}$$

9.4.1.2 Determine Q, Heat Generated By Energized Cable – BIJ46XA/CCM16A

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.3 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 2

R = 1.5763 Ohms/1000Ft @ 18°C (63°F)

A = 0.2922 Inches^2

$$Q = \frac{I^2 (2) \left(1.5763\,\Omega / 1000\,Ft\right)}{0.2922\,Inch^2} \; \frac{1Ft}{12Inch}$$

$$Q = \frac{I^2 (8.9901\text{E} - 4)\Omega}{Inch^3}$$

Table 9.4-1 facilitates substitution of Current (I) Values:

Table 9.4-1
Fire Barrier 41-TW - Cable Load/Heat Data – Normal/Accident Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CCE21A	XET2001C, Transfer Switch for Comp. Cooling Pump C	15 FLA	0.0278
BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0225
CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0225

9.4.2 Calculate Temperature Rise, ΔT, Resulting From Load Current

9.4.2.1 Calculate Temp. Rise, ΔT, Resulting From Load Current – CCE21A

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.41 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.41\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)} \left(\frac{1 Inch}{2.54 cm} \right)$$

$$\Delta T = \left(\frac{6.6181\ °C - Inch^3}{Watt} \right) Q$$

9.4.2.2 Calculate Temp. Rise, ΔT, From Load Current – BIJ46XA/CCM16A

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.31 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.31\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \frac{3.7835\,°C \quad Inch^3}{Watt}\ Q$$

Table 9.4-2 facilitates substitution of Heat (Q) Values:

Table 9.4-2
Fire Barrier 41-TW – Heat/Temperature Rise Data – Normal/Accident Condition

Cable Number	Load	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CCE21A	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0278	0.1840
BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0225	0.0851
CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0225	0.0851

9.5 Appendix R Postulated ASTM E-119 Fire – Fire Barrier 42-TW

9.5.1 Determine Q, Heat Generated By Energized Cable Installation Configuration Prior To ECR 50205

9.5.1.1 Determine Q, Heat Generated By Energized Cable – CCM44B

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

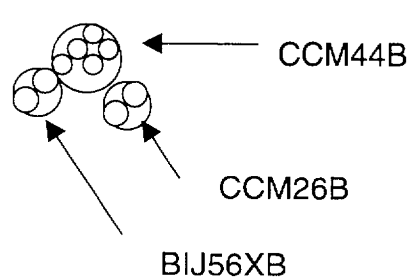
N = 5

R = 3.7718 Ohms/1000Ft @ 370°C (698°F)

A = 0.4301 Inches^2

$$Q = \frac{I^2(5)\left(3.7718\Omega/1000Ft\right)}{0.4301 Inch^2}\left(\frac{1Ft}{12 Inch}\right)$$

$$Q = \frac{I^2(3.654E-3)\Omega}{Inch^3}$$



9.5.1.2 Determine Q, Heat Generated By Energized Cable – BIJ56XB/CCM26B

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 2

R = 3.7718 Ohms/1000Ft @ 370°C (698°F)

A = 2 B/M EK-B1G Cables (Area$_{\text{EK-BIG Cable}}$)
A = 2 (0.2922 Inches^2)

$$Q = \frac{I^2 (2)\left(3.7718\Omega / 1000Ft\right)}{(2) 0.2922 Inch^2} \frac{1Ft}{12Inch}$$

$$Q = \frac{I^2 (1.0757E-3)\Omega}{Inch^3}$$

Table 9.5-1 facilitates substitution of Current (I) Values:

Table 9.5-1
Fire Barrier 42-TW - Cable Load/Heat Data – Appendix R Fire Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CCM44B	XES2001C, Speed Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0913
BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0269
CCM26B	XES2001C, Speed Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0269

9.5.2 Calculate Temperature Rise, Δ T, Resulting From Load Current

9.5.2.1 Calculate Temp. Rise, Δ T, Resulting From Load Current – CCM44B

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.1 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.37 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.37\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)} \left(\frac{1 Inch}{2.54 cm} \right)$$

$$\Delta T = \left(\frac{5.3898°C - Inch^3}{Watt} \right) Q$$

9.5.2.2 Calculate Temp. Rise, ΔT, From Load Current – BIJ56XB/CCM26B

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.31 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.31\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{3.7835°C - Inch^3}{Watt}\right) Q$$

Table 9.5-2 facilitates substitution of Heat (Q) Values:

Table 9.5-2
Fire Barrier 42-TW – Heat/Temperature Rise Data– Appendix R Fire Condition

Cable Number	Load	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CCM44B	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0913	0.4921
BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0269	0.1018
CCM26B	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0269	0.1018

There is a minimal temperature margin in the Appendix R condition for Fire Barrier 11-TW (CCM44B/BIJ56XB/CCM26B) cable air drop case. The heat generated inside of the three (3) layer barrier at the maximum Appendix R internal raceway temperature approaches the peak acceptable temperature. This case is re-evaluated in Analysis Sections 9.1.3 and 9.1.4 considering the impact of the ECR 50205-installed additional cable mass (Ref. Attachments 12.11 and 12.12). The consideration of the thermal mass resulting from the ECR 50205 installation of three (3) additional un-energized cables will modify the configuration such that the internal barrier temperature is reduced. The increased thermal mass results in decreased internal raceway temperatures.

9.5.3 Determine Q, Heat Generated By Energized Cable Installation Configuration Subsequent To ECR 50205

9.5.3.1 Determine Q, Heat Generated By Energized Cable – CCM44B

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

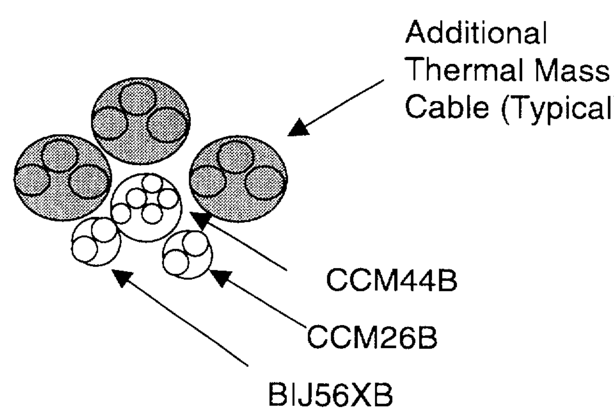
N = 5

R = 3.7718 Ohms/1000Ft @ 370°C (698°F)

A = 3 (Area$_{EK\text{-}A1E\ Cable}$) + Area$_{EK\text{-}B1K\ Cable}$
A = 3 (4.6148 Inches^2) + 0.4301 Inches^2
A = 14.2745 Inches^2

$$Q=\frac{I^2(5)\left(3.7718\Omega/1000Ft\right)}{14.2745Inch^2}\cdot\frac{1Ft}{12Inch}$$

$$Q=\frac{I^2(1.1010E-4)\Omega}{Inch^3}$$



9.5.3.2 Determine Q, Heat Generated By Energized Cable – BIJ56XB/CCM26B

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 2

R = 3.7718 Ohms/1000Ft @ 370°C (698°F)

A = 2 B/M EK-B1G Cables ($Area_{EK\text{-}BIG\ Cable}$)
A = 2 (0.2922 Inches^2)

$$Q = \frac{I^2 (2)\left(3.7718\Omega / 1000Ft\right)}{(2)0.2922Inch^2} \; \frac{1Ft}{12Inch}$$

$$Q = \frac{I^2 (1.0757E-3)\Omega}{Inch^3}$$

Table 9.5-3 facilitates substitution of Current (I) Values:

Table 9.5-3
Fire Barrier 42-TW - Cable Load/Heat Data – Appendix R Fire Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CCM44B	XES2001C, Speed Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0028
BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0269
CCM26B	XES2001C, Speed Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0269

9.5.4 Calculate Temperature Rise, Δ T, Resulting From Load Current

9.5.4.1 Calculate Temp. Rise, Δ T, Resulting From Load Current – CCM44B

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.1 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.37 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.37\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{5.3898°C - Inch^3}{Watt}\right)Q$$

9.5.4.2 Calculate Temp. Rise, ΔT, From Load Current – BIJ56XB/CCM26B

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.31 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3)

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.31\,Inch)^2 Q}{4(0.0025\;Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{3.7835°C - Inch^3}{Watt}\right) Q$$

Table 9.5-4 facilitates substitution of Heat (Q) Values:

Table 9.5-4
Fire Barrier 42-TW – Heat/Temperature Rise Data– Appendix R Fire Condition

Cable Number	Load	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CCM44B	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0028	0.0151
BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0269	0.1018
CCM26B	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0269	0.1018

9.6 Normal/Accident Condition – Fire Barrier 42-TW

9.6.1 Determine Q, Heat Generated By Energized Cable

9.6.1.1 Determine Q, Heat Generated By Energized Cable – CCM44B

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.3 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 5

R = 1.5763 Ohms/1000Ft @ 63°C (18°F)

A = 0.4301 Inches^2

$$Q = \frac{I^2 (5)\left(1.5763\Omega / 1000\text{Ft}\right)}{0.4301\text{Inch}^2} \frac{1\text{Ft}}{12\text{Inch}}$$

$$Q = \frac{I^2 (1.5271\text{E}-3)\Omega}{\text{Inch}^3}$$

9.6.1.2 Determine Q, Heat Generated By Energized Cable – BIJ56XB/CCM26B

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 2

R = 1.5763 Ohms/1000Ft @ 63°C (18°F)

A = 0.2922 Inches^2

$$Q = \frac{I^2 (2)\left(1.5763\Omega / 1000\text{Ft}\right)}{0.2922\text{Inch}^2} \frac{1\text{Ft}}{12\text{Inch}}$$

$$Q = \frac{I^2 (8.9910E-3)\Omega}{\text{Inch}^3}$$

Table 9.6-1 facilitates substitution of Current (I) Values:

Table 9.6-1
Fire Barrier 42-TW - Cable Load/Heat Data – Normal/Accident Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CCM44B	XES2001C, Speed Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0382
BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0225
CCM26B	XES2001C, Speed Switch for Comp. Cooling Pump C	5A (125Vdc)	0.0225

9.6.2 Calculate Temperature Rise, Δ T, Resulting From Load Current

9.6.2.1 Calculate Temp. Rise, Δ T, Resulting From Load Current – CCM44B

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.1 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.37 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.37\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{5.3898°C - Inch^3}{Watt}\right)Q$$

9.6.2.2 Calculate Temp. Rise, ΔT, From Load Current – BIJ56XB/CCM26B

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.31 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.31\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{3.7835°C - Inch^3}{Watt}\right)Q$$

Table 9.6-2 facilitates substitution of Heat (Q) Values:

Table 9.6-2
Fire Barrier 42-TW – Heat/Temperature Rise Data – Normal/Accident Condition

Cable Number	Load	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CCM44B	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0382	0.2059
BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0225	0.0851
CCM26B	XET2001C, Transfer Switch for Comp. Cooling Pump C	0.0225	0.0851

9.7 Appendix R Postulated ASTM E-119 Fire Condition – Fire Barrier 45-TW

9.7.1 Determine Q, Heat Generated By Energized Circuit CSM38C/CSM39C Installation Configuration Prior To ECR 50205

$$Q=\frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

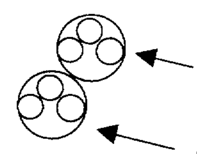
I = Conductor Current (Amps)

N = 3

R = 0.1169 Ohms/1000Ft @ 370°C (698°F)

A = 2 B/M EK-A1E Cables ($Area_{EK\text{-}A1E\ Cable}$)
A = 2 (4.6148 Inches^2)

$$Q=\frac{I^2(3)\left(0.1169/1000Ft\right)}{(2)4.6148Inch^2}\ \frac{1Ft}{12Inch}$$



$$Q=\frac{I^2(3.1665E-6)\Omega}{Inch^3}$$

Table 9.7-1 facilitates substitution of Current (I) Values:

Table 9.7-1
Fire Barrier 45-TW – Cable Load/Heat Data – Appendix R Fire Condition

Cable Number	Load	Load Summary	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CSM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CSM38C or CSM39C can be energized during the Appendix R Scenario.	45 FLA	0.0064
CSM39C	XPP01C, Component Cooling Pump C (Low Speed)	Either CSM38C or CSM42B can be energized during the Appendix R Scenario.		

9.7.2 Calculate Temperature Rise, ΔT, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 1.212 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3)

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(1.212\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{57.8324°C - Inch^3}{Watt}\right)Q$$

Table 9.7-2 facilitates substitution of Heat (Q) Values:

Table 9.7-2
Fire Barrier 45-TW – Heat/Temperature Rise Data – Appendix R Fire Condition

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM38C	XPP01C, Component Cooling Pump C (High Speed)	0.0064	0.3701
CSM39C	XPP01C, Component Cooling Pump C (Low Speed)		

There is a minimal temperature margin in the Appendix R condition for Fire Barrier 45-TW (CCM38C/CCM39C) cable air drop case. The heat generated inside of the three (3) layer barrier at the maximum Appendix R internal raceway temperature approaches the peak acceptable temperature. This case is re-evaluated in Analysis Sections 9.1.3 and 9.1.4 considering the impact of the ECR 50205-installed additional cable mass (Ref. Attachments 12.11 and 12.12). The consideration of the thermal mass resulting from the ECR 50205 installation of three (3) additional un-energized cables will modify the configuration such that the internal barrier temperature is reduced. The increased thermal mass results in decreased internal raceway temperatures.

9.7.3 Determine Q, Heat Generated By Energized Circuit CSM38C/CSM39C Installation Configuration Subsequent To ECR 50205

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.1 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 3

R = 0.1169 Ohms/1000Ft @ 370°C (698°F)

A = 5 B/M EK-A1E Cables (Area$_{\text{EK-A1E Cable}}$) (Ref. Assumption 4.15)
A = 5 (4.6148 Inches^2)
A = 23.074 Inches^2

$$Q = \frac{I^2 (3)\left(0.1169 / 1000Ft\right)}{23.074 Inch^2} \; \frac{1 Ft}{12 Inch}$$

$$Q = \frac{I^2 (1.267E-6)\Omega}{Inch^3}$$

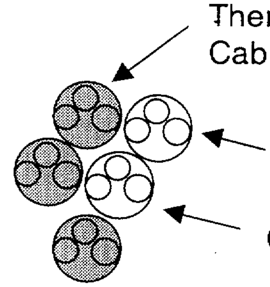


Table 9.7-4 facilitates substitution of Current (I) Values:

Table 9.7-4
Fire Barrier 45-TW – Cable Load/Heat Data – Appendix R Fire Condition

Cable Number	Load	Load Summary	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CSM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CSM38C or CSM39C can be energized during the Appendix R Scenario.	45 FLA	0.0026
CSM39C	XPP01C, Component Cooling Pump C (Low Speed)	Either CSM38C or CSM42B can be energized during the Appendix R Scenario.		

9.7.4 Calculate Temperature Rise, ΔT, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 1.212 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(1.212\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{57.8324°C - Inch^3}{Watt}\right)Q$$

Table 9.7-2 facilitates substitution of Heat (Q) Values:

Table 9.7-4
Fire Barrier 45-TW – Heat/Temperature Rise Data – Appendix R Fire Condition

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM38C	XPP01C, Component Cooling Pump C (High Speed)	0.0026	0.1504
CSM39C	XPP01C, Component Cooling Pump C (Low Speed)		

9.8 Normal/Accident Condition – Fire Barrier 45-TW

9.8.1 Determine Q, Heat Generated By Energized Circuit CSM38C/CSM39C

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.3 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 3

R = 0.0488 Ohms/1000Ft @ 18°C (63°F)

A = 4.6148 Inches^2

$$Q = \frac{I^2 (3)\left(0.0488 \big/ 1000Ft\right)}{4.6148 Inch^2} \; \frac{1Ft}{12 Inch}$$

$$Q = \frac{I^2 (2.644E-6)\Omega}{Inch^3}$$

Table 9.8-1 facilitates substitution of Current (I) Values:

Table 9.8-1
Fire Barrier 45-TW – Cable Load/Heat Data – Normal/Accident Condition

Cable Number	Load	Load Summary	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CSM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CSM38C or CSM39C can be energized during the Appendix R Scenario.	45 FLA	0.0054
CSM39C	XPP01C, Component Cooling Pump C (Low Speed)	Either CSM38C or CSM42B can be energized during the Appendix R Scenario.		

9.8.2 Calculate Temperature Rise, ΔT, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 1.212 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3)

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(1.212\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{57.8324°C - Inch^3}{Watt}\right)Q$$

Table 9.8-2 facilitates substitution of Heat (Q) Values:

Table 9.8-2
Fire Barrier 45-TW – Heat/Temperature Rise Data – Normal/Accident Condition

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM38C	XPP01C, Component Cooling Pump C (High Speed)	0.0054	0.3123
CSM39C	XPP01C, Component Cooling Pump C (Low Speed)		

9.9 Appendix R Postulated ASTM E-119 Fire Condition – Fire Barrier 7-TW

9.9.1 Determine Q, Heat Generated By Energized Circuit CSM1A

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.2 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 3

R = 0.0771 Ohms/1000Ft @ 163.3°C (326°F)

A = 4.6148 Inches^2

$$Q = \frac{I^2 (3)\left(0.0771 / 1000Ft\right)}{4.6148 Inch^2} \frac{1Ft}{12 Inch}$$

$$Q = \frac{I^2 (4.1768E-6)\Omega}{Inch^3}$$

Table 9.9-1 facilitates substitution of Current (I) Values:

Table 9.9-1
Fire Barrier 7-TW – Cable Load/Heat Data – Appendix R Fire Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CSM1A	XPP043A, Charging Injection Pump A	65 FLA	0.0176

9.9.2 Calculate Temperature Rise, ΔT, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 1.212 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches^3)

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(1.212\ Inch)^2 Q}{4(0.0025\ Watt/°C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{57.8324°C - Inch^3}{Watt}\right)Q$$

Table 9.9-2 facilitates substitution of Heat (Q) Values:

Table 9.9-2
Fire Barrier 7-TW – Heat/Temperature Rise Data – Appendix R Fire Condition

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM1A	XPP043A, Charging Injection Pump A	0.0176	1.0206

9.10 Normal/Accident Condition – Fire Barrier 7-TW

9.10.1 Determine Q, Heat Generated By Energized Circuit CSM1A

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.4 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 3

R = 0.0482 Ohms/1000Ft @ 15°C (58°F)

A = 4.6148 Inches^2

$$Q = \frac{I^2 (3)\left(0.0482 / 1000Ft\right)}{4.6148 Inch^2} \frac{1Ft}{12 Inch}$$

$$Q = \frac{I^2 (2.611E - 6)\Omega}{Inch^3}$$

Table 9.10-1 facilitates substitution of Current (I) Values:

Table 9.10-1
Fire Barrier 45-TW – Cable Load/Heat Data – Normal/Accident Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
CSM1A	XPP043A, Charging Injection Pump A	65 FLA	0.0110

9.10.2 Calculate Temperature Rise, ΔT, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 1.212 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(1.212\ Inch)^2 Q}{4(0.0025\ Watt/^\circ C - cm)}\left(\frac{1 Inch}{2.54 cm}\right)$$

$$\Delta T = \left(\frac{57.8324^\circ C - Inch^3}{Watt}\right) Q$$

Table 9.10-2 facilitates substitution of Heat (Q) Values:

Table 9.10-2
Fire Barrier 7-TW – Heat/Temperature Rise Data – Normal/Accident Condition

Cable Number	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
CSM1A	XPP043A, Charging Injection Pump A	0.0110	0.6362

9.11 Appendix R Postulated ASTM E-119 Fire – Fire Barrier 12-TW

9.11.1 Determine Q, Heat Generated By Energized Cable – VLC12C

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.2 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 7

R = 2.0881 Ohms/1000Ft @ 100°C (211°F)*

A = 0.5207 Inches^2

$$Q = \frac{I^2 (7)\left(2.0881\, \Omega / 1000\, Ft\right)}{0.5207\, Inch^2} \; \frac{1 Ft}{12 Inch}$$

$$Q = \frac{I^2 (2.3393E\text{-}3)\Omega}{Inch^3}$$

Table 9.11-1 facilitates substitution of Current (I) Values:

Table 9.11-1
Fire Barrier 12-TW - Cable Load/Heat Data – Appendix R Fire Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	5A	0.0585

9.11.2 Calculate Temperature Rise, Δ T, Resulting From Load Current – VLC12C

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.40 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.40\, Inch)^2\, Q}{4(0.0025\, Watt/^{\circ}C \quad cm)} \; \frac{1 Inch}{2.54 cm}$$

$$\Delta T = \frac{6.2992^{\circ}C \quad Inch^3}{Watt}\; Q$$

Table 9.11-2 facilitates substitution of Heat (Q) Values:

Table 9.11-2
Fire Barrier 12-TW – Heat/Temperature Rise Data – Appendix R Fire Condition

Cable Number	Load	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	0.0585	0.3685

9.12 Normal/Accident Condition – Fire Barrier 12-TW

9.12.1 Determine Q, Heat Generated By Energized Cable – VLC12C

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.2 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 7

R = 1.5698 Ohms/1000Ft @ 17°C (61°F)

A = 0.5207 Inches^2

$$Q = \frac{I^2 (7)\left(1.5698\ \Omega / 1000 Ft\right)}{0.5207\, Inch^2} \ \frac{1 Ft}{12 Inch}$$

$$Q = \frac{I^2 (1.7586\text{E-}3)\Omega}{Inch^3}$$

Table 9.12-1 facilitates substitution of Current (I) Values:

Table 9.12-1
Fire Barrier 12-TW - Cable Load/Heat Data – Normal/Accident Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	5A	0.0440

9.12.2 Calculate Temperature Rise, ΔT, Resulting From Load Current – VLC12C

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.40 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.40\ Inch)^2\ Q}{4(0.0025\ Watt/°C\ \ cm)} \ \frac{1 Inch}{2.54 cm}$$

$$\Delta T = \frac{6.2992°C\ \ Inch^3}{Watt}\ Q$$

Table 9.12-2 facilitates substitution of Heat (Q) Values:

Table 9.12-2
Fire Barrier 12-TW – Heat/Temperature Rise Data – Normal/Accident Condition

Cable Number	Load	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	0.0440	0.2772

9.13 Appendix R Postulated ASTM E-119 Fire – Fire Barrier 13-TW

9.13.1 Determine Q, Heat Generated By Energized Cable – VLC12C

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.2and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 7

R = 2.0881 Ohms/1000Ft @ 100°C (211°F)*

A = 0.5207 Inches^2

$$Q = \frac{I^2 (7)\left(2.0881 \, \Omega / 1000\,Ft\right)}{0.5207\,Inch^2} \; \frac{1Ft}{12Inch}$$

$$Q = \frac{I^2 (2.3393E\text{-}3)\Omega}{Inch^3}$$

Table 9.13-1 facilitates substitution of Current (I) Values:

Table 9.13-1
Fire Barrier 13-TW - Cable Load/Heat Data – Appendix R Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	5A	0.0585

9.13.2 Calculate Temperature Rise, ΔT, Resulting From Load Current– VLC12C

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.40 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.40\ Inch)^2\ Q}{4(0.0025\ Watt/°C \quad cm)}\ \frac{1 Inch}{2.54 cm}$$

$$\Delta T = \frac{6.2992°C \quad Inch^3}{Watt}\ Q$$

Table 9.13-2 facilitates substitution of Heat (Q) Values:

Table 9.13-2
Fire Barrier 13-TW – Heat/Temperature Rise Data – Appendix R Condition

Cable Number	Load	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	0.0585	0.3685

9.14 Normal/Accident Condition – Fire Barrier 13-TW

9.14.1 Determine Q, Heat Generated By Energized Cable – VLC12C

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.4 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N = 7

R = 1.5698 Ohms/1000Ft @ 17°C (61°F)

A = 0.5207 Inches^2

$$Q = \frac{I^2 (7)\left(1.5698\ \Omega/1000Ft\right)}{0.5207\,Inch^2} \quad \frac{1Ft}{12Inch}$$

$$Q = \frac{I^2 (1.7586\text{E-}3)\Omega}{Inch^3}$$

Table 9.14-1 facilitates substitution of Current (I) Values:

Table 9.14-1
Fire Barrier 13-TW - Cable Load/Heat Data – Normal/Accident Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	5A	0.0440

9.14.2 Calculate Temperature Rise, Δ T, Resulting From Load Current – VLC12C

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

ΔT = Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.40 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

K = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.40\ Inch)^2\ Q}{4(0.0025\ Watt/°C\ \ cm)}\ \frac{1 Inch}{2.54 cm}$$

$$\Delta T = \frac{6.2992°C\ \ Inch^3}{Watt}\ Q$$

Table 9.14-2 facilitates substitution of Heat (Q) Values:

Table 9.14-2
Fire Barrier 13-TW – Heat/Temperature Rise Data – Normal/Accident Condition

Cable Number	Load	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	0.0440	0.2772

9.15 Appendix R Postulated ASTM E-119 Fire – Fire Barrier 51-TW

9.15.1 Determine Q, Heat Generated By Energized Cable – VLC44B

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.2 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N= 3

R = 0.5195 Ohms/1000Ft @ 100°C (211°F)

A= 0.5945 Inches^2

$$Q = \frac{I^2 (3)\left(0.5195\ \Omega / 1000\,Ft\right)}{0.5945\,Inch^2} \frac{1Ft}{12Inch}$$

$$Q = \frac{I^2 (2.1846\text{E-}4)\Omega}{Inch^3}$$

Table 9.15-1 facilitates substitution of Current (I) Values:

Table 9.15-1
Fire Barrier 51-TW - Cable Load/Heat Data – Appendix R Condition

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
VLC44B	XFN76-XL, ESF Swgr 1DB Cooling Unit	19.5	0.0831

9.15.2 Calculate Temperature Rise, ΔT, Resulting From Load Current

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.435 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.435\ Inch)^2\ Q}{4(0.0025\ Watt/^\circ C\ \ cm)}\ \frac{1 Inch}{2.54 cm}$$

$$\Delta T = \frac{7.4498^\circ C\ \ Inch^3}{Watt}\ Q$$

Table 9.15-2 facilitates substitution of Heat (Q) Values:

Table 9.15-2
Fire Barrier 51-TW – Heat/Temperature Rise Data – Appendix R Condition

Cable Number	Load	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
VLC44B	XFN76-XL, ESF Swgr 1DB Cooling Unit	0.0831	0.6191

9.16 Normal/Accident Condition – Fire Barrier 51-TW

9.16.1.1 Determine Q, Heat Generated By Energized Cable – VLC44B

$$Q = \frac{I^2 NR}{A}$$

Substituting variables (Ref. Design Input 5.2 and 5.7),

Q = Heat Generated By N-Conductor Cable (Watts/Inch^3)

I = Conductor Current (Amps)

N= 3

R= 0.3873 Ohms/1000Ft @ 15°C (58°F)

A= 0.5945 Inches^2

$$Q = \frac{I^2 (3)\left(0.3873\ \Omega / 1000\,Ft\right)}{0.5945\,Inch^2} \frac{1Ft}{12Inch}$$

$$Q = \frac{I^2 (1.6287E\text{-}4)\Omega}{Inch^3}$$

Table 9.16-1 facilitates substitution of Current (I) Values:

Table 9.16-1
Fire Barrier 51-TW - Cable Load/Heat Data

Cable Number	Load	I, Continuous Load Current	Q, Heat (Watt/Inches^3)
VLC44B	XFN76-XL, ESF Swgr 1DB Cooling Unit	19.5	0.0619

9.16.2 Calculate Temperature Rise, ΔT, Resulting From Load Current – VLC44B

$$\Delta T = \frac{r^2 Q}{4k}$$

Substituting variables (Ref. Design Inputs 5.6 and 5.16),

$\Delta T =$ Change In Cable Temperature Due to Heat Generated By Energized Load

r = 0.435 Inches

Q = Heat Generated By N-Conductor Cable (Watts/Inches ^{3})

k = 0.0025 Watt/°C-cm

$$\Delta T = \frac{(0.435\ Inch)^2\ Q}{4(0.0025\ Watt/°C \quad cm)}\ \frac{1 Inch}{2.54 cm}$$

$$\Delta T = \frac{7.4498°C \quad Inch^3}{Watt}\ Q$$

Table 9.16-2 facilitates substitution of Heat (Q) Values:

Table 9.16-2
Fire Barrier 51-TW – Heat/Temperature Rise Data – Normal/Accident Condition

Cable Number	Load	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
VLC44B	XFN76-XL, ESF Swgr 1DB Cooling Unit	0.0619	0.4611

10.0 Summary Of Results

10.1 Summary of results for the Appendix R Fire Condition

Table 10.1-1
Cable Air Drop – Heat/Temperature Rise Data – Appendix R Fire Condition

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
11-TW (Prior To ECR 50202 Installation)	CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Appendix R, Normal and Accident Scenarios.	0.0134	0.7750
	CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C			
11-TW (Subsequent To ECR 50202 Installation)	CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Appendix R, Normal and Accident Scenarios.	0.0054	0.3123
	CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C			
41-TW (Prior To ECR 50202 Installation)	CCE21A	DPN1HA1, DC DIST. PANEL 1HA1	CCE21A can be energized in the Appendix R, Normal and Accident Scenarios.	0.0666	0.4409
	BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	BIJ46XA can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
	CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	CCM16A can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
41-TW (Subsequent To ECR 50202 Installation)	CCE21A	DPN1HA1, DC DIST. PANEL 1HA1	CCE21A can be energized in the Appendix R, Normal and Accident Scenarios.	0.0024	0.0159
	BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	BIJ46XA can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
	CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	CCM16A can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018

Table 10.1-1, Continued
Cable Air Drop – Heat/Temperature Rise Data – Appendix R Fire Condition

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
42-TW (Prior To ECR 50205 Installation)	CCM44B	XES2001C, Speed Switch for Comp. Cooling Pump C	CCM44B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0913	0.4921
	BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	BIJ56XB can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
	CCM26B	XES2001C, Speed Switch for Comp. Cooling Pump C	CCM26B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
42-TW (Subsequent To ECR 50205 Installation)	CCM44B	XES2001C, Speed Switch for Comp. Cooling Pump C	CCM44B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0028	0.0151
	BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	BIJ56XB can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
	CCM26B	XES2001C, Speed Switch for Comp. Cooling Pump C	CCM26B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
45-TW (Prior To ECR 50205 Installation)	CCM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CCM38C or CCM39C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0064	0.3708
	CCM39C	XES2001C, Speed Switch For Comp. Cooling Pump			
45-TW (Subsequent To ECR 50205 Installation)	CCM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CCM38C or CCM39C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0026	0.1504
	CCM39C	XES2001C, Speed Switch For Comp. Cooling Pump			

Table 10.1-2
Cables In Pull Boxes – Heat/Temperature Rise Data – Appendix R Fire Condition

Fire Barrier	Cable Number	From Device	To Device	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
7-TW	CSM1A	XPP043A, Charging Injection Pump A	CSM1A can be energized during the Appendix R, Normal and Accident Scenarios.	0.0176	1.0206
12-TW	CSC264XC			CIRCUIT VOID	
	VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	VLC12C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0585	0.3685
13-TW	CSC264XC			CIRCUIT VOID	
	VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	VLC12C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0585	0.3685
51-TW	VLC44B	XFN76-XL, ESF Swgr 1DB Cooling Unit	VLC44B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0831	0.6191

10.1.1 Cable Air Drop – Appendix R Fire Condition – Fire Barrier 11-TW Prior to ECR 50205 Installation

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
11-TW	CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Appendix R, Normal and Accident Scenarios.	0.0134	0.7750
	CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C			
Total ΔT, Change In Temperature (°C)					0.7750

Peak Acceptable Temperature (Ref. Design Input 5.9)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.12)
371.1 C	≥	0.7750°C	+	370°C
371.1 C	≥	370.8°C		

There is minimal temperature margin in the Appendix R condition for Fire Barrier 11-TW (CSM11B/CSM42B) cable air drop case. The case has been re-evaluated (Ref. Analysis Sections 9.1.3 and 9.1.4) considering the impact of the additional cable mass. The heat generated inside of the three (3) layer barrier at the given internal raceway temperature approaches the peak acceptable temperature. The consideration of the thermal mass resulting from the ECR 50205 installation of three (3) additional un-energized cables will modify the configuration such that the internal barrier temperature is reduced. The increased thermal mass results in decreased internal raceway temperatures.

10.1.2 Cable Air Drop – Appendix R Fire Condition – Fire Barrier 11-TW Subsequent To ECR 50205 Installation (Three Additional B/M EK-A1E Cables Installed Within Kaowool Blanket)

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
11-TW	CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Appendix R, Normal and Accident Scenarios.	0.0054	0.3123
	CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C			
Total ΔT, Change In Temperature (°C)					0.3123

Peak Acceptable Temperature (Ref. Design Input 5.9)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.12)
371.1°C	≥	0.3123°C	+	370°C
371.1°C	≥	370.3°C		

10.1.3 Cable Air Drop – Appendix R Fire Condition – Fire Barrier 41-TW Prior to ECR 50205 Installation

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
41-TW	CCE21A	DPN1HA1, DC DIST. PANEL 1HA1	CCE21A can be energized in the Appendix R, Normal and Accident Scenarios.	0.0666	0.4409
	BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	BIJ46XA can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
	CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	CCM16A can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
Total ΔT, Change In Temperature (°C)					0.6445

Peak Acceptable Temperature (Ref. Design Input 5.9)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.12)
371.1°C	≥	0.6445°C	+	370°C
371.1°C	≥	370.6°C		

There is a minimal temperature margin in the Appendix R condition for Fire Barrier 41-TW (CCE21A/BIJ46XA/CCM16A) cable air drop case. The heat generated inside of the three (3) layer barrier at the maximum Appendix R internal raceway temperature approaches the peak acceptable temperature. This case is re-evaluated in Analysis Sections 9.3.3 and 9.3.4 considering the impact of the ECR 50205-installed additional cable mass (Ref. Attachments 12.11 and 12.12). The consideration of the thermal mass resulting from the ECR 50205 installation of three (3) additional un-energized cables will modify the configuration such that the internal barrier temperature is reduced. The increased thermal mass results in decreased internal raceway temperatures.

10.1.4 Cable Air Drop – Appendix R Fire Condition – Fire Barrier 41-TW Subsequent To ECR 50205 Installation (Three Additional B/M EK-A1E Cables Installed Within Kaowool Blanket)

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
41-TW	CCE21A	DPN1HA1, DC DIST. PANEL 1HA1	CCE21A can be energized in the Appendix R, Normal and Accident Scenarios.	0.0024	0.0159
	BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	BIJ46XA can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
	CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	CCM16A can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
Total ΔT, Change In Temperature (°C)					0.2195

Peak Acceptable Temperature (Ref. Design Input 5.9)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.12)
371.1°C	≥	0.2195°C	+	370°C
371.1°C	≥	370.2°C		

10.1.5 Cable Air Drop – Appendix R Fire Condition – Fire Barrier 42-TW Prior to ECR 50205 Installation

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
42-TW	CCM44B	XES2001C, Speed Switch for Comp. Cooling Pump C	CCM44B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0913	0.4921
	BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	BIJ56XB can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
	CCM26B	XES2001C, Speed Switch for Comp. Cooling Pump C	CCM26B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
Total ΔT, Change In Temperature (°C)					0.6957

Peak Acceptable Temperature (Ref. Design Input 5.9)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.12)
371.1°C	≥	0.6957°C	+	370°C
371.1°C	≥	370.7°C		

There is a minimal temperature margin in the Appendix R condition for Fire Barrier 11-TW (CCM44B/BIJ56XB/CCM26B) cable air drop case. The heat generated inside of the three (3) layer barrier at the maximum Appendix R internal raceway temperature approaches the peak acceptable temperature. This case is re-evaluated in Analysis Sections 9.1.3 and 9.1.4 considering the impact of the ECR 50205-installed additional cable mass (Ref. Attachments 12.11 and 12.12). The consideration of the thermal mass resulting from the ECR 50205 installation of three (3) additional un-energized cables will modify the configuration such that the internal barrier temperature is reduced. The increased thermal mass results in decreased internal raceway temperatures.

10.1.6 Cable Air Drop – Appendix R Fire Condition – Fire Barrier 42-TW Subsequent To ECR 50205 Installation (Three Additional B/M EK-A1E Cables Installed Within Kaowool Blanket)

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
42-TW	CCM44B	XES2001C, Speed Switch for Comp. Cooling Pump C	CCM44B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0028	0.0151
	BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	BIJ56XB can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
	CCM26B	XES2001C, Speed Switch for Comp. Cooling Pump C	CCM26B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0269	0.1018
Total ΔT, Change In Temperature (°C)					0.2187

Peak Acceptable Temperature (Ref. Design Input 5.9)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.12)
371.1°C	≥	0.2187°C	+	370°C
371.1°C	≥	370.2°C		

10.1.7 Cable Air Drop – Appendix R Fire Condition – Fire Barrier 45-TW Prior to ECR 50205 Installation

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
45-TW	CCM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CCM38C or CCM39C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0064	0.3708
	CCM39C	XES2001C, Speed Switch For Comp. Cooling Pump			
Total ΔT, Change In Temperature (°C)					0.3708

Peak Acceptable Temperature (Ref. Design Input 5.9)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.12)
371.1°C	≥	0.3708°C	+	370°C
371.1°C	≥	370.4°C		

There is a minimal temperature margin in the Appendix R condition for Fire Barrier 45-TW (CCM38C/CCM39C) cable air drop case. The heat generated inside of the three (3) layer barrier at the maximum Appendix R internal raceway temperature approaches the peak acceptable temperature. This case is re-evaluated in Analysis Sections 9.1.3 and 9.1.4 considering the impact of the ECR 50205-installed additional cable mass (Ref. Attachments 12.11 and 12.12). The consideration of the thermal mass resulting from the ECR 50205 installation of three (3) additional un-energized cables will modify the configuration such that the internal barrier temperature is reduced. The increased thermal mass results in decreased internal raceway temperatures.

10.1.8 Cable Air Drop – Appendix R Fire Condition – Fire Barrier 45-TW Subsequent To ECR 50205 Installation (Three Additional B/M EK-A1E Cables Installed Within Kaowool Blanket)

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
45-TW	CCM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CCM38C or CCM39C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0027	0.1504
	CCM39C	XES2001C, Speed Switch For Comp. Cooling Pump			
Total ΔT, Change In Temperature (°C)					0.1504

Peak Acceptable Temperature (Ref. Design Input 5.9)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.12)
371.1°C	≥	0.1504°C	+	370°C
371.1°C	≥	370.2°C		

10.1.9 Cables In Pull Boxes – Appendix R Fire Condition – Fire Barrier 7-TW

Fire Barrier	Cable Number	From Device	To Device	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
7-TW	CSM1A	XPP043A, Charging Injection Pump A	CSM1A can be energized during the Appendix R, Normal and Accident Scenarios.	0.0176	1.0206
Total ΔT, Change In Temperature (°C)					1.0206

Peak Acceptable Temperature (Ref. Design Input 5.10)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.11)
171°C	≥	1.0206°C	+	99.4°C
171°C	≥	100.4°C		

10.1.10 Cables In Pull Boxes – Appendix R Fire Condition – Fire Barrier 12-TW

Fire Barrier	Cable Number	From Device	To Device	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
12-TW	CSC264XC			CIRCUIT VOID	
	VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	VLC12C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0585	0.3685
Total ΔT, Change In Temperature (°C)					0.3685

Peak Acceptable Temperature (Ref. Design Input 5.10)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.11)
171°C	≥	0.3685°C	+	99.4°C
171°C	≥	99.8°C		

10.1.11 Cables In Pull Boxes – Appendix R Fire Condition – Fire Barrier 13-TW

Fire Barrier	Cable Number	From Device	To Device	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
13-TW	CSC264XC			CIRCUIT VOID	
	VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	VLC12C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0585	0.3685
Total ΔT, Change In Temperature (°C)					0.3685

Peak Acceptable Temperature (Ref. Design Input 5.10)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.11)
171°C	≥	0.3685°C	+	99.4°C
171°C	≥	99.8°C		

10.1.12 Cables In Pull Boxes – Appendix R Fire Condition – Fire Barrier 51-TW

Fire Barrier	Cable Number	From Device	To Device	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
51-TW	VLC44B	XFN76-XL, ESF Swgr 1DB Cooling Unit	VLC44B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0989	0.7370
Total ΔT, Change In Temperature (°C)					0.7370

Peak Acceptable Temperature (Ref. Design Input 5.10)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.11)
171°C	≥	0.7370°C	+	99.4°C
171°C	≥	100.1°C		

10.2 Summary of results for the Normal/Accident Condition

Table 10.2-1
Cable Air Drop – Heat/Temperature Rise Data – Normal/Accident Condition

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
11-TW	CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Appendix R, Normal and Accident Scenarios.	0.0112	0.6477
	CSM42B	XET2002C, Transfer Switch for Charging Injection Pump C			
41-TW	CCE21A	DPN1HA1, DC DIST. PANEL 1HA1	CCE21A can be energized in the Appendix R, Normal and Accident Scenarios.	0.0278	0.1840
	BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	BIJ46XA can be energized in the Appendix R, Normal and Accident Scenarios.	0.0225	0.0851
	CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	CCM16A can be energized in the Appendix R, Normal and Accident Scenarios.	0.0225	0.0851
42-TW	CCM44B	XES2001C, Speed Switch for Comp. Cooling Pump C	CCM44B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0382	0.2059
	BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	BIJ56XB can be energized in the Appendix R, Normal and Accident Scenarios.	0.0225	0.0851
	CCM26B	XES2001C, Speed Switch for Comp. Cooling Pump C	CCM26B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0225	0.0851

Table 10.2-1, Continued
Cable Air Drop – Heat/Temperature Rise Data – Normal/Accident Condition

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
45-TW	CCM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CCM38C or CCM39C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0054	0.3123
	CCM39C	XES2001C, Speed Switch For Comp. Cooling Pump			

Table 10.2-2

Cables In Pull Boxes – Heat/Temperature Rise Data – Normal/Accident Condition

Fire Barrier	Cable Number	From Device	To Device	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
7-TW	CSM1A	XPP043A, Charging Injection Pump A	CSM1A can be energized during the Appendix R, Normal and Accident Scenarios.	0.0110	0.6362
12-TW	CSC264XC			CIRCUIT VOID	
	VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	VLC12C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0440	0.2772
13-TW	CSC264XC			CIRCUIT VOID	
	VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	VLC12C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0440	0.2772
51-TW	VLC44B	XFN76-XL, ESF Swgr 1DB Cooling Unit	VLC44B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0619	0.4611

10.2.1 Cable Air Drop – Normal/Accident Condition – Fire Barrier 11-TW

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
11-TW	CSM11B	XPP043B, Charging Injection Pump B	Either CSM11B or CSM42B can be energized during the Appendix R, Normal and Accident Scenarios.	0.0112	0.6477
Total ΔT, Change In Temperature (°C)					0.6477

Peak Acceptable Temperature (Ref. Design Input 5.13)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.15)
90°C	≥	0.6477°C	+	17.2C
90°C	≥	17.8°C		

10.2.2 Cable Air Drop – Normal/Accident Condition – Fire Barrier 41-TW

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
41-TW	CCE21A	DPN1HA1, DC DIST. PANEL 1HA1	CCE21A can be energized in the Appendix R, Normal and Accident Scenarios.	0.0278	0.1840
	BIJ46XA	XET2001C, Transfer Switch for Comp. Cooling Pump C	BIJ46XA can be energized in the Appendix R, Normal and Accident Scenarios.	0.0225	0.0851
	CCM16A	XET2001C, Transfer Switch for Comp. Cooling Pump C	CCM16A can be energized in the Appendix R, Normal and Accident Scenarios.	0.0225	0.0851
Total ΔT, Change In Temperature (°C)					0.3542

Peak Acceptable Temperature (Ref. Design Input 5.13)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.15)
90°C	≥	0.3542°C	+	17.2°C
90°C	≥	17.6°C		

10.2.3 Cable Air Drop – Normal/Accident Condition – Fire Barrier 42-TW

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
42-TW	CCM44B	XES2001C, Speed Switch for Comp. Cooling Pump C	CCM44B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0382	0.2059
	BIJ56XB	XET2001C, Transfer Switch for Comp. Cooling Pump C	BIJ56XB can be energized in the Appendix R, Normal and Accident Scenarios.	0.0225	0.0851
	CCM26B	XES2001C, Speed Switch for Comp. Cooling Pump C	CCM26B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0225	0.0851
Total ΔT, Change In Temperature (°C)					0.3761

Peak Acceptable Temperature (Ref. Design Input 5.13)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.15)
90°C	≥	0.3761°C	+	17.2°C
90°C	≥	17.6°C		

10.2.4 Cable Air Drop – Normal/Accident Condition – Fire Barrier 45-TW

Fire Barrier	Cable Number	Load Description	Load Summary	Q, Heat (Watt/Inches[3])	ΔT, Change In Temperature (°C)
45-TW	CCM38C	XPP01C, Component Cooling Pump C (High Speed)	Either CCM38C or CCM39C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0054	0.3123
	CCM39C	XES2001C, Speed Switch For Comp. Cooling Pump			
Total ΔT, Change In Temperature (°C)					0.3123

Peak Acceptable Temperature (Ref. Design Input 5.9)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.12)
90°C	≥	0.3123°C	+	17.2°C
90°C	≥	17.5°C		

10.2.5 Cables In Pull Boxes – Normal/Accident Condition – Fire Barrier 7-TW

Fire Barrier	Cable Number	From Device	To Device	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
7-TW	CSM1A	XPP043A, Charging Injection Pump A	CSM1A can be energized during the Appendix R, Normal and Accident Scenarios.	0.0110	0.6362
Total ΔT, Change In Temperature (°C)					0.6362

Peak Acceptable Temperature (Ref. Design Input 5.13)		Temperature Rise Due To Cable Load		Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.16)
90°C	≥	0.6362°C	+	16.1°C
90°C	≥	16.7°C		

10.2.6 Cables In Pull Boxes – Normal/Accident Condition – Fire Barrier 12-TW

Fire Barrier	Cable Number	From Device	To Device	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
12-TW	CSC264XC			CIRCUIT VOID	
	VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	VLC12C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0440	0.2772
Total ΔT, Change In Temperature (°C)					0.2772

Peak Acceptable Temperature (Ref. Design Input 5.13)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.16)
90°C	≥	0.2772	+	16.1°C
90°C	≥	16.4°C		

10.2.7 Cables In Pull Boxes – Normal/Accident Condition – Fire Barrier 13-TW

Fire Barrier	Cable Number	From Device	To Device	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
13-TW	CSC264XC			CIRCUIT VOID	
	VLC12C	Term Box TB-CS102 For 120V Control Of XFN47	VLC12C can be energized in the Appendix R, Normal and Accident Scenarios.	0.0440	0.2772
Total ΔT, Change In Temperature (°C)					0.2772

Peak Acceptable Temperature (Ref. Design Input 5.13)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.16)
90°C	≥	0.2772	+	16.1°C
90°C	≥	16.4°C		

10.2.8 Cables In Pull Boxes – Normal/Accident Condition – Fire Barrier 51-TW

Fire Barrier	Cable Number	From Device	To Device	Q, Heat (Watt/Inches^3)	ΔT, Change In Temperature (°C)
51-TW	VLC44B	XFN76-XL, ESF Swgr 1DB Cooling Unit	VLC44B can be energized in the Appendix R, Normal and Accident Scenarios.	0.0619	0.4611
Total ΔT, Change In Temperature (°C)					0.4611

Peak Acceptable Temperature (Ref. Design Input 5.13)	≥	Temperature Rise Due To Cable Load	+	Ambient Temperature Due To ASTM E-119 Fire (Ref. Design Input 5.16)
90 C	≥	0.4611°C	+	16.1°C
90 C	≥	16.6°C		

11.0 CONCLUSION

The calculation results demonstrate that all cables installed in cable air drops and smaller-than-tested (Transco Fire Endurance Test) junction/pull boxes that are wrapped within Kaowool fire barrier are sized adequately to meet ampacity requirements and satisfy the Acceptance Criteria of Section 8.0. The calculation presents that the ECR 50205 upgrade – installation of two (2) additional layers of Kaowool barrier material and the addition of three (3) un-energized cables in air drop configurations – will render the Kaowool fire barrier circuits capable of providing the intended function given Normal, Accident and Appendix R fire conditions.

Noteworthy is that for all cases, the results meet the acceptance criteria for the Appendix R scenerio without relying on the thermal mass of the ECR 50205-installed additional un-energized cables. The additional thermal mass in the air drop cables provide an additional measure of margin. Additionally, the ECR 50205-installed additional two (2) Kaowool layers provide a measure of margin that has not been quantified in this calcuation, but is demonstrated relationally via Attachments 12.5 and 12.6.

12.0 ATTACHMENTS

12.1 "Theory And Problems Of Heat Transfer", Schaum's Outline Series, Pitts, Donald R. and Sissom, Leighton E., 1977, Pages 19 – 20 and 36 - 37.

12.2 ASTM E-119 Representative Time-Temperature Curve

12.3 Technical Report #TR 07870-001, Transco Fire Test Results, Item #10, Cables In Air Drop (Reference 6.10)

12.4 Technical Report #TR 07870-001, Transco Fire Test Results, Item #1 Open Air 4" Conduit and Item #2, 4" Surface Mounted Conduit (Representing Small Pull Boxes) (Reference 6.10)

12.5 Graphical Comparison – Cable Air Drop Time Temperature Profile

12.6 Graphical Comparison – 4" Conduit Time Temperature Profile

12.7 Technical Report #TR 07870-001, Transco Fire Test Results, Item #4, Open Air 1" Conduit (Reference 6.10)

12.8 Faxsimile, Thermal Ceramics Corporation, Michael T. Johnson, Senior Engineer; Dated 5/8/2000.

12.9 Faxsimile, Thermal Ceramics Corporation, Michael T. Johnson, Senior Engineer; Dated 5/9/2000.

12.10 Faxsimile Transmission, Okonite Company, Regional Engineering Office, Bob Finke.

12.11 Kaowool Ceramic Fiber Blanket Product Data, Thermal Ceramics, Catalog Number 5 14-209, Dated December, 1997.

12.12 ECR 50205, Sketch #2, Cable Air Drop, Option #1

12.13 ECR 50205, Sketch #3, Cable Air Drop, Option #2

12.14 ECR 50205, Sketch #5, Pull/Junction Box