FPL

Florida Power & Light Company, 6501 South Ocean Drive, Jensen Beach, FL 34957

November 29, 2001

L-2001-267
10 CFR 50.12
10 CFR 50.4

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Re: St. Lucie Unit 1
Docket No. 50-335
FPL Response to Request for Additional Information for
10 CFR 50 Appendix R K1 Exemption Clarification/Request

The March 5, 1987 NRC SER for the St. Lucie fire protection features states that 25 feet of vertical separation exists between raceways containing redundant divisions of safe shutdown cables in the Unit 1 containment. The statement in the SER does not match the actual plant condition. On October 4, 2000, via FPL letter L-2000-164, Florida Power & Light (FPL) resubmitted exemption K1 to correct the discrepancy identified in the NRC SER for the St. Lucie Unit 1 containment building regarding vertical separation criteria.

Following discussions with the NRC Staff, FPL supplemented that submittal with a risk-informed evaluation of exemption K1 via FPL letter L-2001-153, dated June 28, 2001. Subsequently, during an August 16, 2001 teleconference with NRC Staff, the decision was made that a risk informed approach to resolving this vertical separation issue would not be appropriate at this time. Also, during this teleconference, FPL indicated to NRC staff that a plant specific fire model could be provided which would support a deterministic evaluation of the exemption K1 resubmittal. The NRC staff agreed to continue its evaluation using a deterministic approach and identified certain additional information necessary to support a deterministic evaluation. The NRC request for additional information (RAI) was transmitted to FPL via NRC letter, subject "Request for Additional Information Regarding the 10 CFR Part 50, Appendix R, Exemption Request K1 for the St. Lucie Plant, Unit 1 (TAC No. MB0300)," dated August 31, 2001.

This letter provides FPL's response to the NRC RAI dated August 31, 2001 and provides a plant specific fire model to support the deterministic evaluation of redundant cable tray separation in the St. Lucie Unit 1 containment. This evaluation concludes that seven feet of horizontal separation (no vertical separation) between redundant cable trays is adequate to ensure safe shutdown following a fire. This information supercedes the information provided by FPL letter L-2001-153 and provides supplemental information to the original FPL exemption K1 resubmittal dated October 4, 2000.

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Please contact us if there are any questions regarding this submittal. NRC Regulatory Issue Summary 2001-05 waived the requirements that multiple copies of documents be submitted to the NRC. Therefore, hard copies usually sent to the Regional Administrator and Senior Resident Inspector will not be sent.

Very truly yours,

Donald E. Jernigan
Vice President
St. Lucie Plant

DEJ/KWF

Attachment 1 -Proposed Change to Exemption K1 .... 2 Pages
Attachment 2 -FPL Response to NRC RAI Dated August 31, 2001 .... 4 Pages
Attachment 3 -Fire Hazard Assessment of Exposure to Safe Shutdown Raceways at St. Lucie Plant [Hughes & Associates, 2001] .... 113 Pages

Proposed Change to Exemption K1
(Excerpt from Unit 1 UFSAR)

Exemption K1

An exemption was granted from Section III-G.2.d of Appendix R by the NRC (Reference 14) where the containment cables and associated non-safety circuits of redundant trains are not in all cases separated by 20 ft. with no intervening combustibles.

Evaluation K1

a) A Reactor Cooling Pump Oil Collection System is provided to collect pressurized and unpressurized leaks from each of the Reactor Coolant Pump Lube Oil Systems. This installation confines the major portion of combustible inventory to a separate oil collection tank in accordance with Appendix R, Section III-0. The remaining combustible loading in the fire area is low.

b) Fire detection is provided as shown on drawing 8770-G-424, Figures 9.5A-8 through 9.5A-17.

c) Redundant safety-related equipment is protected from exposure to localized combustible sources by spatial separation and/or the use of existing barriers/partitions (i.e., concrete walls, floors and ceilings) having greater than three hours fire resistive rating.

   Separation is provided to maintain independence of electrical circuits and equipment so that the protective function required during any design basis event can be accomplished. The degree and method of separation varies with the potential hazards in a particular area. This is accomplished by use of spatial separation, barriers, and radiant energy shields where required.

d) Electrical cables are concentrated at the penetration areas at EL. 23.00 ft. between Column Lines 6 and 8. The cables trays are immediately separated and routed to the several items of equipment.

   A radiant energy shield is provided between safety-related A and B cables trays in the cable penetration area to provide separation.

e) Non-IEEE-383 1974 cables in Fire Area "K" were coated with Flamemastic fire protective coating system. New cables meet the IEEE-383 1974 criteria.

f) Fire Area "K" is a high radiation area and personnel access is limited, thus minimizing the probability of introducing transient combustibles.

g) The large free volume (2.5 million cubic feet) of Fire Area "K" allows for dissipation of hot off-gas temperatures and reduces the effect of stratified hot gases at essential components.

h) Instrument cable trays are covered.

i) Separation of redundant cables in cable trays between column lines 2 and 6 above and below EL. 45.00 ft. is by more than 7 feet horizontally. Addition of any combustibles must be reconciled with PSL-FPER-01-053 (including cable to the cable trays).

Proposed Change to Exemption K1(cont.)
(Excerpt from Unit 1 UFSAR)

Conclusion K1

Based on our evaluation, the existing features in Fire Area "K" provide adequate separation for a fire in transient or in situ combustibles. Additional modification would not augment or materially enhance the safety of the plant since it would not aid in the prevention of fire damage to redundant components essential for safe shutdown. Therefore, we conclude, this is an acceptable exemption to Appendix R to 10 CFR 50, Section III-G.2.d.

Response to NRC Request for Additional Information

NRC QUESTION 1

The original exemption dated February 21, 1985, addressed the entire containment annular region. FP & L has stated that corrective actions have been completed in several areas and an exemption is needed only for a segment of the containment annular region between columns 2 and 6 above and below the 45' elevation. Provide specific details of the area requiring the exemption.

FPL RESPONSE:

The specific scope of this assessment involves the space defined by the containment structure and the interior biological shield between radial lines 2 and 6. The width of this area is approximately 20 ft. The electrical raceways in this area are divided into two separate sections defined by the divisional assignment of circuits: system SA, MA, MC and system SB, MB, MD. The electrical raceways in the containment structure are arranged with 'system' SA raceways installed along the biological shield wall (inner wall of the area). The 'system' SB raceways are installed along the outer wall of the area. Between radial lines 2 and 6, raceways are installed to allow the routing of circuits around the containment structure at both 23 ft-0 in. and 45 ft-0 in. elevations. The area is described in more detail in Attachment 3 to L-2001-267, Section 3.

NRC QUESTION 2

The revised exemption dated March 5, 1987, indicated that there were limited "intervening combustibles" in the containment annular region. Provide a full description of any intervening combustibles in the area for which the exemption is sought and include them in the fire model.

FPL RESPONSE:

Insitu combustibles and ignition sources in the area are discussed and evaluated generically in Sections 3 and 8.3 of the fire hazard assessment (Attachment 3 to L-2001-267).

As evaluated in Attachment 3 to L-2001-267, the insignificant quantities and relative locations of the combustibles do not pose a potential threat to any safe shutdown cables.

NRC QUESTION 3 (PART 1)

Radiant exposure was listed as the only credible scenario. Can the set of cable trays on the lower elevation involve the cable trays in the same train on the upper elevation?

FPL RESPONSE:

The upper tray stack is the same train as the lower tray stack. Therefore, involvement of both tray stacks of one train would not present a concern for safe shutdown.

The potential for multiple burning cable tray stacks is evaluated in Section 8.2.2 of Attachment 3 to L-2001-267.

Response to NRC Request for Additional Information (cont.)

NRC QUESTION 3 (PART 2)

Are there any other structures, systems or components important to safety, which could be in the plume?

FPL RESPONSE:

Yes. Structures, systems, and components important to safety could be in the plume.

However, essential equipment (e.g., structures, systems, and components required to achieve and maintain safe shutdown following a fire) have been identified and evaluated. The essential systems and components are unaffected by fire, adequately separated from redundant counterparts, or protected. Conduits containing safe shutdown cables have been identified and protected where required.

NRC QUESTION 4

Provide the basis for the assumption that solid enclosures of cable trays eliminates them as a fuel source.

FPL RESPONSE:

Attachment 3 to L-2001-267, Section 7.2 provides the bases for the number of trays considered in the analysis. The bottom instrumentation tray was excluded from the maximum expected fire scenario (MEFS), since no credible heating mechanism is present and an internal tray fire would not contribute significantly to the heat release rate. In the limiting fire scenarios (LFS), the fourth tray is included and evaluated in Section 9 of Attachment 3 to L-2001-267.

NRC QUESTION 5

The bench scale heat release rate uses an average of one type of non-rated cable and two types of rated cables. Is this representative of the amount of non-rated cable installed? Why not assume all non-rated cable to obtain bounding results?

FPL RESPONSE:

This value (bench scale heat release rate) is discussed in Attachment 3 to L-2001-267, Section 7.1 & Table 2. In the analysis, the bench scale heat release rate is varied from 200 to 1000 kW/m^2 in the LFS, with 400 kW/m^2 assumed in the MEFS.

Response to NRC Request for Additional Information (cont.)

NRC QUESTION 6 (PART 1)

What are the pass/fail criteria?

FPL RESPONSE:

Pass/fail criteria (critical temperature) are discussed in detail in Attachment 3 to L-2001-267, Section 5. The failure criteria used in Attachment 3 to L-2001-267 are as follows:

IEEE 383 qualified cables

- Failure temperature of 371°C [EPRI, 1991],
- Critical incident heat flux of 11.4 kW/m^2 [EPRI, 1991]; and

Non-IEEE 383 qualified cables

- Failure temperature of 218°C [EPRI, 1991], and
- Critical incident heat flux of 5.7 kW/m^2 [EPRI, 1991].

The analysis in Attachment 3 to L-2001-267 takes credit in some scenarios (exceeding the MEFS) for the ability of the coating to increase the damage threshold to a level consistent with IEEE 383 qualified cables.

NRC QUESTION 6 (PART 2)

What is the maximum credible length of cable in a cable tray that can be involved in a fire?

FPL RESPONSE:

This value (Spread Distance) is discussed in Section 6.6 of Attachment 3 to L-2001-267. The spread distance in the MEFS is approximately 3 meters (Reference Attachment 3 to L-2001-267, Section 8, Table 3). In the LFS, the spread distance varies from less than .5 meters to more than 8 meters depending on the assumptions used (Reference Attachment 3 to L-2001-267, Section 9, Table 5a – 5h).

NRC QUESTION 6 (PART 3)

How fast will a fire in a cable tray grow?

FPL RESPONSE:

This value (Spread Rate or Flame Spread Velocity) is discussed in Section 6.5 of Attachment 3 to L-2001-267. The maximum expected fire scenario (MEFS) is based upon a flame spread rate of 1.8 mm/s (Reference Attachment 3 to L-2001-267, Section 8, Table 3). In the LFS, the flame spread rate is varied from .33 mm/s to 12.60 mm/s depending on assumptions used (Reference Attachment 3 to L-2001-267, Section 9, Table 5a – 5h).

Response to NRC Request for Additional Information (cont.)

NRC QUESTION 6 (PART 4)

Will a fire in cable tray risers grow faster than in horizontal cable trays, and how does it affect the analysis?

FPL RESPONSE:

Yes, fire growth in a cable tray riser would grow faster than in a horizontal tray. The vertical risers were considered in the analysis and determined to not represent the MEFS (See Section 8.2.1 of Attachment 3 to L-2001-267).

NRC QUESTION 6 (PART 5)

What is the response time for the fire brigade to extinguish a fire in a containment cable tray at full power or following a plant trip?

FPL RESPONSE:

Based upon previous announced and unannounced drills to locations near the containment entrance, the Fire Brigade, Security, and Health Physics support will arrive at the containment personnel hatch between 5 to 10 minutes after receipt of a fire alarm. (Reference fire drills dated 6/14/01 (U1 Hot Chemistry Room), 7/18/01(U1 Cold Chemistry Lab), and 9/19/01 (U1 "A" Cable Loft). Entry into containment is estimated to occur within 5 to 10 minutes of arrival. Therefore, it is estimated that brigade response to the fire location will occur within 10 to 20 minutes of the alarm.

The actual time required to extinguish a fire cannot be accurately estimated since it is dependent upon the location and size of the fire. Based upon the MEFS (i.e., relatively light loading of the cable trays, the duration to burn out, the flame spread rate, lack of intervening combustibles, etc.), the fire would be expected to have peaked prior to brigade entry. The brigade would therefore have two smaller fires to extinguish (with a burned out section of tray between). These trays are fairly accessible to immediate brigade fire extinguishment activities from the grated floor above and from the floor below. Since the trays are lightly loaded and all equipment necessary for prompt response is readily available, suppression efforts using portable fire extinguishers would occur promptly upon brigade arrival. Extinguishment is estimated to occur from 10 to 30 minutes from arrival of the brigade at the fire with the "flaming" portion of the fire extinguished early in the attack.

Therefore the time from initial alarm to extinguishment is between 20 and 50 minutes with the "flaming" portion of the fire extinguished early in the attack. However, as indicated in Attachment 3 to L-2001-267, while the amount of burned cable in the tray section may increase, the growth of the fire (overall fire size) will not. Instead, the fire will burn out at the point of origination and the fire will separate into two smaller fires. This arrangement represents a diminished threat to the redundant tray stack that is at least 7 feet horizontally separated from the fire location.

HAI Project 6372

Fire Hazard Assessment of Exposure to Safe Shutdown Raceways, St. Lucie Unit 1

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1. Introduction

Exemption K1 accepted 7 ft horizontal and 25 ft vertical separation without radiant energy shields between redundant safe shutdown trains (cable trays) in containment. In a submittal dated October 4, 2000, Florida Power and Light Company (FPL) requested a revised (clarified) Exemption K1 that requires only 7 ft of horizontal separation (no vertical separation). FPL contended that the 25 ft vertical separation requirement was erroneously stipulated by NRC (an administrative error) due to a misinterpretation of past FPL's submittal(s) related to Exemption K1. On August 31, 2001 (following a phone conference on August 16, 2001), NRC requested additional information that supports a deterministic approach for resolving the issue identified in the October 4, 2000 FPL submittal.

As part of preparing a response to the August 31, 2001 NRC Request for Additional Information, Hughes Associates, Inc. was contracted by FPL to perform a fire hazard assessment/fire model of the area of concern. The fire hazard assessment was performed to demonstrate that 7 ft of horizontal separation without a radiant energy shield is adequate for the redundant cable trays located in the Unit 1 containment above and below the 45 ft elevation and between radial lines 2 and 6. The analysis employs methods and procedures in accordance with Appendix C of NFPA 805 [2001].

2. Scope

The specific scope of this assessment involves the space defined by the containment structure and the interior biological shield between radial lines 2 and 6. The width of this area is approximately 20 ft. The electrical raceways in this area are divided into two separate sections defined by the divisional assignment of circuits: system SA, MA, MC and system SB, MB, MD. The electrical raceways in the containment structure are arranged with 'system' SA raceways installed along the biological shield wall (inner wall of the area). The 'system' SB raceways are installed along the outer wall of the area. Between radial lines 2 and 6, raceways are installed to

allow the routing of circuits around the containment structure at both 23 ft-0 in. and 45 ft-0 in. elevations.

3. Problem Geometry and Conditions

The space between the containment structure and the interior biological shield between radial lines 2 and 6 does not contain any significant fire exposure sources. An engineering walkdown conducted during refueling outage SL1-17 to identify potential fire ignition sources found a limited number of motor operated valves (MOVs) and electrical cabinets to be located in the area as defined in Section 3.2.

3.1 Cable Raceway Geometry

The trays are arranged in vertical stacks. The bottom tray in each stack is an instrumentation tray that is provided with a solid bottom and top cover. The circuits in the instrumentation trays are considered to be low energy circuits that are not potential ignition sources. The top tray in each stack also has a solid cover where exposed to overhead traffic (i.e., directly beneath a grating or opening). The top tray in each stack typically carries 480 VAC power circuits. Between the top and bottom tray are either one or two control circuit trays. All trays are coated with Flamemastic.

In the area of interest, the system SA trays are arranged in two stacks as described above. One stack is located on the 23 ft nominal elevation with another located directly above it at the 45 ft nominal elevation. The highest tray on the 23 ft nominal elevation is at 42 ft-0 in. The lowest tray on the 45 ft nominal elevation is at 54 ft-2 in. A similar configuration exists for the system SB trays. The highest tray on the 23 ft nominal elevation is at 42 ft-0 in. The lowest tray on the 45 ft nominal elevation is at 57 ft-2 in. However, in the area between radial lines 5 and 6, the 'lower' stack of system SB trays transitions to the upper elevation via cable tray risers. The arrangement of these trays is shown in the Figures 1 and 2.

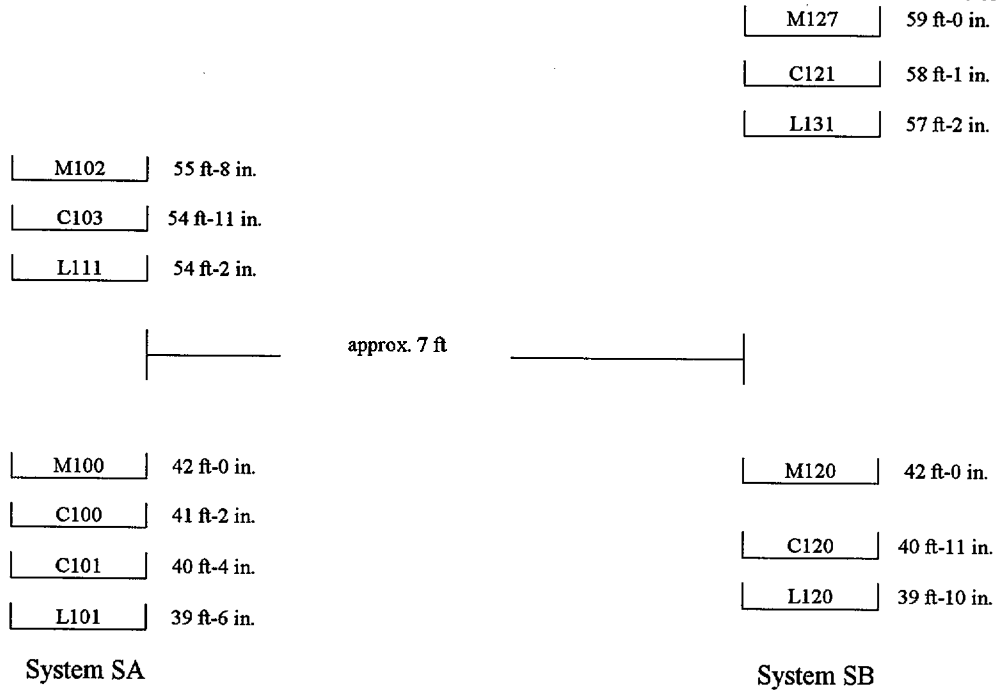


Figure 1 – Arrangement of trays between Radial Lines 2 and 5.5

- not to scale -

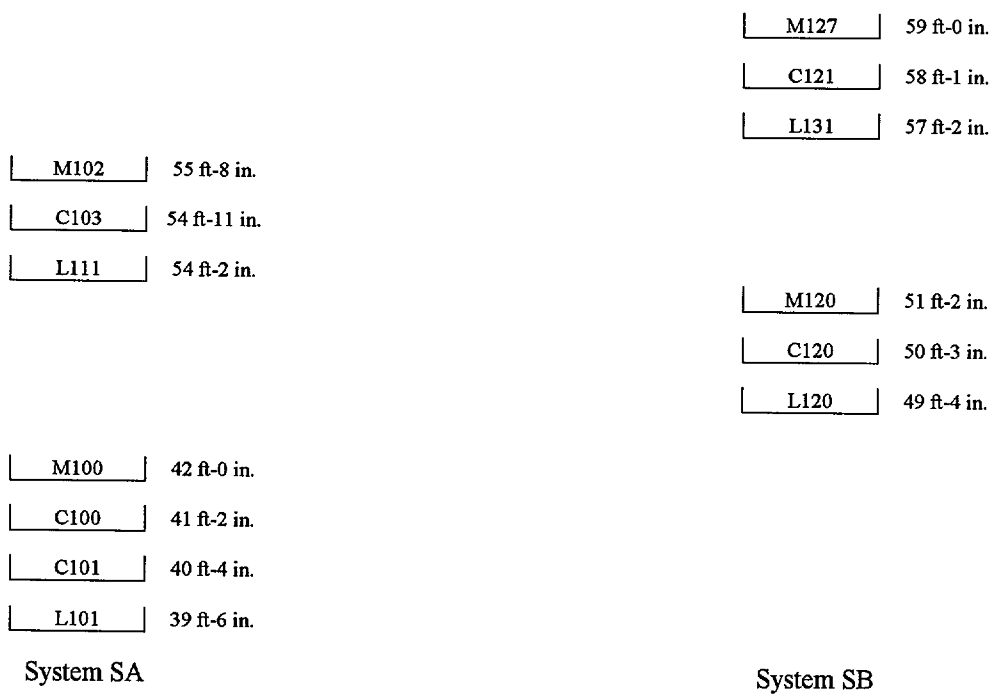


Figure 2 – Arrangement of trays between Radial Lines 5.5 and 6

- not to scale -

The system SA and SB tray stacks are separated by a horizontal distance of approximately 7 ft. Based on these elevations, the key interactions distances are 12 ft vertically and 7 ft horizontally.

Postulated Fire Source	Target Distances			
	SA		SB	
	Vertical	Horizontal	Vertical	Horizontal
SA	-	-	15 ft-2 in. [1]	7 ft
SB	12 ft- 2 in. [1]	7 ft	-	-

Note 1: the vertical spacing distances are applicable only between column lines 2 and 5.5. Between column lines 5.5 and 6, the trays of have limited vertical spacing, but maintain the 7 ft horizontal spacing.

The minimum 'available' vertical separation of the redundant systems of cable trays is about 12 ft with a horizontal separation of 7 ft. The configuration of this area involves grating that forms the nominal floor elevations at 23 ft-0 in., 45 ft-0 in., and 62 ft-0 in.

3.2 Walkdown Summary

A walkdown of the 23 and 45 ft elevations of containment was conducted on 04/7/2001 during SL1-17 to assess the potential ignition sources and combustibles available in the area from radial line 6 (immediately outside the penetration area) to radial line 2 [FPL, 2001]. Only one SB tray is routed past radial line 3 towards radial line 1.

Below are the detailed walkdown observations:

3.2.1 23 ft Elevation

At the 23 ft elevation, the A and B cable tray stacks are routed approximately 13 ft to 16 ft above the floor and generally follow the bioshield wall (system SA trays) and the outside/annulus wall (system SB trays). Between radial lines 1 and 3, a slab exists at the 45 ft elevation. The system SA trays end near radial line 2, two of three system SB trays end at radial line 3, and the third SB tray ends prior to radial line 1.

The ignition sources present above the 23 ft elevation (below the 45 ft elevation) are relatively small MOVs for the following:

Charging and auxiliary spray valves – I-SE-02-1, 2, 3, & 4;
Supply valves for RCP seal injection – MV-02-1 & 2; and
Safety injection tank 1B1 outlet valve – V3634.

The charging/auxiliary spray valves are located approximately 5 ft to 9 ft-6 in. above floor elevation, between radial lines 1 and 2, and below the slab. The system SB cable tray is located approximately 5 ft above and 3 ft offset from the charging/auxiliary spray valves; all system SA trays ended near radial line 2. The RCP seal injection supply and safety injection tank 1B1 outlet valves are located near the floor elevation. The system SA trays are located directly above these valves by approximately 13 ft. The valves/motors contain an insignificant quantity of grease and do not represent a hazard to either the system SA or SB trays. Electrical cabinets/boxes throughout the area do not contain openings or vents.

No exposed *in situ* combustibles are located between the cable tray stacks. The area between the tray stacks (below the 45 ft elevation grating) contains support steel, piping, conduit, etc. The area below the trays along the bioshield wall contains numerous instruments, tubing, cabinets, and transmitters. None of this equipment is considered a potential ignition source(s) for the cable trays because of the vertical separation. In various locations at the 23 ft elevation, Thermo-Lag 330-1 has been used as a radiant energy shield on conduit. In all cases, the Thermo-lag is encased in stainless steel sheet metal. Therefore, the Thermo-lag material in the radiant energy shields is not considered an intervening combustible.

3.2.2 45 ft Elevation

The A and B cable tray stacks are routed approximately 5 to 15 ft above the floor elevation and generally follow the bioshield wall (system SA trays) and the outside/annulus wall (system SB trays). The system SA trays end near radial line 2; the system SB trays end near radial line 3.

No major ignition sources are present above the 45 ft elevation (below the 62 ft elevation) with exception to four of the eight heater distribution bank panels (PP-124 through PP-131). The heater distribution bank panels are mounted on the bioshield wall and above the 41 ft elevation slab between radial lines 1 and 3. PP-124, PP-126, PP-127, and PP-128 are located approximately 4 feet below and 2 feet offset from the system SA cable trays. These distribution panels contain no openings or vents. The other four panels are located nearer to radial line 1 where no cable trays are present. The system SA trays are located above these panels between radial lines 2 and 3. At this location, the tray loading is significantly diminished since many cables have previously exited the trays.

The motor for the containment fan cooler CFC-1B is located between radial lines 1and 2 where no trays are routed. The system SA trays stop at radial line 2 while the system SB trays stop near radial line 3. The containment fan cooler and motor does not contain significant quantities of combustibles.

Between radial lines 3 and 5, the system SB trays (near the outside/annular wall) are routed directly above and within inches of a heavy gauge metal 3-ft wide HVAC duct. This duct will provide significant protection (heat shield) to the trays should a fire originate below. No exposed *in situ* combustibles are located between the cable tray stacks. The area between the tray stacks (below the 62 ft elevation grating) contains support steel, piping, conduit, etc. In various locations at the 45 ft elevation, Thermo-lag 330-1 has been used as a radiant energy shield on conduit. In all cases, the Thermo-lag material is encased in stainless steel sheet metal. Therefore, the Thermo-lag material in the radiant energy shields is not considered an intervening combustible.

The area below the system SA trays (bioshield wall) contains numerous instruments, tubing, cabinets, and transmitters. None of this equipment is considered a potential ignition source(s) to the cable trays because of the vertical separation. The bottoms of the safety injection tanks are at the 48 ft-4 in. elevation and the tops are well above the 62 ft elevation (~80 ft elevation). These relatively large diameter tanks (~9 ft-2 in. diameter each) are located between the system SA and SB trays and provide a significant amount of shielding above the 45 ft elevation. Considering the HVAC duct, the system SB trays are relatively well shielded from a fire below. The safety injection tanks provide significant shielding from the system SA trays. Where only spatial separation exists between the system SA and SB trays, no combustibles or ignition sources are present. As with the 23 ft elevation, electrical cabinets throughout the area do not contain openings.

3.2.3 Walkdown Conclusions

Potential ignition sources between radial lines 1 and 6 do not contain sufficient quantities of combustibles and are spatially separated such that there is no pathway to propagate a fire to other combustibles. No significant intervening combustibles are present between the system SA and SB trays on either elevation.

On the 45 ft elevation, the system SB trays are shielded for approximately 18 ft from the system SA trays by the safety injection tanks. If a fire occurred below the 45 ft elevation, the system SB trays are shielded from below by an HVAC duct from radial lines 3 to 5. The same HVAC duct is routed between the cable tray stacks from radial line 5 to 6.

The top tray in every stack is covered with a sheet metal top when located under grating or other areas subject to dirt and oil drippings; the cover extends approximately 3 ft beyond the hazard area (Reference drawing 8770-B-328, Sheet 5). All instrument (bottom) trays have solid bottoms. All trays are coated with Flamemastic.

4. Modeling and Calculations

The scenarios evaluated involve the ignition of one of the two raceway systems through some unspecified electrical fault, subsequent growth and spread of the fire along the initially involved set of cable trays, and calculation of the resultant radiant exposure to the uninvolved raceway set. Since the precise ignition, flame spread, and energy release rates of the cables involved are unknown, a range of values is evaluated. The cable tray conditions modeled are described in Section 6 based on the geometries described in Section 3. A typical cross-section is shown in Figure 3.

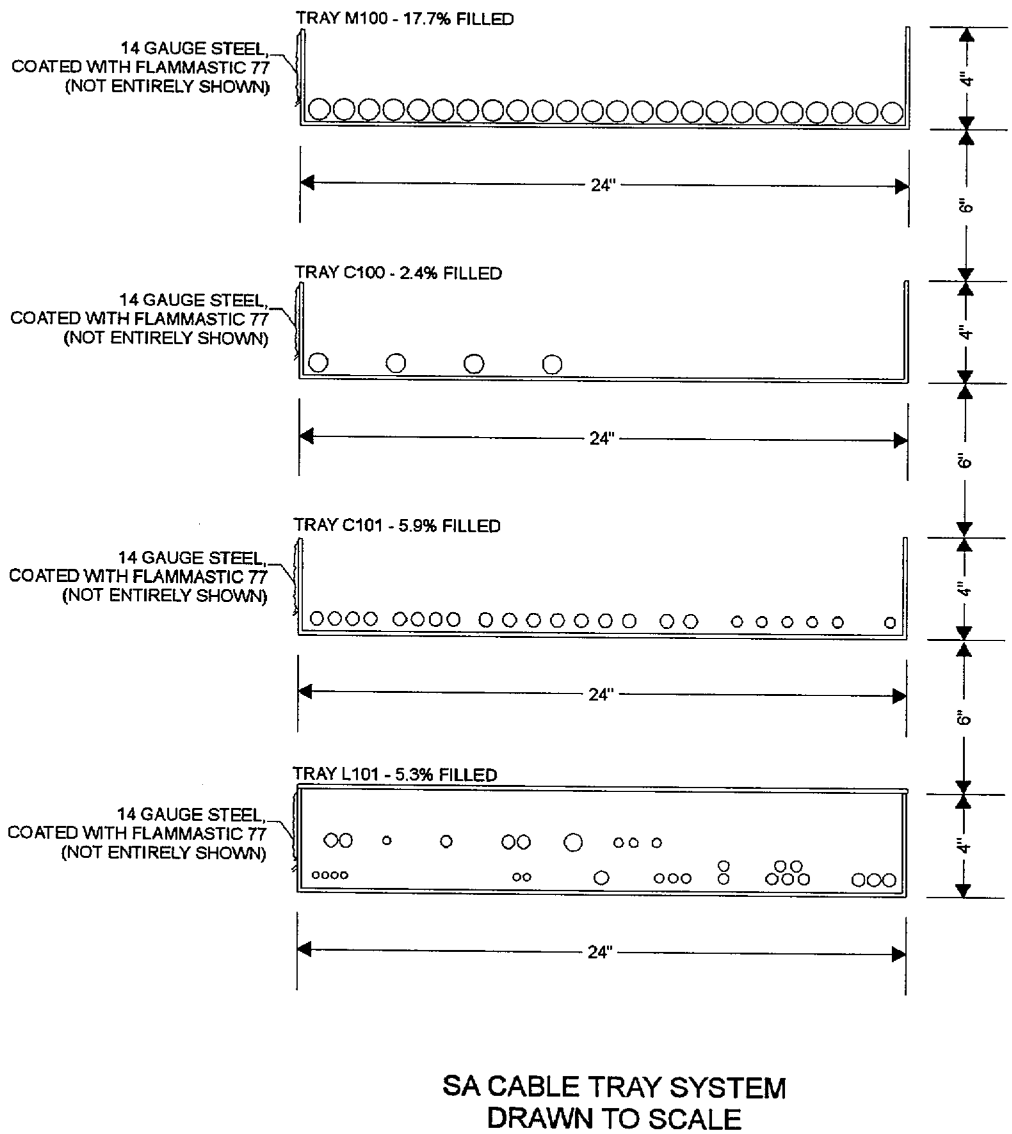


Figure 3 – Schematic diagram of the SA cable tray array

Once ignited, the flame is assumed to travel at a fixed horizontal spread rate in two directions in three or four cable trays in a vertical bank. The fire spreads horizontally to a maximum distance determined by the spread rate and burning duration (see Figures 4a-4d). The burning duration is determined by the fuel loading and the energy release rate. The flame geometry is then fixed by the length of trays burning and the flame height. This flame then radiates energy to the target trays located 7 ft away horizontally. The calculations used to estimate the spread and thermal radiation levels are detailed in Section 6.

In addition to the horizontal cable tray array scenario, a combination of a horizontal tray length and a vertical cable array were evaluated. The vertical flame spread is assumed to be instantaneous. The analysis that demonstrates the horizontal tray array poses a higher exposure threat is given in Section 8.

The radiant exposure to the horizontally separated safe shutdown system is calculated at this maximum flame length. Beyond the maximum burning duration, the fire at the point of ignition begins to burnout due to fuel consumption.

This calculation is done across a range of horizontal spread rates and heat release rates. The flux calculated is the steady state radiation from a thick line flame of fixed length. The calculated flux and cable surface temperatures are compared to critical flux and temperature levels for both IEEE 383 qualified and unqualified cable as detailed in Section 9. There are three failure parameters evaluated for both qualified and unqualified cables:

- Failure temperature,
- Critical incident heat flux, and
- Critical steady state heat flux (minimum heat flux required to heat cables to the failure temperature given the specific orientation).

Section 8 presents results for the Maximum Expected Fire Scenario. The sensitivity analysis of this base case and resulting limiting fire scenarios are given in Section 9.

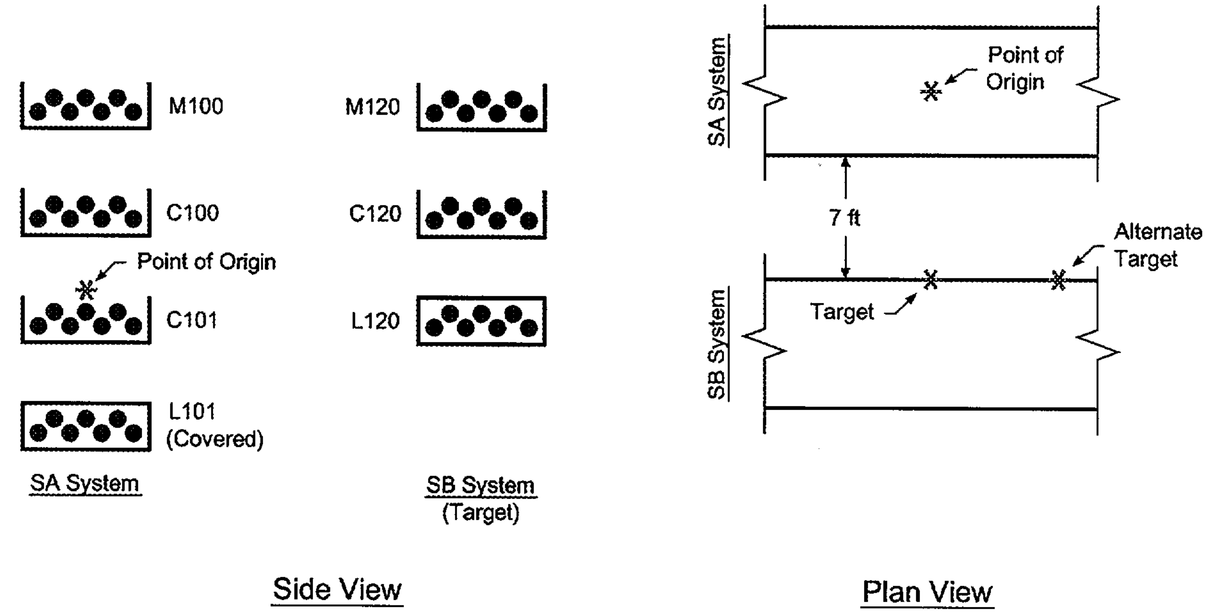


Figure 4a – Ignition of cable tray array

Legend:
Vs = Flame Spread Velocity (mm / s)
t = Time After Ignition (s)

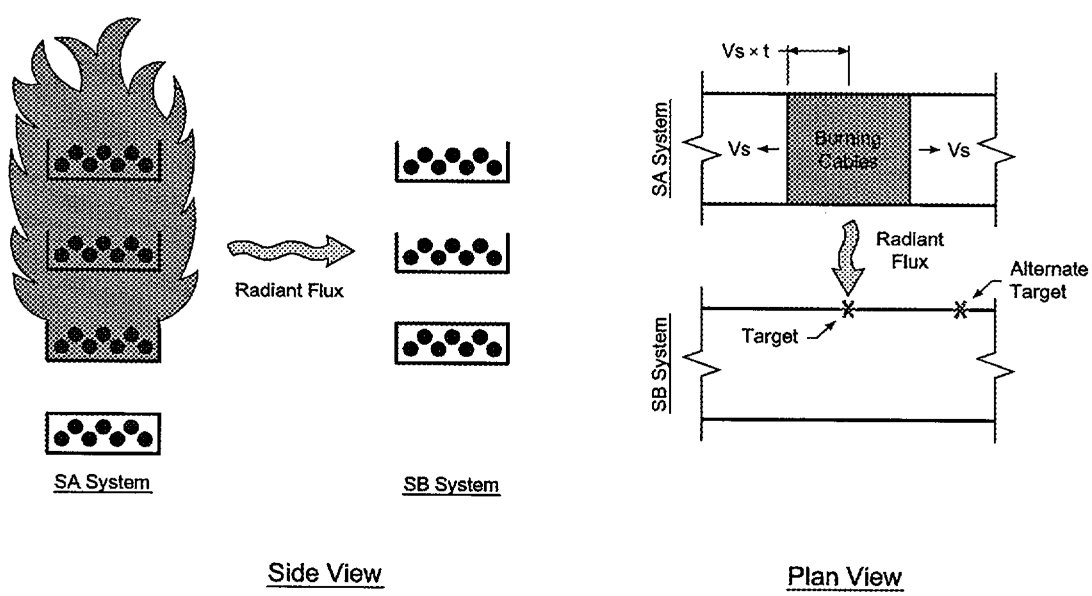


Figure 4b – Initial fire growth in cable tray array

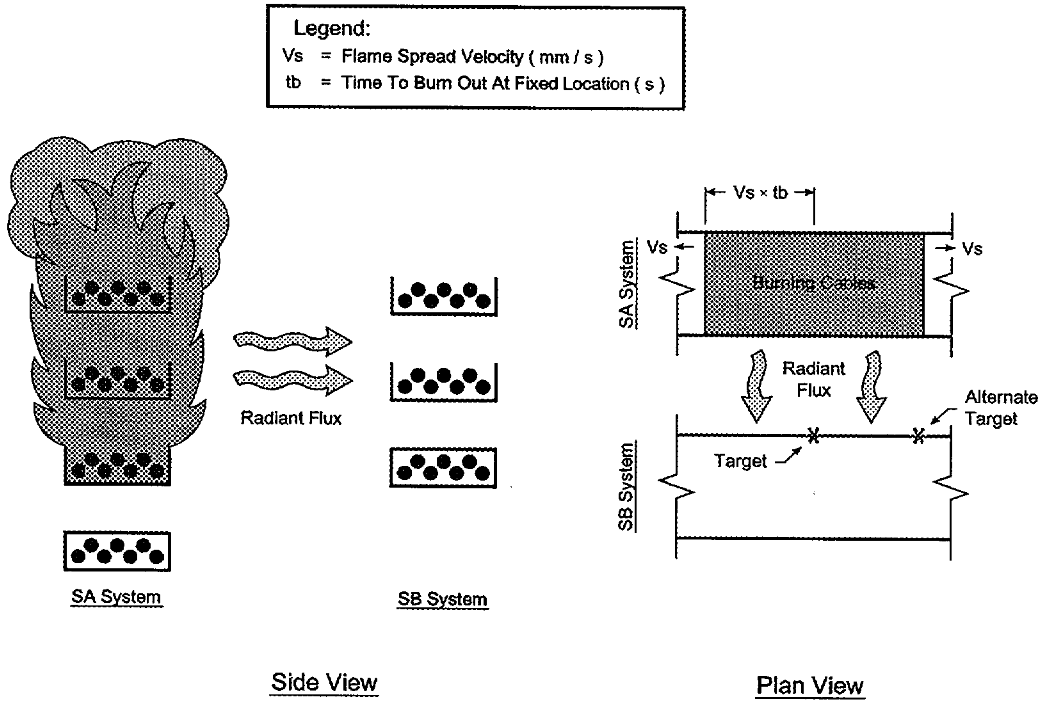


Figure 4c – Cable tray array fire at a maximum single fire size

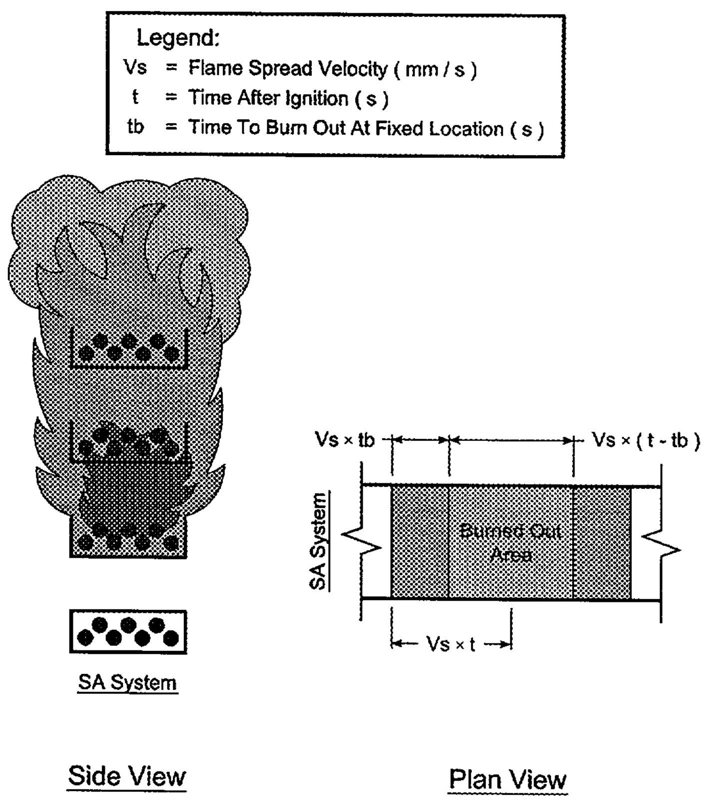


Figure 4d – Cable tray array fire after burnout occurs

Section 10 is a calculation of the quantity of additional cable that could be placed in the raceway systems under certain conditions. The results of the analysis conducted are compared with the analogous calculations using the FIVE Methodology.

5. Failure Criteria

Three failure criteria are used in this report, for both IEEE 383 qualified and unqualified cables. Two failure temperatures and critical incident heat fluxes are taken from EPRI references and used in the FIVE Methodology [1991] and are generally accepted as conservative values. The third "critical steady state heat flux" relates these baseline values to the geometry under consideration by accounting for radiative, convective, and conductive losses, for the particular geometry under evaluation. The critical steady state heat flux is calculated in Section 12, and is only used to demonstrate additional conservatism in the analysis when comparing calculated results to the critical temperature and incident heat flux values used.

The failure criteria used in this report are as follows:

1. IEEE 383 qualified cables
   a. Failure temperature of 371°C [EPRI, 1991],
   b. Critical incident heat flux of 11.4 kW/m^2 [EPRI, 1991]; and

2. Non-IEEE 383 qualified cables
   a. Failure temperature of 218°C [EPRI, 1991], and
   b. Critical incident heat flux of 5.7 kW/m^2 [EPRI, 1991].

The analysis takes credit in some scenarios (exceeding the Maximum Expected Fire Scenario) for the ability of the coating to increase the damage threshold to a level consistent with IEEE 383 qualified cables (11.4 kW/m^2/371°C for IEEE 383 versus 5.7 kW/m^2/218°C for non-IEEE 383 cables). This is justified following the data of Klamerus and the conclusion that in all cases coated nonqualified cables yielded improved performance over the IEEE 383 qualified cables. In tests involving two 40% filled cable trays subject to a gas burner exposure, the time to damage for the coated nonqualified cables (as measured by a short circuit) exceeded by a factor

of two (14 minutes v. 7 minutes) those of the IEEE qualified cables. Further, there was no flame propagation from the lower to the upper cable tray for the Flamemastic coated cables while propagation occurred for the qualified cable.

This analysis assumes that the Flamemastic coated cables have damage thresholds equivalent to IEEE 383 qualified cables. While the assumption of a damage threshold equivalent to IEEE 383 qualified cables is justified as described above, in many cases, the damage threshold for unqualified cables is not exceeded, particularly when a transient thermal analysis is performed.

6. Horizontal Cable Fire Spread and Thermal Radiation Tray Model Description

The incident heat flux is calculated using several aspects of the assumed flame spread, the geometry, and test data. Each component of the model is described below. Figures 4a through 4d depict the various stages of the multi-tiered cable tray fire growth.

6.1 Specific Assumptions

The analysis method described in this section is subject to certain cable loading and geometry conditions. The individual trays within the SA and SB systems are vertically separated by 1 to 2 ft. All cable trays are 2-ft wide [PSL-FPER-01-052, 2001]. The bottom tray is fully enclosed with galvanized steel; the top tray is enclosed only where there is overhead traffic.

The elevation of the SA and SB systems relative to each other is variable; the minimum horizontal separation is 7 ft.

The SA cable tray system considered in this analysis is shown in Figure 3. The array consists of the following individual cable trays [PSL-FPER-01-052, 2001]:

- M100, 17.7 percent filled, 42 ft elevation, partially covered;
- C100, 2.4 percent filled, 41.2 ft elevation;
- C101, 5.9 percent filled, 40.3 ft elevation; and

- L101, 5.3 percent filled, 39.5 ft elevation, fully covered.

These sections represent the most heavily loaded portions of the SA tray system and are thus most conservative for use in this evaluation. The individual cable tray constituents of the SB cable tray system are not material because they are the assumed targets. A fire that originates in the SB cable tray system would be less severe than one that occurs in the SA system because there are fewer cable trays and a less overall energy content.

All combustible portions of the cable jacket are black Polyvinyl Chloride (PVC). The insulation material is either black PVC, cross linked polyethylene (XLPE), or polyethylene (PE). The middle trays are filled 2 and 6 percent respectively; the top tray is filled about 16-18 percent filled [PSL-FPER-01-052, 2001]. The bottom tray is not considered because there is no credible heating mechanism.

The material properties for the PVC, XLPE, and the PE insulation and jacket materials that are of importance to this analysis are the density and the heat of combustion. Table 1 summarizes these parameters [Babrauskas, 1997; Babrauskas and Grayson, 1992; Johnson, 1994].

Table 1. Material Properties of Cable Jacket and Insulation Materials

Material	**Density (kg/m^3)**	**Heat of Combustion (kJ/kg)**
PVC	1,441	17,950
XLPE	924	23,800
PE	924	46,500

The combustible energy load within the cable trays was determined using the material properties and the cable loading tables and cable dimensions that were provided by the facility. Refer to Appendix A and C for a summary of the cable load and the cable energy load calculations. The energy load for each of the four cable trays considered is as follows:

- M100 - 83,980 kJ/m;
- C100 - 11,700 kJ/m;
- C101 - 33,960 kJ/m; and

- L101 - 39,190 kJ/m.

The peak steady state incident heat flux is estimated under the assumption that the fire originates at a single point and spreads away from the ignition location in two directions. The peak incident heat flux occurs when the fire has spread farthest from the point of origin, but before any portion of the tray has become depleted of combustible fuel.

The source fire is treated as a line fire with a base positioned at the lowest burning cable tray. This assumption results in the most conservative (greatest) radiant heat flux exposure to a target cable tray when compared to a pool fire type fire exposure.

6.2 Flame Height

The flame height from a line fire is given by the following equation [Tu and Quintiere, 1991]:

$$F_h = 0.042\dot{q}'^{2/3}_{tot} \qquad (1)$$

where $\dot{q}'_{tot}$ is the heat release rate per unit length of the entire cable tray system (kW/m).

6.3 Heat Release Rate

The release rate of the cable tray system is a function of the plan area of the cables as follows:

$$\dot{q}'_{tot} = \dot{q}''_{fs} \cdot W_{p,c} \qquad (2)$$

where $\dot{q}''_{fs}$ is the full-scale single cable tray heat release rate (kW/m^2) and $W_{p,c}$ is the maximum plan width of the cables (m). The plan width is equal to the sum of all individual cable outer diameters.

The full-scale heat release rate is determined using the equation [Lee, 1985]:

$$\dot{q}''_{fs} = 0.45 \cdot \dot{q}''_{bs} \qquad (3)$$

where $\dot{q}''_{bs}$ is the heat release rate per unit area measured at an incident heat flux of 60 kW/m^2 in a bench-scale (cone calorimeter) apparatus.

6.4 Burning Duration

The burning duration at a single point is in direct proportion to the quantity of combustible material available and the burning rate. The following equation is used to determine the burning duration:

$$t_b = \frac{Q'}{\dot{q}'_{tot}} \quad (4)$$

where t_b is the fire duration at a specific location (s), and Q' is the energy load of the cable tray system (kJ/m).

6.5 Spread Rate

Evidence suggests the spread rate in cable tray fires is a function of the bench-scale heat release rate [Lee, 1985]. Lee [1985] correlated bench-scale data to moderate-scale tests in terms of an *area* spread rate for a single cable tray *array*. The cable tray array contained six tiers or two cable trays. Each individual tray within the array was 0.46 m wide [Sumitra, 1982].

As noted by Lee [1985], the correlated area spread rate is valid "...only to [for] cable tray arrangements, cable packing densities, and exposure fires similar to those tested by Sumitra."

The arrangement of the SA cable tray system is considerably smaller than those that were tested. Consequently, some modification to the Lee [1985] methods is required before the test results can be applied to the configuration at hand.

There are two key assumptions, both of which would tend to produce an overestimate of the flame spread rate in the SA system. The first addresses the significance of the cable packing density. The packing density of the Sumitra tests was on the order of 40 percent [Sumitra, 1982; Lee, 1985]. The SA system has a maximum packing density of 18 percent, with some trays as

low as 2-5 percent. In fact, none of the trays under consideration have a sufficient number of cables to uniformly cover the entire width of a single cable tray. The assumption made in this analysis is that the flame spread rate in a sparsely packed cable tray would not significantly change from that of a moderately packed cable tray. It is expected that a sparse cable layout would tend to slow or limit flame spread because of gaps between the combustible material and other localized effects. The assumption is thus conservative.

The second assumption is that the flame spread rate calculated using the Sumitra data would overpredict the flame spread rate because there is no pool fire ignition source assumed in the SA cable tray system. Sumitra [1982] used a 1.5-ft by 3-ft wide heptane pool fire below the cable tray array as an ignition source. Such a source undoubtedly has a major impact on the maximum flame spread as well as the flame spread velocity. Ignoring the impact of the ignition source clearly imparts conservatism to the analysis.

Given the above assumptions, the correlation derived by Lee was modified using the actual test observations by Sumitra [1982]. Sumitra noted the number of trays involved before the onset of suppression for each test. This information, along with the burn area at the time suppression as determined by Lee [1985] was used to calculate the actual flame spread rate. Figure 5 shows the flame spread rate versus bench-scale heat release rate along with a linear curve fit. The following correlation was obtained from the linear curve fit:

$$v_s = (7.55E-3)\cdot \dot{q}''_{bs} - 1.25 \qquad (5)$$

where v_s is the area spread rate (mm/s).

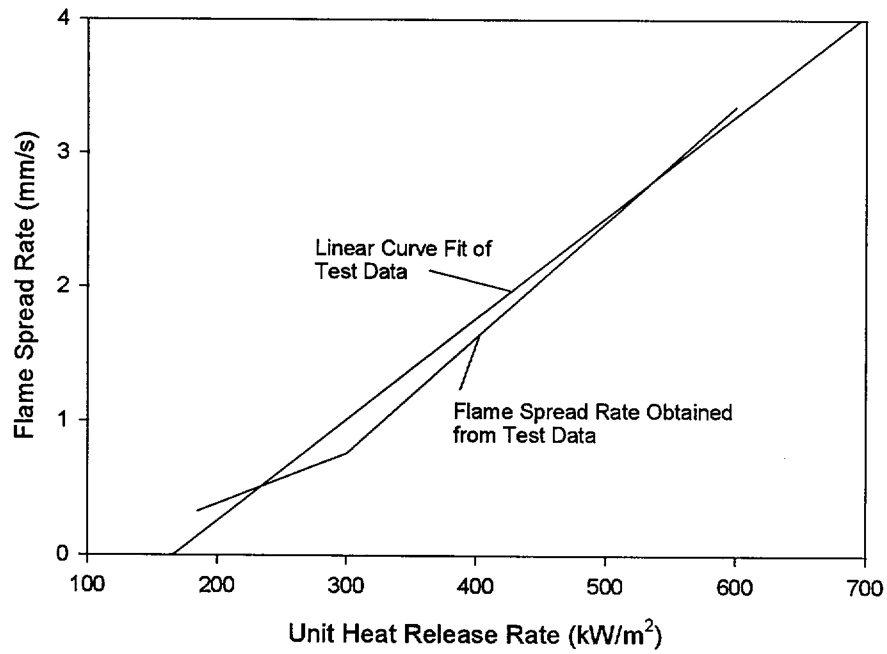


Figure 5 – Flame spread rate as a function of unit heat release rate

The flame spread velocity as calculated using Equation 5 was compared to other test data on cable trays and cable fires for validity. Factory Mutual researcher's observations indicate that the horizontal spread velocity in a communications cables is about 0.63 mm/s for a three-tiered cable tray arrangement [Tewarson *et al.*, 1993]. Investigations of a power cable fault fire [FTIC, 1989] concluded that the spread velocity in these cables was about 2 mm/s. Vertical cable trays with various types of cables have been shown to have a flame spread rate between 2 mm/s and 7 mm/s [Tewarson and Kahn, 1988]. Thus, the flame spread rate is expected to lie between 0.63 mm/s and 7-mm/s, which is nearly the case for Equation 5.

Test data on vertical cable tray tests indicates that the flame spread rate in cables is sensitive to the packing density [Hasegawa *et al.*, 1983]. Hasegawa *et al.* [1983] found that cable trays with a packing density of 25 percent had a 50 percent or greater reduction in the flame spread rate. The cable trays that are under consideration have a maximum packing density of 18 percent and may be as low as 2 to 6 percent filled. Figure 3 shows a scaled drawing of the three open cable trays (M100, C100, and C101), indicating how sparse the packing actually is.

While this effect is not explicitly accounted for in this analysis, it is worthwhile to note because it introduces an element of conservatism.

6.6 Spread Distance

The maximum flame spread distance from the point of origin in one direction is

$$X_s = t_{dur} v_s \tag{6}$$

where X_s is the distance the flame spreads from the origin before the onset of burnout (m). Note that the total spread distance is *twice* this value because it is assumed that flame spread occurs in two directions.

6.7 Emissive Power

The emissive power is the heat flux per unit area that a source fire emits as radiation. The emissive power may be estimated from the fraction of energy released as radiation and the assumed shape of the flame.

The fraction of energy released as radiation, Π_r, depends on the material and the size of the fire. Most materials have a radiant fraction between 0.2 and 0.4 [Tewarson, 1995]. This analysis assumes a value of 0.4; a conservative upper bound of 0.5 is also used for comparison.

The radiant heat release rate is thus

$$\dot{Q}_r = \chi_r \dot{Q} \tag{7}$$

where $\dot{Q}_r$ is the radiant heat released (kW) and $\dot{Q}$ is the total heat released (kW). The total heat release rate is easily determined from the width of the cable tray and the maximum flame spread length as follows:

$$\dot{Q} = \dot{q}''_{tot} \cdot W_{p,c} \cdot \left(2 \cdot X_s\right) \tag{8}$$

where all terms have been defined.

6.8 Incident Heat Flux to Target

The peak heat flux exposure from one burning tray to the exposed side of another tray is calculated from the estimated emissive power of the burning cable tray. The heat flux at a target is given by the following equation:

$$\dot{q}_t'' = F_{s-t} E_s \qquad (9)$$

where $\dot{q}_t''$ is the incident heat flux at the target (kW/m^2) (SB cable tray system), F_{s-t} is the radiation shape factor between the source fire and the target, and E_s is the emissive power of the source fire (kW/m^2).

Because the relative elevation of the trays varies, the worst case incident flux location occurs when there is some part of the SB system directly across from the horizontal and vertical centerline of the rectangular SA system flame. The configuration factor for this case is as follows [Tien *et al.*, 1995]:

$$F_{s-t} = \left(\frac{2}{\pi}\right)\left\{\frac{X}{\sqrt{1+X^2}}\tan^{-1}\frac{Y}{\sqrt{1+X^2}} + \frac{Y}{\sqrt{1+Y^2}}\tan^{-1}\frac{X}{\sqrt{1+Y^2}}\right\} \qquad (10)$$

with

$$X = \frac{0.5 \cdot F_h}{S}$$
$$Y = \frac{X_s}{S} \qquad (11)$$

where F_h is the flame height (m), S is the cable tray separation (2.1 m), and X_s is the maximum flame spread length from the point of origin in either direction (m).

The emissive power of the source fire is calculated assuming that the radiant energy is emitted from the flame and from the top of the cable tray. The following equation is used:

$$E_s = \frac{\dot{Q}_R}{(2 \cdot X_s \cdot F_h) + W_t} \qquad (12)$$

where W_t is the width of the top cable tray (m).

7. Parameters

There are four parameters that have a significant impact on the results of the incident heat flux calculation, described in Section 6:

- The bench-scale heat release rate per unit area, $\dot{q}''_{bs}$;
- The number of cable trays involved in the fire;
- The linear flame spread velocity; and
- The radiant heat release rate fraction.

7.1 Bench-scale Heat Release Rate

The bench-scale heat release rate is a measured value that is generally between 88 and 963 kW/m^2 for cable jacket and insulation materials [Lee, 1985; EPRI, 1991]. The bench-scale heat release rate for most cable materials is between 184 and 530 kW/m^2. The average bench scale heat release rate for non-IEEE cables per the FIVE methodology is 423 kW/m^2 [EPRI, 1991]. Values between 200 and 1,000 are assumed in this analysis. Fire propagation in materials with a lower unit heat release rate is questionable, as evidenced by the correlation developed by Lee [1985] using data obtained by Sumitra [1982].

Appendix A contains a listing of the type and location of the cables in the general area. The dominant types of cables in the SA tray array considered in this analysis are the following:

- PVC/XLPP: Polyvinyl chloride and cross-linked polyethylene;
- PVC/XLPPP: Polyvinyl chloride and thermosetting polyethylene; and
- PVC/XLPN: Polyvinyl chloride and flame resistant thermosetting polyethylene.

There are lesser quantities of various types of signal cables, coaxial cables, and low power cables.

Most cables considered in this analysis consist of PVC jackets and XLPE or insulation. The heat release rate for these types of materials is varied. EPRI [1991] reports values for

PE/PVC cable between 312 kW/m^2 and 589 kW/m^2. Cables that contain nylon, PVC and PE are reported to have a unit heat release rate of 212-263 kW/m^2 [EPRI, 1991]. Table 2 summarizes the range of values reported for cables that contain PVC and PE materials. Note that the unit heat release rate is sensitive to the exposure heat flux. The heat flux can vary considerably; however, a typical value is between 50 and 75 kW/m^2. Most of the heat release rate data was obtained using a 60 kW/m^2 or 75 kW/m^2 exposure flux.

Table 2 indicates that most cables with PVC have a unit heat release rate less than 400 kW/m^2. The bulk of the test data suggests that the heat release rate is on the order of 200-300 kW/m^2 even for materials that are not fire retardant. Thus, a maximum expected fire scenario value of 400 kW/m^2 is conservatively assumed in this evaluation.

7.2 Number of Cable Trays Involved

The maximum number of cable trays in close proximity (less than 4 ft vertical separation) is four in the SA system and three in the SB system. The bottom cable tray is enclosed. However, there is no credible mechanism to heat the bottom tray such that the cables pyrolize and contribute fuel to the fire. The worst case scenario in a bottom tray would involve an internal cable fire that heats the metal which then radiates to the surroundings. This scenario would be bounded by an open fire in the trays located above. Hence, the bottom tray is not included in the maximum expected fire scenario. The maximum number of trays for the Maximum Expected Fire Loss (MEFL) is thus three for the SA system.

7.3 Flame Spread Velocity

The flame spread velocity calculated using the modified Lee [1985] correlation is expected to provide the most realistic estimate. However, the results of this correlation are doubled in order to observe the impact on the results. In addition, the measured/estimated horizontal cable tray flame spread rates of 0.63 mm/s and 2 mm/s are used in this evaluation for comparison.

Table 2. Summary of Heat Release Rate Data for Cables that Contain PVC and PE

Cable Type	Exposure Flux (kW/m^2)	Average Unit Heat Release (kW/m^2)	Reference
PE/PVC	60	312	EPRI [1991]
PE/PVC	60	395	EPRI [1991]
PE/PVC	60	589	EPRI [1991]
PE/PVC/Nylon	60	212	EPRI [1991]
PE/PVC/Nylon	60	263	EPRI [1991]
PE/PVC	60	359	Lee [1985]
PE/PVC/Nylon	60	231	Lee [1985]
PVC/PVC	75	210	Braun *et al.* [1989]
PVC/PVC	100	260	Braun *et al.* [1989]
PVC/XLPE	75	1,123[1]	Grayson *et al.* [2000]
PVC/XLPE	75	223[1]	Grayson *et al.* [2000]
RPPVC/XLPE	75	364[1]	Grayson *et al.* [2000]
PVC/XLPE	75	358[1]	Grayson *et al.* [2000]
RPPVC/XLPE	75	211[1]	Grayson *et al.* [2000]
PVC/XLPE	75	176[1]	Grayson *et al.* [2000]
RPPVC/XLPE	75	522[1]	Grayson *et al.* [2000]
PVC/XLPE	75	357[1]	Grayson *et al.* [2000]
RPPVC/XLPE	75	358[1]	Grayson *et al.* [2000]
PVC/PVC	75	394[1]	Grayson *et al.* [2000]
PVC/PVC	75	211[1]	Grayson *et al.* [2000]
RPPVC/PVC	75	254[1]	Grayson *et al.* [2000]
PVC/PVC	75	219[1]	Grayson *et al.* [2000]
PVC/PVC	75	243[1]	Grayson *et al.* [2000]
PVC/PE	75	203[1]	Grayson *et al.* [2000]
PVC/PE	75	516[1]	Grayson *et al.* [2000]
PVC/PVC	75	483[1]	Grayson *et al.* [2000]
PVC/PE	75	272[1]	Grayson *et al.* [2000]
PVC/PE	75	642[1]	Grayson *et al.* [2000]
PVC/PVC	75	435[1]	Grayson *et al.* [2000]
PVC/PE	75	233[1]	Grayson *et al.* [2000]
PVC/PE	75	409[1]	Grayson *et al.* [2000]
PVC/PE	75	396[1]	Grayson *et al.* [2000]

[1]Peak heat release rate

XLPE - Cross Linked Polyethylene　RPPVC - Reduced Propagation PVC

PE – Polyethylene　PVC – Polyvinyl chloride

7.4 <u>Radiant Heat Release Rate Fraction</u>

The radiant heat release rate for cable tray fires is expected to lie between 0.2 and 0.4. A fraction of 0.4 is conservatively used; values of 0.3 and 0.5 are used to quantify the impact of this parameter on the calculation results.

8. Maximum Expected Fire Scenario

8.1 Maximum Expected Scenario Results

A maximum expected fire scenario may be constructed from the parameters described in Section 7.0. The maximum expected fire scenario is defined as the worst case credible scenario. This would consist of three cable trays containing IEEE-383 cables or equivalent, a bench-scale unit heat release rate of 400 kW/m^2, a horizontal flame spread rate of 1.8 mm/s, and a radiant fraction of 0.4. The target is assumed to be the side of the cable tray located directly across from the burning tray array. As will be shown, this target orientation bounds the one in which the cable is assumed to be heated directly through the gap between cable trays. The results of this maximum expected fire scenario are given in Table 3. The peak fire length is the greatest distance the flames can spread before the onset of burnout. The spread distance (in one direction), which is the velocity multiplied by the total burn time, constantly increases until the fire is extinguished.

Table 3. Incident Heat Flux Calculation for Maximum Expected Fire Scenario

$\dot{q}_{bs}$ (kW/m^2)	Number of Trays	χ_r	v_s (mm/s)	t_d (s)	Maximum Fire Length ($2 \cdot X_s$) (m)	$\dot{q}''_r$ (kW/m^2)
400	3	0.4	1.8	834	2.97	3.79

The heat flux from the burning maximum expected fire scenario array to the target array was calculated using the methods described in Section 6. The target heat flux is predicted to be 3.79 kW/m^2. This flux is less than the critical incident heat flux for non-IEEE 383 cable (5.7 kW/m^2). The heat flux is significantly less than the critical incident value of 11.4 kW/m^2 for IEEE 383 cables. The maximum expected fire scenario, or worst case credible scenario, thus would not exceed the critical incident heat flux or heat the cables in the SB cable tray array

above the critical temperature. This conclusion holds true even if the maximum expected fire scenario cables were assumed non-IEEE 383 compliant.

8.2 Alternative Cable Tray Arrangements

In addition to the baseline maximum expected scenario described in Section 8.1, two additional cable tray arrangements were evaluated in order to establish the maximum expected fire scenario:

1. Target located directly across from a horizontal and vertical cable tray arrangement; and

2. Target located across from a seven tray horizontal array with 7-ft vertical separation.

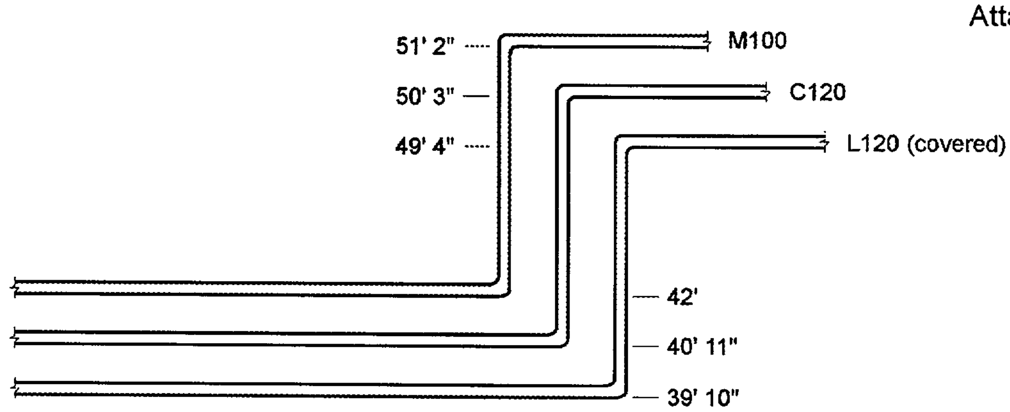
These are described below.

8.2.1 Horizontal and Vertical Cable Tray Arrangement

Figure 6 shows the location and geometry considered. The source fire cable tray involves a horizontal and vertical tray component. Figure 6 indicates the assumed ignition location as well as the shape of the flame. Appendix A summarizes the cable loading in this tray system.

A single fire scenario was evaluated in the horizontal/vertical configuration, and the results compared to those that would be obtained if the tray were horizontal. The following parameters were assumed:

- Unit Cable Heat Release Rate of 500 kW/m^2;
- Radiant Fraction of 0.4;
- Two cable trays (C120 and M120);



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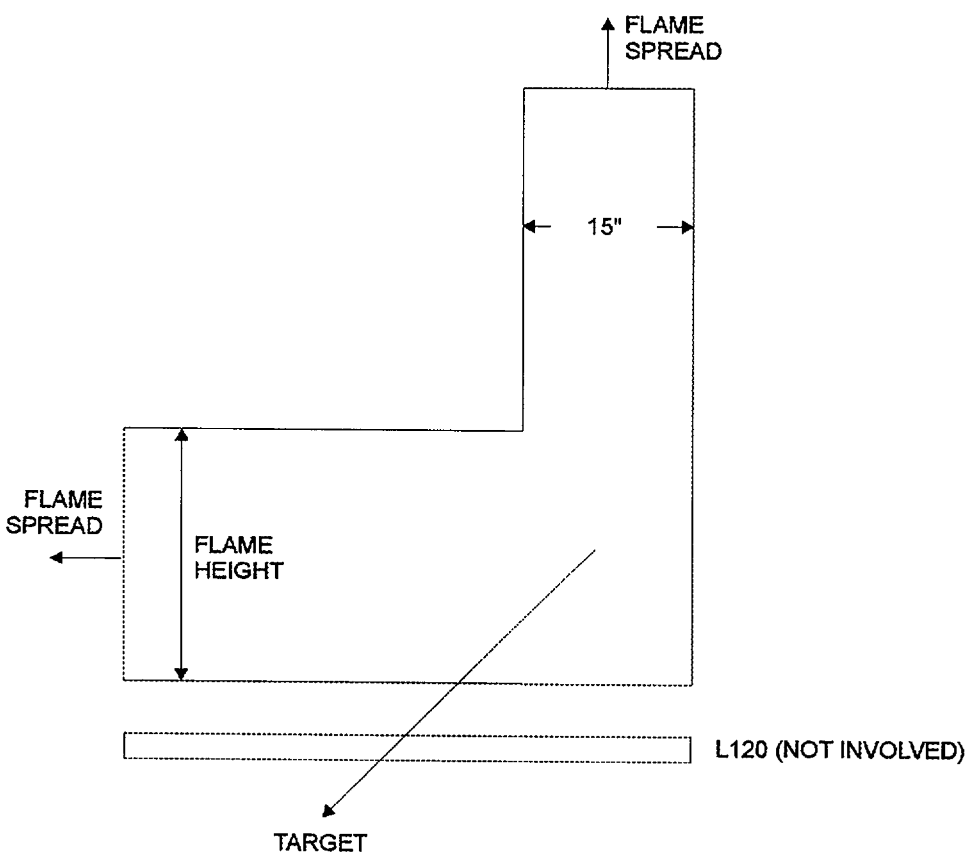
HORIZONTAL AND VERTICAL CABLE TRAY LAYOUT



ASSUMED FLAME SHAPE IN HORIZONTAL AND VERTICAL CABLE TRAYS

Figure 6 – Horizontal-vertical cable tray configuration

- A flame spread rate of 2 mm/s (horizontal portion); and

- Instantaneous vertical flame spread.

The intent of this calculation is to determine the worst case raceway geometry, i.e., whether the horizontal tray array or vertical/horizontal combination results in higher target heat fluxes. Hence, the relation of parameters is somewhat arbitrary since the comparative target heat flux is what is being calculated.

Figure 7 shows the heat flux to the target as a function of time up to the peak heat flux. The figure indicates that the horizontal/vertical orientation is considerably less severe that the analogous horizontal cable tray arrangement described above. The result is due to two factors: there are fewer cable trays (albeit loaded with more cable) and the shape factor from the vertical burning cable tray is less than the horizontal. The assumption that the horizontal cable tray arrangement is worst case is therefore validated.

8.2.2 Horizontal Array with Vertical Separation

An alternate tray arrangement comprised of seven cable trays as indicated in Figure 2 was evaluated. The analysis consisted of evaluating the possibility of ignition of the three tray array located above the 42 ft-0 in. elevation. If the three trays were ignited, then the total heat flux exposure to the SB cable tray system may exceed the calculated heat flux for the Maximum Expected Fire Scenario. If the three trays do not ignite, then the calculated heat flux would always exceed the heat flux for the cases shown in Figure 2 because the SB system is assumed to be located at mid-flame height.

The potential for a multiple cable tray arrays was evaluated by calculating the maximum centerline thermal plume temperature from the lower burning array at the elevation of the upper, target array. A specific arrangement is shown in Figure 2. The exposing array consists of cable trays L101, C101, C100, and M101. The target cable tray array consists of trays L111, C103, and M102. If the second cable tray were to ignite, then there is the potential for larger incident heat fluxes to the redundant SB cable tray system.

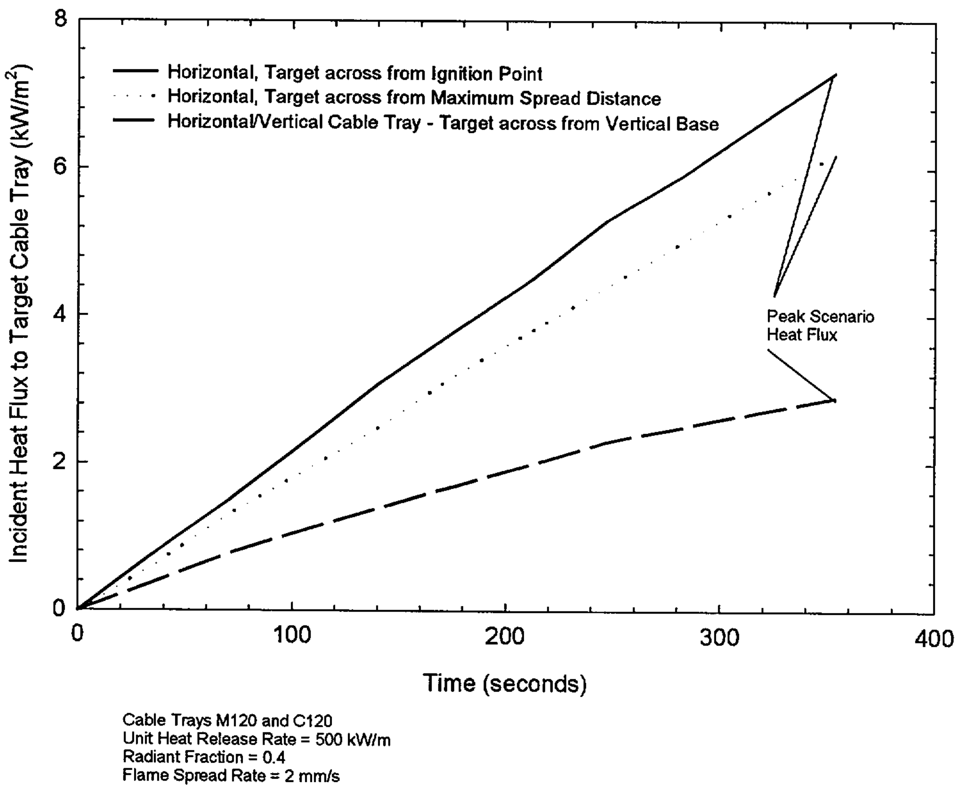


Figure 7 – Comparison of heat flux to target cable tray at various locations

The centerline plume temperature for a line fire is given by the following equation:

$$T_C = T_\infty + \left(0.83 \cdot T_\infty^{1/2} \cdot \dot{q}'_{tot}\right) \cdot Z^{-1} \qquad (13)$$

where T_c is the centerline plume temperature (K), T_4 is the ambient temperature (K), and Z is the height of the base of the target cable tray array above the base of the burning cable tray array (m). The height of the target cable tray array is 4.5-m (14.7-ft) above the base of the exposing cable tray. The resulting centerline plume temperature is 88°C. This is significantly less than the ignition temperature of PVC, thus ignition of the upper cable tray is not possible given a fire in the lower tray array.

Cable tray system SB was evaluated in the same manner (refer to Figure 2). The vertical separation is less (6-ft), however the number of trays involved is only two (M120 and C120).

The calculated plume center line temperature at the base of cable tray L131 is 114 °C, which is also significantly less than the ignition temperature of PDC.

The results of these calculations indicate that the worst case scenario is a 3 or 4 horizontal tray array radiating to a target directly across from the centerline of the flame. This scenario described in Section 8.1 forms the basis for the maximum expected scenario.

8.3 Incidental Combustibles

In order to establish that the exposure from one horizontal cable tray array was the worst case, an evaluation of other combustibles located below the two raceway system was evaluated.

The minimum heat release rate/fire size need to expose both SA and SB cable tray systems was calculated using thermal plume and flame height correlations [Beyler, 1986]. Specific fire scenarios are not evaluated; rather, the minimum fire size that could expose two overhead cable trays separated by 7 ft to a temperature of 218°C was determined.

Two types of source fires were considered: a miscellaneous Class A material fire with a unit heat release rate of 400 kW/m^2 and a combustible liquid fire with a unit heat release rate of 2,000 kW/m^2. Cable tray elevations above the floor are between 5 and 20 ft.

The minimum fire size necessary to expose both trays was first determined using thermal plume equations. The required fire diameter in all cases was found to be greater than 7 ft, typically on the order of 20 ft. The flame height was then calculated using the heat release rate that was calculated. In all cases, the flame height exceeded the height of the cable tray; thus, the flame height correlation is the determining factor. Table 4 summarizes the minimum fire size (heat release rate and diameter) that could cause flame impingement to the cable tray. The minimum diameter is 7 ft, the separation of the two cable trays.

Based on the physical geometry and walkdown results presented in Sections 3.1 and 3.2 and the small size of any fires involving these fuel packages, there is no thermal exposure risk to the redundant sets of arrays.

Table 4. Minimum Size Fires that Could Damage Two Cable Tray Systems Located 7 ft Apart

Elevation (m [ft])	**Class A Material Fire**		**Combustible Liquid**	
	Heat Release (kW)	Diameter (m [ft])	Heat Release (kW)	Diameter (m [ft])
1.5 (5)	1,385	2.1 (7.0)	7,150	2.1 (7.0)
3.0 (10)	3,880	3.5 (11.5)	7,150	2.1 (7.0)
4.6 (15)	11,300	6.0 (20.0)	11,300	2.7 (8.8)
6.1 (20)	22,900	8.5 (28)	22,900	3.8 (12.5)

9. Sensitivity Analysis and Limiting Fire Scenarios

This section of the report presents results of a systematic variation in the parameters discussed in Section 7. Using the Maximum Expected Fire Scenario (MEFS) as a baseline, this analysis demonstrates the sensitivity of the results of the calculations to variations in the parameters. These results clarify the degree of conservatism and the factors of safety inherent in the calculations. In addition, these calculations are completed over a parameter space that includes conditions that will result in failure. These Limiting Fire Scenario calculations are required by Appendix C of NFPA 805 [2001].

The varied parameters include the following:

- Heat release rate of cable,
- Number of cable trays involved,
- Flame spread rate,
- Burning duration (as calculated), and
- Radiative fraction.

Parameters and conditions calculated for the MEFS are given on each table for comparison. The results of the analysis are shown in Table 5a-5h. Incident heat fluxes that exceed the critical incident heat flux of 11.4 kW/m^2 for IEEE 383 qualified cable are shown in bold.

Table 5a. Cable Tray Incident Heat Flux Results (200 kW/m^2 Unit Heat Release Rate for Cables)

Variable Parameters				Results			
$\dot{q}_{bs}$ (kW/m^2)	No. Trays	v_s (mm/s)	Π_r	t_d (s)	$\dot{Q}_p$ (kW)	Maximum Fire Length (2·X$_s$) (m)	$\dot{q}_r$ (kW/m^2)
200	2	0.33	0.3	1,418	30	0.94	0.18
			0.4				0.24
			0.5				0.3
		0.66	0.3		60	1.87	0.33
			0.4				0.43
			0.5				0.54
		0.63	0.3		58	1.79	0.31
			0.4				0.42
			0.5				0.52
		2	0.3		183	5.67	0.59
			0.4				0.78
			0.5				0.98
200	3	0.33	0.3	1,675	86	1.11	0.6
			0.4				0.8
			0.5				1.0
		0.66	0.3		171	2.21	1.08
			0.4				1.43
			0.5				1.79
		0.63	0.3		163	2.11	1.04
			0.4				1.39
			0.5				1.73
		2	0.3		519	6.7	1.77
			0.4				2.36
			0.5				2.95
200	4	0.33	0.3	1,590	108	1.05	0.8
			0.4				1.06
			0.5				1.33
		0.66	0.3		217	2.1	1.44
			0.4				1.92
			0.5				2.4
		0.63	0.3		207	2.0	1.39
			0.4				1.85
			0.5				2.32
		2	0.3		657	6.63	2.44
			0.4				3.26
			0.5				4.07
MAXIMUM EXPECTED FIRE SCENARIO				834	459	2.97	3.79

Boldface indicates that the incident heat flux ($\dot{q}_r$) exceeds the critical incident heat flux for IEEE 383 cables.

Table 5b. Cable Tray Incident Heat Flux Results (300 kW/m^2 Unit Heat Release Rate for Cables)

Variable Parameters				Results			
$\dot{q}_{bs}$ (kW/m^2)	No. Trays	v_s (mm/s)	Π_r	t_d (s)	$\dot{Q}_p$ (kW)	Maximum Fire Length ($2 \cdot X_s$) (m)	$\dot{q}_r$ (kW/m^2)
300	2	1.02	0.3	945	93	1.93	0.55
			0.4				0.74
			0.5				0.92
		2.04	0.3		186	3.86	0.85
			0.4				1.14
			0.5				1.42
		0.63	0.3		58	1.19	0.37
			0.4				0.49
			0.5				0.61
		2.0	0.3		183	3.78	0.85
			0.4				1.13
			0.5				1.41
300	3	1.02	0.3	1,117	264	2.28	1.74
			0.4				2.32
			0.5				2.91
		2.04	0.3		529	4.57	2.54
			0.4				3.39
			0.5				4.24
		0.63	0.3		163	1.47	1.18
			0.4				1.57
			0.5				1.97
		2.0	0.3		519	4.47	2.53
			0.4				3.37
			0.5				4.21
300	4	1.02	0.3	1,060	335	2.16	2.3
			0.4				3.07
			0.5				3.83
		2.04	0.3		670	4.33	3.42
			0.4				4.56
			0.5				5.7
		0.63	0.3		207	1.34	1.55
			0.4				2.07
			0.5				2.58
		2.0	0.3		656	4.24	3.4
			0.4				4.53
			0.5				5.66
MAXIMUM EXPECTED FIRE SCENARIO				834	459	2.97	3.79

Boldface indicates that the incident heat flux ($\dot{q}_r$) exceeds the critical incident heat flux for IEEE 383 cables.

Table 5c. Cable Tray Incident Heat Flux Results (400 kW/m² Unit Heat Release Rate for Cables)

Variable Parameters				Results			
$\dot{q}_{bs}$ (kW/m²)	No. Trays	v_s (mm/s)	Π_r	t_d (s)	$\dot{Q}_p$ (kW)	Maximum Fire Length ($2 \cdot X_s$) (m)	$\dot{q}_r$ (kW/m²)
400	2	1.77	0.3	709	162	2.51	0.95
			0.4				1.26
			0.5				1.58
		3.54	0.3		323	5.02	1.33
			0.4				1.78
			0.5				2.22
		0.63	0.3		58	0.89	0.4
			0.4				0.53
			0.5				0.66
		2.0	0.3		183	2.84	1.02
			0.4				1.37
			0.5				1.71
400	3	1.77	0.3	834	459	2.97	2.84
			0.4				3.79
			0.5				4.74
		3.54	0.3		918	5.93	3.77
			0.4				5.03
			0.5				6.28
		0.63	0.3		163	1.06	1.25
			0.4				1.67
			0.5				2.08
		2.0	0.3		519	3.35	3.04
			0.4				4.06
			0.5				5.07
400	4	1.77	0.3	795	581	2.81	3.73
			0.4				4.97
			0.5				6.21
		3.54	0.3		1,162	5.63	5.05
			0.4				6.74
			0.5				8.42
		0.63	0.3		308	1.0	1.61
			0.4				2.15
			0.5				2.68
		2.0	0.3		657	3.18	4.0
			0.4				5.34
			0.5				6.68
MAXIMUM EXPECTED FIRE SCENARIO				834	459	2.97	3.79

Boldface indicates that the incident heat flux ($\dot{q}_r$) exceeds the critical incident heat flux for IEEE 383 cables.

Table 5d. Cable Tray Incident Heat Flux Results (500 kW/m^2 Unit Heat Release Rate for Cables)

Variable Parameters				Results			
$\dot{q}_{bs}$ (kW/m^2)	No. Trays	v_s (mm/s)	Π_r	t_d (s)	$\dot{Q}_p$ (kW)	Maximum Fire Length ($2 \cdot X_s$) (m)	$\dot{q}_r$ (kW/m^2)
500	2	2.52	0.3	567	230	2.86	1.34
			0.4				1.78
			0.5				2.23
		5.04	0.3		430	5.72	1.79
			0.4				2.39
			0.5				2.99
		0.63	0.3		58	0.71	0.42
			0.4				0.56
			0.5				0.7
		2.0	0.3		183	2.27	1.15
			0.4				1.53
			0.5				1.91
500	3	2.52	0.3	670	653	3.38	3.87
			0.4				5.16
			0.5				6.45
		5.04	0.3		1,307	6.75	4.91
			0.4				6.55
			0.5				8.19
		0.63	0.3		163	0.84	1.28
			0.4				1.71
			0.5				2.14
		2.0	0.3		519	2.68	3.38
			0.4				4.51
			0.5				5.63
500	4	2.52	0.3	636	827	3.21	5.05
			0.4				6.73
			0.5				8.41
		5.04	0.3		1,655	6.41	6.54
			0.4				8.72
			0.5				10.9
		0.63	0.3		207	0.8	1.63
			0.4				2.18
			0.5				2.72
		2.0	0.3		657	2.54	4.37
			0.4				5.83
			0.5				7.29
MAXIMUM EXPECTED FIRE SCENARIO				834	459	2.97	3.79

Boldface indicates that the incident heat flux ($\dot{q}_r$) exceeds the critical incident heat flux for IEEE 383 cables.

Table 5e. Cable Tray Incident Heat Flux Results (600 kW/m² Unit Heat Release Rate for Cables)

Variable Parameters				Results			
$\dot{q}_{bs}$ (kW/m²)	No. Trays	v_s (mm/s)	Π_r	t_d (s)	$\dot{Q}_p$ (kW)	Maximum Fire Length ($2 \cdot X_s$) (m)	$\dot{q}_r$ (kW/m²)
600	2	3.28	0.3	473	300	3.1	1.73
			0.4				2.31
			0.5				2.88
		6.6	0.3		603	6.24	2.26
			0.4				3.01
			0.5				3.77
		0.63	0.3		58	0.6	0.43
			0.4				0.57
			0.5				0.72
		2.0	0.3		163	1.89	1.23
			0.4				1.64
			0.5				2.05
600	3	3.28	0.3	558	851	3.66	4.87
			0.4				6.49
			0.5				8.11
		6.6	0.3		1,711	7.37	6.02
			0.4				8.03
			0.5				10.04
		0.63	0.3		163	0.7	1.3
			0.4				1.73
			0.5				2.16
		2.0	0.3		519	2.23	3.59
			0.4				4.79
			0.5				5.99
600	4	3.28	0.3	530	1,077	3.48	6.3
			0.4				8.4
			0.5				10.5
		6.6	0.3		2,167	7.0	7.96
			0.4				10.61
			0.5				**13.27**
		0.63	0.3		207	0.67	1.63
			0.4				2.18
			0.5				2.72
		2.0	0.3		657	2.12	4.58
			0.4				6.11
			0.5				7.64
MAXIMUM EXPECTED FIRE SCENARIO				834	459	2.97	3.79

Boldface indicates that the incident heat flux ($\dot{q}_r$) exceeds the critical incident heat flux for IEEE 383 cables.

Table 5f. Cable Tray Incident Heat Flux Results (700 kW/m^2 Unit Heat Release Rate for Cables)

Variable Parameters				Results			
$\dot{q}_{bs}$ (kW/m^2)	No. Trays	v_s (mm/s)	Π_r	t_d (s)	$\dot{Q}_p$ (kW)	Maximum Fire Length (2·X_s) (m)	$\dot{q}_r$ (kW/m^2)
700	2	4.04	0.3	405	367	3.27	2.12
			0.4				2.82
			0.5				3.54
		8.08	0.3		738	6.55	2.72
			0.4				3.62
			0.5				4.53
		0.63	0.3		58	0.51	0.44
			0.4				0.59
			0.5				0.73
		2	0.3		183	1.62	1.29
			0.4				1.72
			0.5				2.16
700	3	4.04	0.3	479	1,046	3.86	5.82
			0.4				7.76
			0.5				9.70
		8.08	0.3		2,095	7.73	7.09
			0.4				9.45
			0.5				**11.81**
		0.63	0.3		163	0.60	1.30
			0.4				1.73
			0.5				2.17
		2	0.3		519	1.91	3.72
			0.4				4.96
			0.5				6.20
700	4	4.04	0.3	467	1,363	3.77	7.59
			0.4				10.12
			0.5				**12.65**
		8.08	0.3		2,729	7.55	9.34
			0.4				**12.46**
			0.5				**15.57**
		0.63	0.3		213	0.59	1.67
			0.4				2.22
			0.5				2.78
		2	0.3		675	1.87	4.80
			0.4				6.40
			0.5				8.00
MAXIMUM EXPECTED FIRE SCENARIO				834	459	2.97	3.79

Boldface indicates that the incident heat flux ($\dot{q}_r$) exceeds the critical incident heat flux for IEEE 383 cables.

Table 5g. Cable Tray Incident Heat Flux Results (800 kW/m^2 Unit Heat Release Rate for Cables)

Variable Parameters				Results			
$\dot{q}_{bs}$ (kW/m^2)	No. Trays	v_s (mm/s)	Π_r	t_d (s)	$\dot{Q}_p$ (kW)	Maximum Fire Length (2·X$_s$) (m)	$\dot{q}_r$ (kW/m^2)
800	2	4.79	0.3	354	438	3.40	2.51
			0.4				3.35
			0.5				4.18
		9.58	0.3		875	6.79	3.17
			0.4				4.23
			0.5				5.29
		0.63	0.3		58	0.45	0.45
			0.4				0.60
			0.5				0.75
		2	0.3		183	1.42	1.34
			0.4				1.78
			0.5				2.23
800	3	4.79	0.3	419	1,242	4.01	6.74
			0.4				8.99
			0.5				11.24
		9.58	0.3		2,484	8.02	8.13
			0.4				10.83
			0.5				**13.54**
		0.63	0.3		163	0.53	1.30
			0.4				1.73
			0.5				2.16
		2	0.3		519	1.68	3.80
			0.4				5.06
			0.5				6.33
800	4	4.79	0.3	409	1,618	3.92	8.73
			0.4				**11.64**
			0.5				**14.55**
		9.58	0.3		3,235	7.83	10.64
			0.4				**14.18**
			0.5				**17.73**
		0.63	0.3		213	0.52	1.65
			0.4				2.20
			0.5				2.75
		2	0.3		675	1.64	4.85
			0.4				6.47
			0.5				8.08
MAXIMUM EXPECTED FIRE SCENARIO				834	459	2.97	3.79

Boldface indicates that the incident heat flux ($\dot{q}_r$) exceeds the critical incident heat flux for IEEE 383 cables.

Table 5h. Cable Tray Incident Heat Flux Results (1,000 kW/m^2 Unit Heat Release Rate for Cables)

Variable Parameters				Results			
$\dot{q}_{bs}$ (kW/m^2)	No. Trays	v_s (mm/s)	Π_r	t_d (s)	$\dot{Q}_p$ (kW)	Maximum Fire Length (2·X$_s$) (m)	$\dot{q}_r$ (kW/m^2)
1,000	2	6.30	0.3	284	575	3.57	3.28
			0.4				4.38
			0.5				5.47
		12.60	0.3		1,151	7.14	4.08
			0.4				5.44
			0.5				6.81
		0.63	0.3		58	0.36	0.46
			0.4				0.61
			0.5				0.76
		2	0.3		183	1.13	1.39
			0.4				1.86
			0.5				2.32
1,000	3	6.30	0.3	335	1,634	4.22	8.50
			0.4				11.33
			0.5				**14.17**
		12.60	0.3		3,267	8.44	10.11
			0.4				**13.49**
			0.5				**16.86**
		0.63	0.3		163	0.42	1.28
			0.4				1.70
			0.5				2.13
		2	0.3		519	1.34	3.85
			0.4				5.14
			0.5				6.42
1,000	4	6.30	0.3	327	2,127	4.12	10.86
			0.4				**14.49**
			0.5				**18.11**
		12.60	0.3		4,255	8.24	**13.07**
			0.4				**17.43**
			0.5				**21.79**
		0.63	0.3		213	0.41	1.60
			0.4				2.13
			0.5				2.67
		2	0.3		675	1.31	4.84
			0.4				6.45
			0.5				8.06
MAXIMUM EXPECTED FIRE SCENARIO				834	459	2.97	3.79

Boldface indicates that the incident heat flux ($\dot{q}_r$) exceeds the critical incident heat flux for IEEE 383 cables.

The results summarized in these tables indicate that under worst case credible conditions, the critical incident flux for IEEE 383 qualified cables is not exceeded until the heat release rate per unit area exceeds 11.4 kW/m^2, which is approximately twice the expected maximum heat release rate.

If it is assumed that the covered lower instrumentation tray of the four tray array becomes involved, the critical flux is not exceeded until the heat release rate is approximately 600 kW/m^2.

The results of these calculations indicate that the failure conditions are not exceeded until the following critical conditions are met or exceeded, as summarized below.

Heat Release Rate (kW/m^2)	Number of Trays	v_s (mm/sec)	χ_r	Target Heat Flux (kW/m^2)
400	**3**	**1.8**	**0.4**	**3.79**
600	4	6.6	0.5	13.27
700	3	8.08	0.5	11.81
700	4	4.04	0.5	12.65
800	3	9.58	0.5	13.34
800	4	4.79	0.4	11.64
1000	3	6.3	0.5	14.17
1000	4	6.3	0.4	14.49

Bold indicates the Maximum Expected Fire Scenario

These results demonstrate a substantial degree of conservatism relative to the MEFS and indicate that extreme variations of the expected parameters is required to exceed the failure criteria.

Additional analysis and calculations presented in Sections 12 and 13 indicate the significant additional conservatism in the analysis.

10. Maximum Allowable Cable Loading

In order to evaluate a limiting condition represented by placing additional cables in the three tray array evaluated as the maximum expected fire scenario, calculations of the maximum allowable cable loading were conducted. A representative cable with the following characteristics was assumed:

- 0.823-inch outer diameter;
- 45-mil PVC jacket;
- 55-mil XLPE insulation; and
- 400 kW/m^2 unit heat release rate.

This cable contains the maximum combustible content among the cables in trays C100, C101, and M101. Cables were added until the incident heat flux exceeded the maximum allowable heat flux for IEEE-383 qualified cables, or 11.4 kW/m^2. The results indicated that 177 of the representative cables may be added in any combination in trays M101, C101, and C100 before the incident heat flux exceeds 11.4 kW/m^2.

While the precise number depends on the cable size and construction, a reasonable limit, with a safety factor of 2, is 85 additional cables meeting the following conditions:

1. IEEE 383 qualified, and
2. Heat release rate less than 400 kW/m^2.

11. FIVE Methodology

The FIVE Methodology for screening potential exposure hazards was used for comparison to the results obtained in Sections 9 and 10. The critical separation distance is based on the classical point source equation [EPRI, 1991; SFPE, 1999], which is given by the following equation:

$$R_{cr} = \sqrt{\frac{\dot{Q}_r}{4\pi\dot{q}''_{cr}}} \qquad (14)$$

where R_{cr} is the critical separation distance (m), $\dot{Q}_r$ is the radiant heat release rate (kW), and $\dot{q}''_{cr}$ is the critical heat flux exposure to the target (kW/m^2). The suggested radiant heat release rate per the FIVE methodology is 40 percent of the full heat release rate [EPRI, 1991]. The critical incident heat flux for non-IEEE 383 cables is 5.7 kW/m^2, and the critical steady state heat flux was shown to be between 6 kW/m^2 and 7 kW/m^2.

The total and radiant heat release rate components are a function of the flame spread velocity only, as may be seen by examining Equations 1-11. Table 6 summarizes the results for the five most rapid spread velocities identified in Tables 5a-5h. The maximum heat release rate per flame spread velocity was obtained from Tables 5a-5h.

Table 6. Critical Separation Distances using the FIVE Screening Methodology

Spread Velocity (mm/s)	**Radiant Heat Release (kW)**	**Separation for 11.4 kW/m^2 (m [ft])**
12.60	3267	3.02 (9.90)
9.58	2484	2.63 (8.64)
8.08	2095	2.42 (7.93)
6.60	1711	2.18 (7.17)
6.30	1634	2.14 (7.00)
5.04	1307	1.91 (6.30)

The minimum actual cable tray separation is 7 ft; thus, scenarios with flame spread rates less than 6.3 mm/s would not exceed the critical heat flux for IEEE 383 qualified or equivalent cables.

12. Steady State Critical Heat Flux

This section of the report describes an additional series of calculations that adjust the EPRI/FIVE Methodology critical incident heat flux to the actual conditions of the problem analyzed in this report. A modified incident heat flux for failure is calculated, called the steady state critical heat flux. The steady state critical heat flux is the minimum heat flux required to heat the surface of the target cable to the critical temperature. The critical flux is a function of the orientation of the cable relative to the exposure fire and the heat losses to ambient. This calculation relates the critical heat flux and failure temperature given in the FIVE Methodology to the cable geometry and exposure problem considered in this report.

This calculated steady state critical heat flux is higher than the failure criteria previously described because it accounts for radiative cooling, convective cooling, and conduction losses that exist in the problem being modeled. It is intended to demonstrate additional conservatism in the analysis.

The steady state critical heat flux was calculated for IEEE 383 rated cable and for non-IEEE 383 rated cable using the finite difference heat transfer model HEATING [Childs, 1998]. HEATING is a finite difference numerical heat transfer program that was developed at Oak Ridge National Laboratories Radiation Safety Information Computation Center to analyze the thermal impact of various high energy research projects. It has one of the longest development histories among computational heat transfer software [Fowler and Volk, 1959; Childs, 1991; Childs, 1998]. Validation studies for this software by Oak Ridge National Laboratories are available in Bryan *et al.* [1986] and Chu [1989]. These validation studies demonstrate that the implementation of the heat transfer equations is correct in HEATING.

The thermal material properties for steel were obtained from Abrams [1978], copper from Holman [1990], and PVC from Marks [1996]. Appendix B summarizes the material properties for each material used in this evaluation. There are two possible exposure scenarios as shown in Figures 8 and 9. The orientation shown in Figure 8, which involves direct exposure to the side of

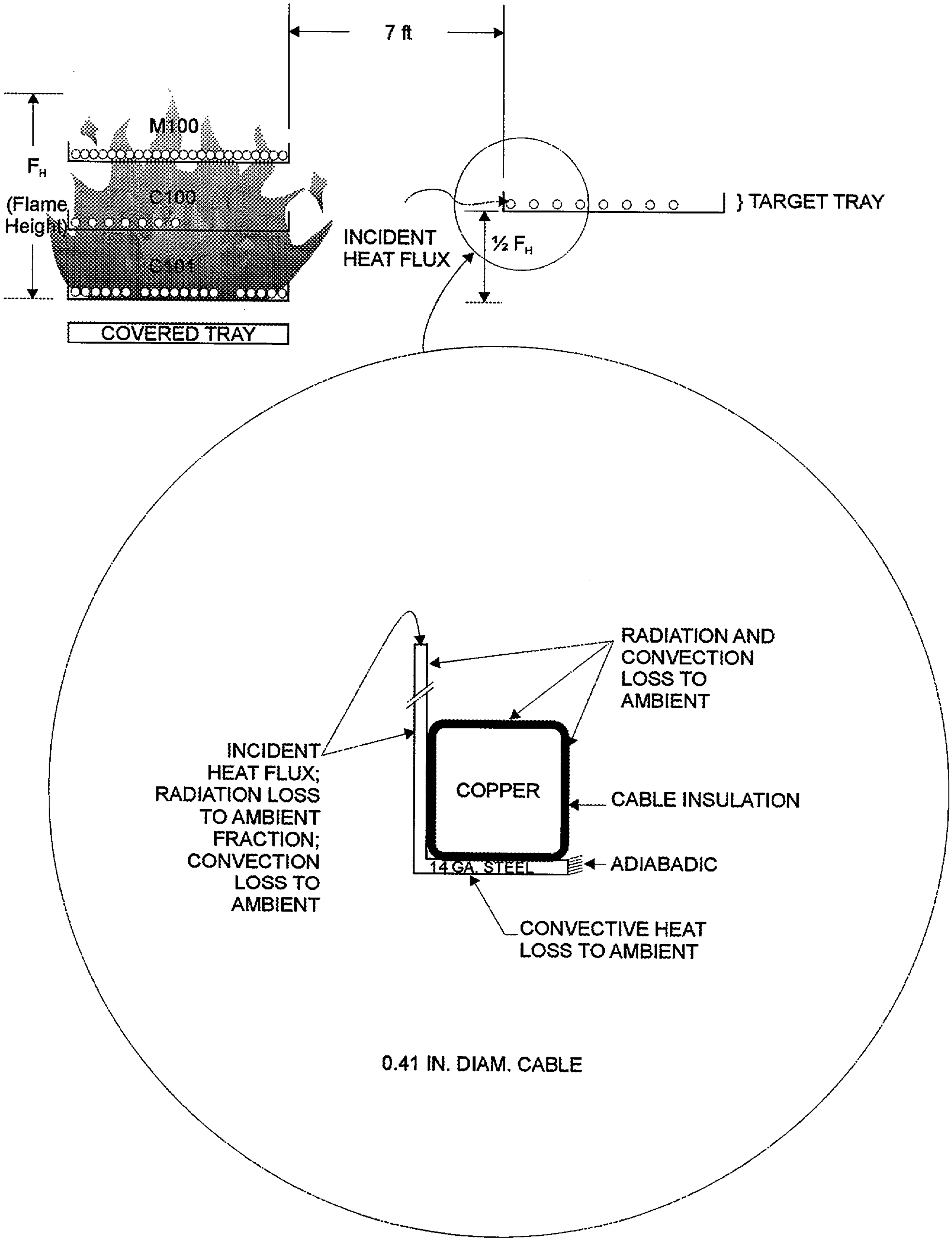


Figure 8 – Target cable tray and cable located directly across burning cable tray

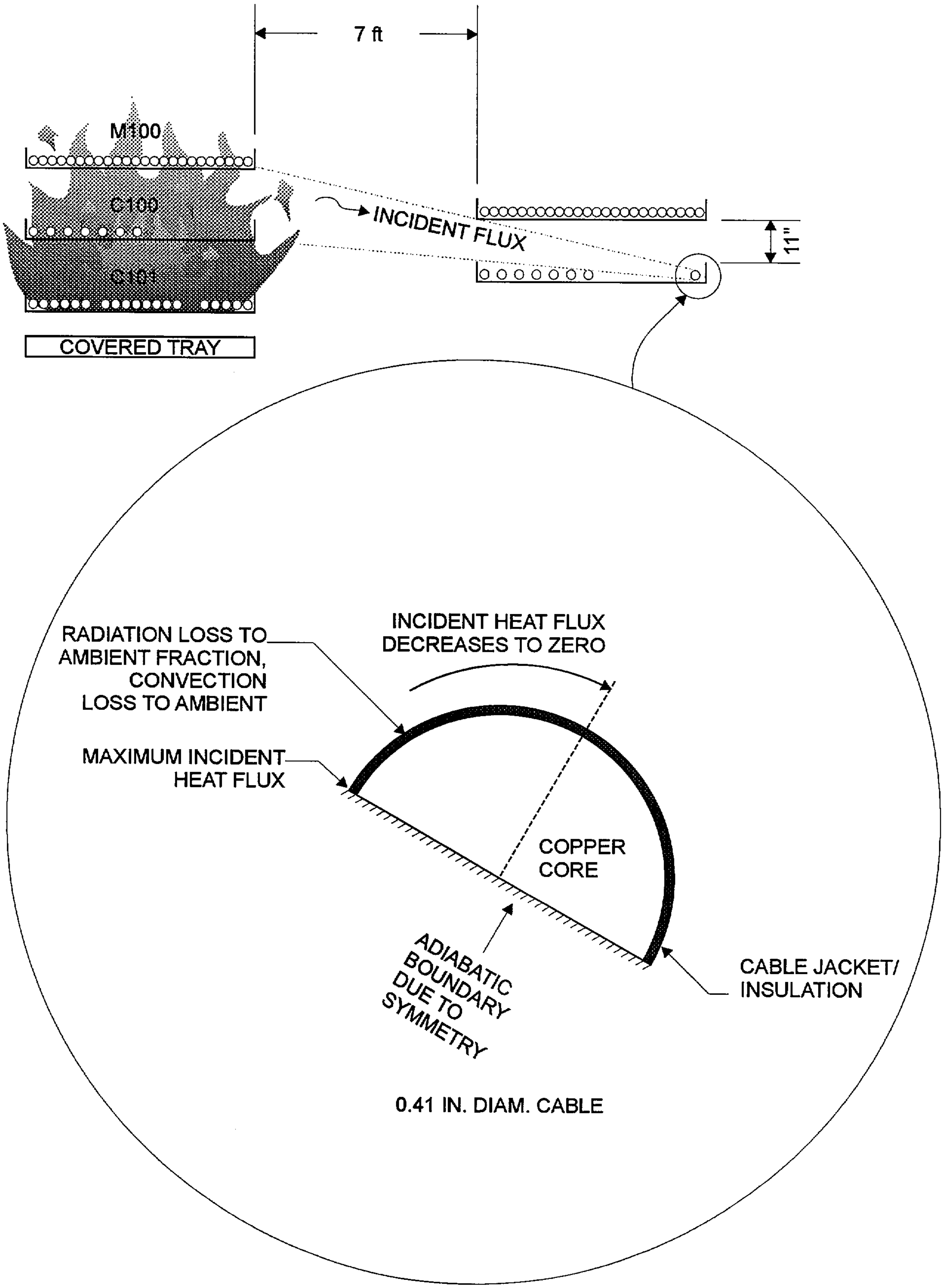


Figure 9 – Direct exposure of cable on far side of target cable tray

the target cable tray and with heat conduction into cable as shown, was evaluated first. The cable was assumed to be square, with each side equal to the smallest size cable diameter [See Appendix A for cable loading information]. This approximation was necessary because of the difficulty encountered when mixing rectilinear and cylindrical coordinate systems. The density of the copper was decreased by a factor of 0.78 (area of cylinder cross section divided by area of square cross section) such that the thermal capacity of the core remained constant. The net result is very conservative because the heat flow into the cable is greatly overestimated whereas the thermal capacity remains the same. The energy that is lost to the surroundings is a function of the configuration factor between the fire and the target. The configuration factor will fall between nearly 0 to about 0.4, depending on the size of the fire. Figure 10 summarizes the critical steady state heat flux for non-IEEE 383 qualified cables as a function of the shape factor.

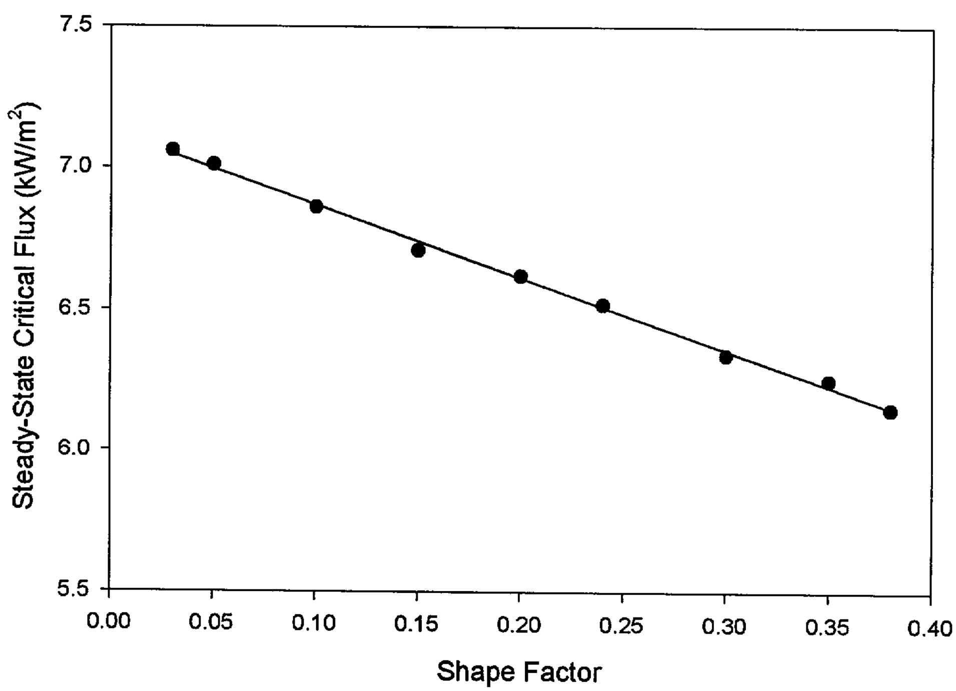


Figure 10. Critical steady state heat flux as a function of the shape factor for non-IEEE 383 qualified cables

IEEE 383 Qualified Cables

- Failure temperature of 371 °C [EPRI, 1991];
- Critical incident heat flux of 11.4 kW/m^2 [EPRI, 1991]; and
- Critical steady state heat flux between 18.5 kW/m^2 and 19.5 kW/m^2.

non-IEEE 383 Qualified Cables

- Failure temperature of 218 °C [EPRI, 1991];
- Critical incident heat flux of 5.7 kW/m^2; and
- Critical steady state heat flux between 6.0 kW/m^2 and 7.0 kW/m^2 (Figure 10).

The critical steady state heat flux is greater than the critical incident heat flux because the specific geometry is evaluated. The critical incident heat flux is based on small scale test data and generally represents a worst case scenario.

It is evident that steady state conditions, which account for heat losses and the actual cable orientation, allow for an incident heat flux exposure that is reported by EPRI [1991].

The second configuration shown in Figures 4a-4d was analyzed next. The cable is assumed located in the far corner of the cable tray and intercepts radiation through the aperture formed between the two trays. Because the cable is located further from the flame in this orientation, for a given fire scenario the maximum configuration factor and incident heat flux will always be less than the corresponding exposure to the side tray. A bounding approximation thus assumes that the shape factor is the same for both the side exposure and direct exposure orientations.

Another important consideration for this case is that the radiant heat flux decreases rapidly in either direction when moving away from the maximum, as shown in Figure 9.

The critical steady state heat flux for non-IEEE 383 cables was estimated and calculated using HEATING to be 19.8 kW/m^2 assuming a shape factor of 0.24. The heating calculation includes radiation and convection heat losses, which are particularly important in this case due to the surface dependent incident heat flux. This means that this configuration is bounded by the exposure to the tray that conducts into the cable. This is made obvious by comparing the 6.5 kW/m^2 critical steady state heat flux obtained using a shape factor of 0.24 (see Figure 10) to the 19.8 kW/m^2 critical steady state heat flux. Consequently, the direct cable exposure configuration is not considered further in this evaluation.

12.1 Sensitivity of Steady-State Critical Heat Flux to Boundary Conditions

The sensitivity of the steady state critical heat flux to the assumed target tray boundary conditions was evaluated in accordance with NFPA 805 [2001]. The thermal material properties of the steel, copper, and PVC are well established and do not require parametric study.

There are two key boundary condition assumptions: the radiation emissivity of the cable tray is 0.8 and the convection coefficient is 5.0 W/m^2-°C. The emissivity was selected assuming that there would be a coating of Flamemastic. The emissivity of galvanized steel may be as low as 0.3. The emissivity of the Flamemastic may also be greater than 0.8 but must be less than 1.0. The emissivity is thus assumed to vary between 0.3 and 1.0.

The convection coefficient is based on the local air flow and is difficult to estimate without intensive computation. A value of 5 W/m^2-°C is on the low end of fire exposure conditions. This parameter was varied from 5 W/m^2-°C to 15.0 W/m^2-°C.

The results are summarized in Table 7 for non-IEEE 383 cables. The table indicates that the steady state critical heat flux is somewhat sensitive to both boundary conditions. The table suggests that the maximum expected fire scenario critical heat flux is likely under-estimated because the only instances where the value decreased are unrealistic: either zero convection heat loss or complete absorbtion of all incident thermal radiation.

Table 7. Sensitivity of Steady-State Critical Heat Flux to Boundary Conditions (non-IEEE 383 cables)

Parameter Modification	Steady State Critical Heat Flux (kW/m^2)	Impact
MAXIMUM EXPECTED FIRE SCENARIO	6.5	N/A
Target Emissivity Decreased to 0.3	8.2	+ 1.7 W/m^2
Target Emissivity Decreased to 0.5	7.6	+ 1.1 W/m^2
Target Emissivity Increased to 1.0	6.1	- 0.4 W/m^2
Target Convection Decreased to 0.0 W/m^2-°C	5.5	- 1.0 W/m^2
Target Convection Increased to 10.0 W/m^2-°C	7.8	+ 1.3 W/m^2
Target Convection Increased to 15.0 W/m^2-°C	9.1	+ 2.4 W/m^2

It should be noted that the calculated steady state heat flux is below the critical exposure heat flux of 5.7 kW/m^2 when convection is ignored. This provides strong evidence cables in general. This seemingly anomalous result arises because conservative boundary condition parameters were selected for the exterior of the cable tray. A blackbody temperature of 293°C would produce a heat flux of 5.7 kW/m^2. This means that the critical heat flux incorporates some cable surface boundary condition parameters (emissivity and absorbtivity).

13. Transient Heat Transfer Analysis

An additional analysis was performed that models the transient thermal response of the exposed cables. It focuses on the transient response of non-IEEE qualified cable, and is intended to demonstrate that if the exposed cables were treated as non-qualified cables, the critical failure temperature of these cables would not be exceeded for cases where the critical steady state heat flux for non-qualified cables is exceeded in the calculations presented in Section 10. For IEEE 383 qualified cables or equivalent, this analysis is not important.

A transient heat transfer analysis was performed using basic principles of heat transfer and thermal equilibrium and the finite difference computer model HEATING [Childs, 1998].

The configuration considered is shown in Figure 8. Because of the complexity that arises when mixing cylindrical and rectilinear coordinate systems, the cable cross section was assumed

square with a side dimension equal to the diameter of the cable. The density of the copper was reduced in proportion with the increase in volume, namely the thermal capacity of the round and square systems remains constant. The boundary conditions and material properties are as described in Section 6.

The critical temperature is known to be 218°C for non-IEEE 383 compliant cables and 371°C for IEEE 383 cables. Ambient temperature is assumed to be 20°C. A conservative estimate of the convection coefficient is 5 W/m^2-K [Babrauskas, 1979], and the emissivity of the steel is assumed to be 0.8 due to the presence of the Flamemastic fire retardant material. The radiation configuration factor varies from scenario to scenario because of the different fire sizes; however, the maximum radiation shape factor between the target and the fire identified in the evaluations summarized in Table 5a-5h is 0.27. The critical steady state heat flux in this case is 6.5 kW/m^2. Only scenarios with an incident target heat flux greater than 6.5 kW/m^2 were modeled.

A transient heat transfer analysis of the scenarios shown in Table 5a-5f that exceed the critical steady state heat flux was performed using HEATING for the side of the cable tray exposure. A two-dimensional analysis was performed as shown in Figure 8. In all cases, the smallest cable (0.41 in. diameter) was assumed because there is a smaller heat sink. Figure 8 also depicts the assumed boundary conditions on the cable tray and the cable jacket. The transient analysis calculates the temperature response of the surface of the cable as the fire grows and spreads away from the point of origin. Table 8 summarizes the peak cable surface temperature for each scenario in which the incident heat flux exceeded the critical steady state heat flux.

Table 8 indicates that none of the scenarios where the incident heat flux exceeded the critical steady state value would result in a surface temperature greater than 218 °C.

Table 8. Results of Transient Heat Transfer Analysis for Select Cases from Table 2.

$\dot{q}''_{bs}$ (kW/m^2)	No. Trays	v_s (mm/s)	Π_r	$\dot{q}''_r$ (kW/m^2)	Peak Temp (°C)
400	4	3.54	0.4	6.74	158
			0.5	8.42	183
		2.0	0.5	6.68	170
500	3	5.04	0.4	6.55	141
			0.5	8.19	164
	4	2.52	0.4	6.73	160
			0.5	8.41	186
		5.04	0.3	6.54	140
			0.4	8.72	170
			0.5	10.9	198
		2.0	0.5	7.29	176
600	3	3.28	0.4	6.49	146
			0.5	8.11	169
		6.6	0.4	8.03	148
			0.5	10.04	173
	4	3.28	0.4	8.4	173
			0.5	10.5	201
		6.6	0.3	7.96	146
			0.4	10.61	179
			0.5	13.27	208
		2.0	0.5	7.64	179

13.1 Impact of Ambient Temperature on Transient Temperature Calculations

The impact of the ambient temperature on the results was performed in accordance with NFPA 805 [2001]. A bounding estimate of the ambient temperature is 49°C. Table 9 summarizes the results of this calculation modification.

Table 9. Impact of Increasing Ambient Temperature to 49°C on Transient Heat Transfer Results

$\dot{q}''_{bs}$ (kW/m^2)	No. Trays	v_s (mm/s)	Π_r	$\dot{q}''_r$ (kW/m^2)	Peak Temp (°C)
400	4	3.54	0.4	6.74	176
			0.5	8.42	200
		2.0	0.5	6.68	186
500	3	5.04	0.4	6.55	162
			0.5	8.19	197
	4	2.52	0.4	6.73	178
			0.5	8.41	202
		5.04	0.3	6.54	161
			0.4	8.72	190
			0.5	10.9	216
		2.0	0.5	7.29	192
600	3	3.28	0.4	6.49	165
			0.5	8.11	187
		6.6	0.4	8.03	170
			0.5	10.04	193
	4	3.28	0.4	8.4	191
			0.5	10.5	217
		6.6	0.3	7.96	168
			0.4	10.61	199
			0.5	13.27	226
		2.0	0.5	7.64	195

Boldface font indicates scenario causes target to exceed critical temperature of 218°C for non-IEEE 383 cables (Limiting Fire Scenario).

Comparing Tables 8 and 9 lead to the conclusion that the increase in ambient to 49°C causes the maximum cable insulation temperature to increase by about 16-17°C. Even with this increase, only one scenario is identified that would exceed the non-IEEE 383 critical temperature of 218°C, and none exceeded the IEEE 383 critical temperature of 371°C.

14. Conclusions

14.1 A 7-ft horizontal separation between the SA and SB cable tray systems is adequate to ensure that fire induced failure of both systems will not occur given the fire hazard present.

14.2 The Flamemastic coated cables are equivalent to IEEE qualified cables from the standpoint of damageability performance.

14.3 The critical incident heat flux for IEEE 383 qualified cables is 11.4 kW/m^2. When adjusted for the specific conditions of this installation, the critical steady state heat flux is increased to between 18.5 kW/m^2 and 19.5 kW/m^2. For unqualified cables, the critical incident flux is 5.7 kW/m^2, and the steady state critical flux is between 6.0 kW/m^2 and 7.0 kW/m^2.

14.4 The maximum expected fire scenario as defined in NFPA 805 [2001], Appendix C, consists of a three cable tray array exposing a target cable tray located 7 ft away. A heat release rate of 400 kW/m^2 with a radiative fraction of 0.4 and a flame spread rate of 1.8 mm/s forms the fire source for this maximum expected fire scenario.

14.5 The results of the maximum expected fire scenario indicate that the critical incident flux conditions are not exceeded for either IEEE 383 qualified or unqualified cables.

14.6 The limiting fire scenario for the condition evaluated requires a heat release rate of 800 kW/m^2 and a flame spread rate of 9.6 mm/s with three trays involved. If the covered bottom tray is assumed to contribute, the limiting fire scenario requires a heat release rate of 700 kW/m^2 and greater than expected flame spread rate. A complete sensitivity analysis and evaluation of limiting fire scenarios is given.

14.7 The use of a steady state critical heat flux that is related to failure temperature results in additional conservatism in the analysis.

14.8 If the Flamemastic coated cables are assumed to have performance equivalent to non-IEEE 383 qualified cables, the limiting fire scenarios can be achieved with a heat release rate of 500 kW/m^2 and a elevated flame spread velocity.

14.9 For cases where an unqualified cable is assumed and heat release rates do not exceed 600 kW/m^2, a transient heat transfer analysis indicates that the failure temperature will not be reached.

14.10 An analysis of limiting conditions of adding additional cables indicates that IEEE 383 qualified cable is used and the heat release rate is limited to 400 kW/m^2, up to 170 cables of a fixed size and construction can be added to a three tray array. If a safety factor of two is assumed, then 85 cables can be added without exceeding the critical heat flux of 11.4 kW/m^2 for IEEE 383 qualified cables.

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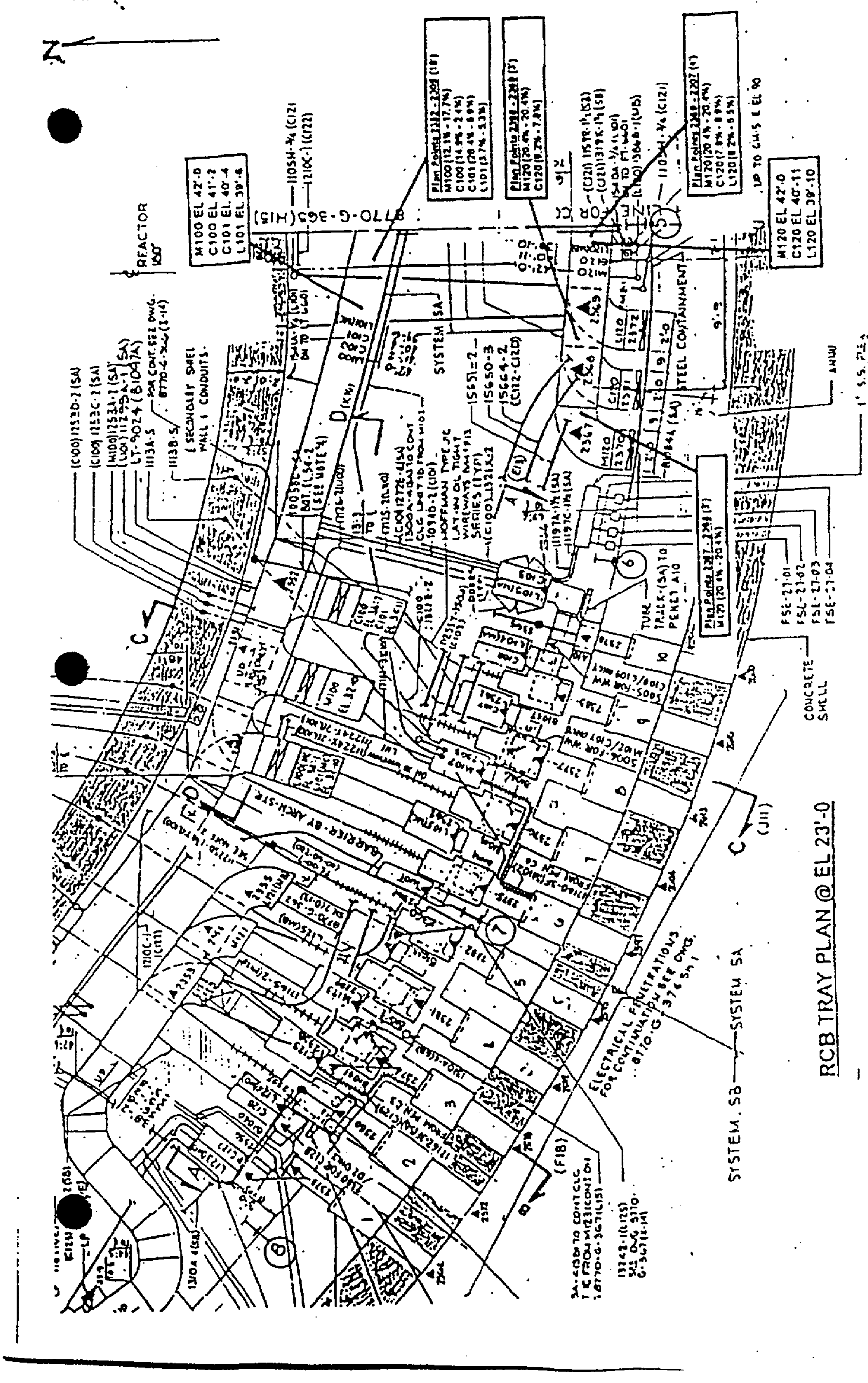

RCB TRAY PLAN @ EL 23'-0

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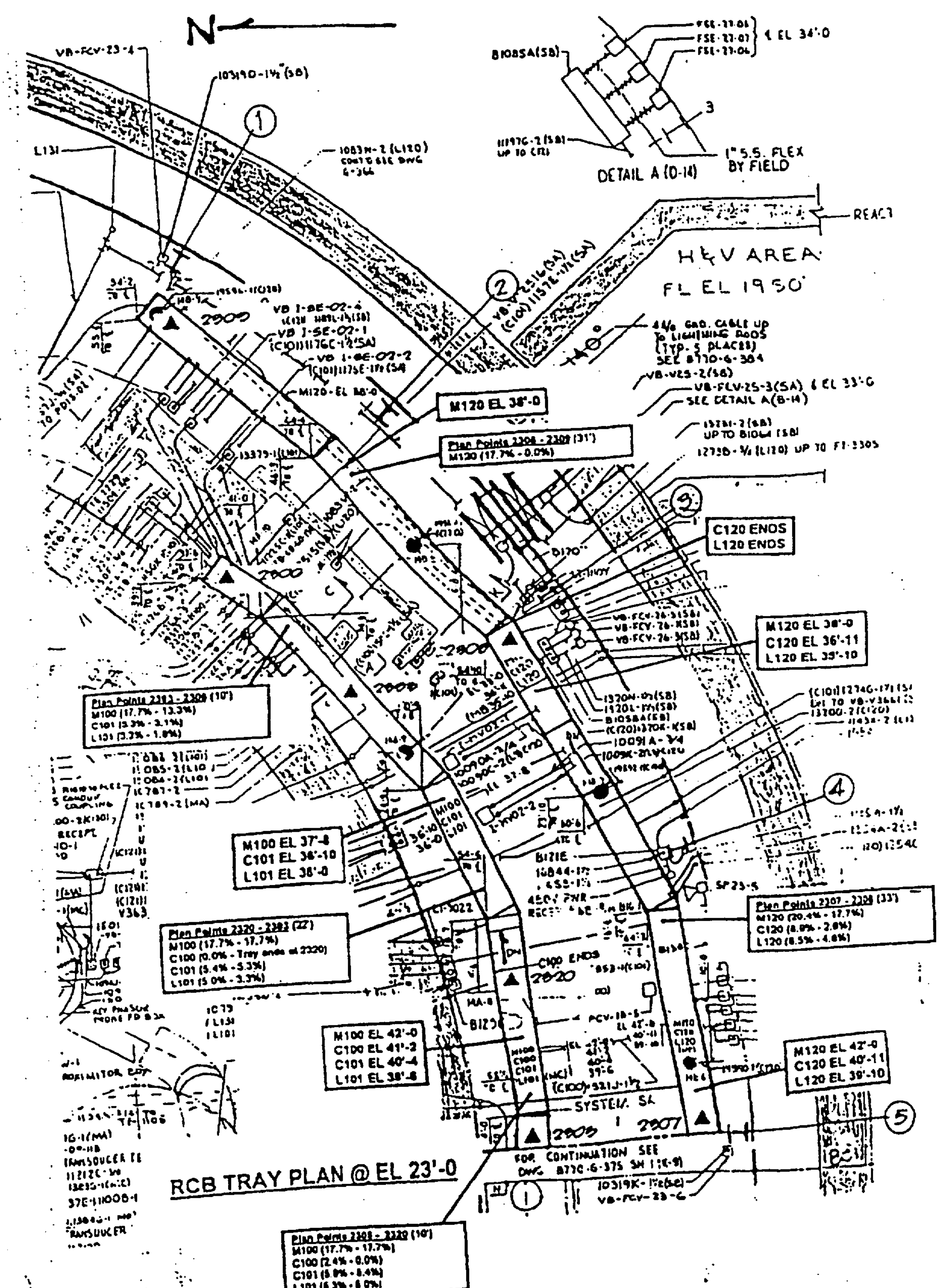

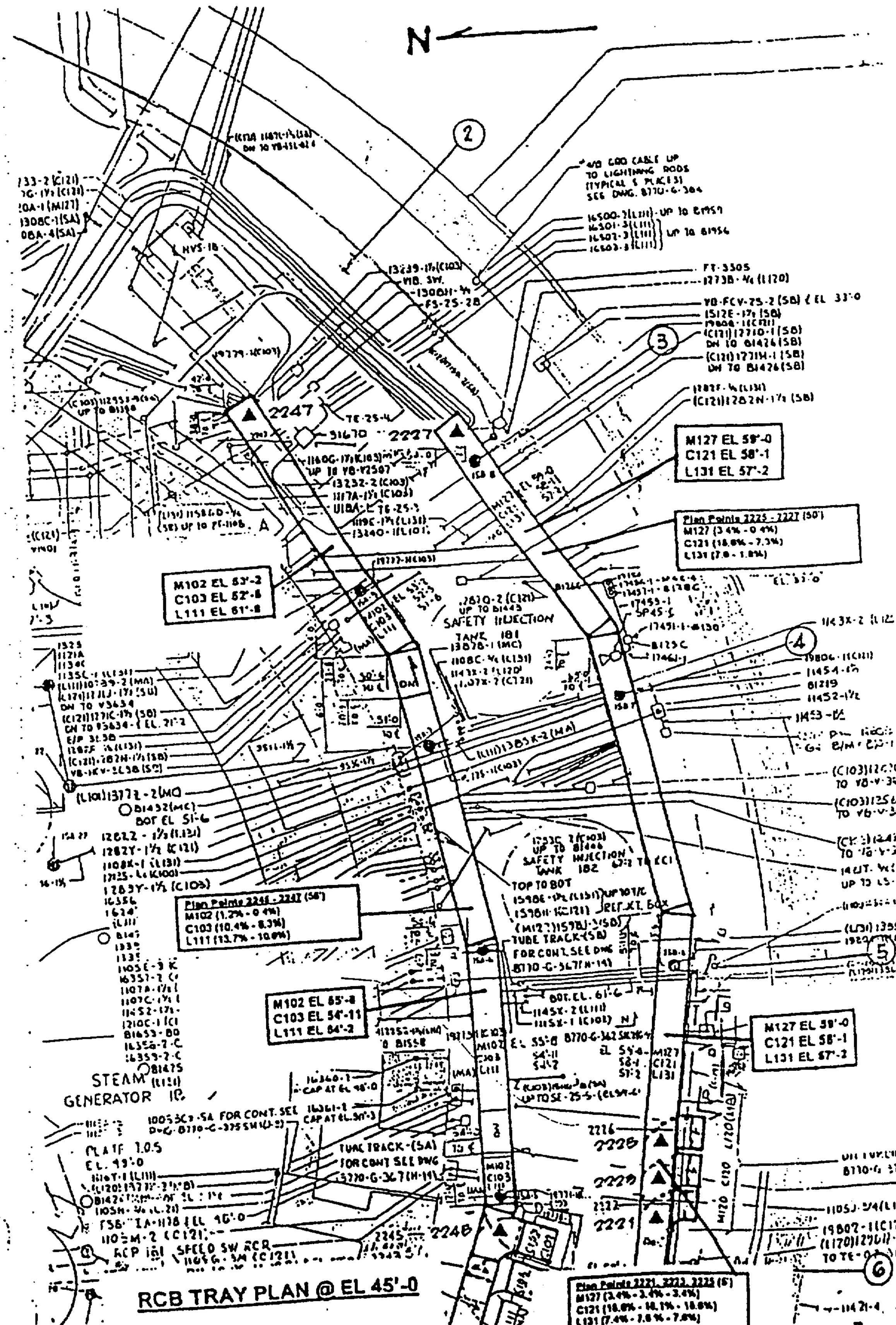

RCB TRAY PLAN @ EL 45'-0

10/12/2001 8:47 AM
Prepared by: D E Roxas
Verified by: M R Zokan

St. Lucie Plant Unit No. 1
RCB - Cable Trays at Floor El 23.00'

u1rcbplanptsBOM R01

Plan Point	Raceway ID	% Fill	Cables Contained	Symbol	Cable B/M	Qty	Ref Project ID No.
2305	M100	17.7%	3 - 1/C #4/0	XLPP	D02-03	24	FLO-8770-291-A
	C100	2.4%	7/C #12	XLPN	D10-42	4	FLO-8770-292-K
	C101	5.9%	2/C #12	XLPPP	D03-08	4	FLO-8770-292-A
			2/C #12	XLPN	D10-40	4	FLO-8770-292-K
			5/C #16	XLPN	D10-44	7	FLO-8770-292-K
			5/C #16	XLPPP	D03-11	2	FLO-8770-292-A
			2/C #16	XLPPP	D03-12	5	FLO-8770-292-A
			2/C #16	XLPN	D10-45	1	FLO-8770-292-K
	L101	5.3%	RG-59/U	COA	D10-60	4	FLO-8770-292-J
			RG-71B/U	COA	D10-61	2	FLO-8770-292-J
			6/C #18 SH	XLPSN (1-M/C)	D10-53	1	FLO-8770-292-J
			2/C #16 (CC)	XLPSMP (TE)	D05-01	3	FLO-8770-292-C
			2/C #16 1-STP	XLPSN (1)	D10-51	2	FLO-8770-292-K
			2/C #14 1-STP	XLPSMP	D04-02	2	FLO-8770-292-A
			3/C #16 1-STT	XLPSMP	D04-06	5	FLO-8770-292-A
			4/C #16 SH	XLPSN (1-M/C)	D10-52	2	FLO-8770-292-J
			RG-58A/U	XLPE	D10-17	1	FLO-8770-292-E
			2/C #16 TC (CA)	TEW	D71-01	2	FLO-2998-293-AA
			2/C #16 (CC)	EPDMHYP	D05-04	1	FLO-8770-292-M
			2/C #14 1-STP	XLPSN	D10-50	3	FLO-8770-292-J
2320	M100	17.7%	3 - 1/C #4/0	XLPP	D02-03	24	FLO-8770-291-A
	C100	0.0%	-		-	-	
	C101	5.4%	5/C #16	XLPPP	D03-11	2	FLO-8770-292-A
			2/C #12	XLPPP	D03-08	4	FLO-8770-292-A
			2/C #16	XLPPP	D03-12	6	FLO-8770-292-A
			5/C #16	XLPN	D10-44	6	FLO-8770-292-K
			2/C #12	XLPN	D10-40	3	FLO-8770-292-K
	L101	5.0%	RG-59/U	COA	D10-60	4	FLO-8770-292-J
			RG-71B/U	COA	D10-61	2	FLO-8770-292-J
			6/C #18 SH	XLPSN (1-M/C)	D10-53	1	FLO-8770-292-J
			2/C #16 (CC)	XLPSMP (TE)	D05-01	3	FLO-8770-292-C
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			3/C #16 1-STT	XLPSMP	D04-06	5	FLO-8770-292-A
			2/C #14 1-STP	XLPSMP	D04-02	2	FLO-8770-292-A
			2/C #16 TC (CA)	TEW	D71-01	2	FLO-2998-293-AA
			2/C #16 (CC)	EPDMHYP	D05-04	1	FLO-8770-292-M
			2/C #14 1-STP	XLPSN	D10-50	3	FLO-8770-292-J
2393	M100	17.7%	3 - 1/C #4/0	XLPP	D02-03	24	FLO-8770-291-A
	C101	5.3%	2/C #12	XLPPP	D03-08	3	FLO-8770-292-A
			5/C #16	XLPPP	D03-11	2	FLO-8770-292-A
			2/C #16	XLPPP	D03-12	3	FLO-8770-292-A
			5/C #12	XLPN	D10-41	1	FLO-8770-292-J
			2/C #12	XLPN	D10-40	4	FLO-8770-292-K
			5/C #16	XLPN	D10-44	6	FLO-8770-292-K
	L101	3.3%	RG-59/U	COA	D10-60	4	FLO-8770-292-J
			RG-71B/U	COA	D10-61	2	FLO-8770-292-J
			6/C #18 SH	XLPSN (1-M/C)	D10-53	1	FLO-8770-292-J
			2/C #16 1-STP	XLPSN (1)	D10-51	1	FLO-8770-292-K
			2/C #14 1-STP	XLPSMP	D04-02	2	FLO-8770-292-A
			3/C #16 1-STT	XLPSMP	D04-06	5	FLO-8770-292-A

Plan Point	Raceway ID	% Fill	Cables Contained	Symbol	Cable B/M	Qty	Ref Project ID No.
2393	L101 (Cont'd)		2/C #16 TC (CA)	TEW	D71-01	2	FLO-2998-293-AA
			2/C #14 1-STP	XLPSN	D10-50	1	FLO-8770-292-J
			2/C #16 (CC)	XLPSMP	D05-01	2	FLO-8770-292-C
2306	M100	13.3%	3 - 1/C #4/0	XLPP	D02-03	18	FLO-8770-291-A
	C101	3.1%	2/C #12	XLPPP	D03-08	1	FLO-8770-292-A
			5/C #16	XLPPP	D03-11	1	FLO-8770-292-A
			2/C #12	XLPN	D10-40	3	FLO-8770-292-K
			5/C #16	XLPN	D10-44	4	FLO-8770-292-K
			2/C #16	XLPPP	D03-12	3	FLO-8770-292-A
	L101	1.8%	2/C #16 1-STP	XLPSN (1)	D10-51	1	FLO-8770-292-K
			2/C #14 1-STP	XLPSMP	D04-02	2	FLO-8770-292-A
			3/C #16 1-STT	XLPSMP	D04-06	5	FLO-8770-292-A
			2/C #14 1-STP	XLPSN	D10-50	1	FLO-8770-292-J
2369	M120	20.4%	5/C #12	MCCC	D52-07	2	FLO-2998-292
			3 - 1/C #4/0	XLPP	D02-03	24	FLO-8770-291-A
			3/C #12	XLPN	D10-31	2	FLO-8770-292-K
			3 - 1/C #2	XLPP	D02-06	3	FLO-8770-291-A
	C120	7.8%	7/C #12	XLPN	D10-42	2	FLO-8770-292-K
			5/C #12	MCCC	D52-07	4	FLO-2998-292
			9/C #12	MCCC	D52-05	1	FLO-2998-292
			5/C #16	XLPPP	D03-11	3	FLO-8770-292-A
			2/C #12	XLPPP	D03-08	1	FLO-8770-292-A
			2/C #16	XLPPP	D03-12	7	FLO-8770-292-A
			7/C #12	MCCC	D52-06	1	FLO-2998-292
			2/C #12	XLPN	D10-40	1	FLO-8770-292-K
			5/C #16	XLPN	D10-44	1	FLO-8770-292-K
	L120	8.2%	12/C #16 6-STP	XLPSMP	D04-03	2	FLO-8770-292-A
			2/C #16 1-STP	INSTS	D61-05	5	FLO-2998-293-AA
			3/C #16 1-STT	XLPSMP	D04-06	2	FLO-8770-292-A
			2/C #16 (CC)	XLPSMP (TE)	D05-01	1	FLO-8770-292-C
			2/C #14 1-STP	XLPSN	D10-50	3	FLO-8770-292-J
			4/C #16 SH	XLPSN (1-M/C)	D10-52	3	FLO-8770-292-J
			2/C #16 (CC)	EPDMHYP	D05-04	2	FLO-8770-292-M
			4/C #16 SH	XLPP	D04-14	3	FLO-8770-292-C
			2/C #14 1-STP	XLPSMP	D04-02	2	FLO-8770-292-A
			2/C #16 1-STP	XLPSMP	D04-07	3	FLO-8770-292-A, -H
			4/C #16 DOST	INSTS	D61-08	1	FLO-2998-293-AA
2307	M120	20.4%	5/C #12	MCCC	D52-07	2	FLO-2998-292
			3 - 1/C #4/0	XLPP	D02-03	24	FLO-8770-291-A
			3/C #12	XLPN	D10-31	2	FLO-8770-292-K
			3 - 1/C #2	XLPP	D02-06	3	FLO-8770-291-A
	C120	8.9%	7/C #12	XLPN	D10-42	2	FLO-8770-292-K
			5/C #12	MCCC	D52-07	6	FLO-2998-292
			9/C #12	MCCC	D52-05	1	FLO-2998-292
			5/C #16	XLPPP	D03-11	3	FLO-8770-292-A
			2/C #12	XLPPP	D03-08	1	FLO-8770-292-A
			2/C #16	XLPPP	D03-12	7	FLO-8770-292-A
			7/C #12	MCCC	D52-06	1	FLO-2998-292
			2/C #12	XLPN	D10-40	1	FLO-8770-292-K
			5/C #16	XLPN	D10-44	1	FLO-8770-292-K

10/12/2001 8:47 AM
Prepared by: D E Roxas
Verified by: M R Zoken

St. Lucie Plant Unit No. 1
RCB - Cable Trays at Floor El 23.00'

u1rcbplanptsBOM R01

Plan Point	Raceway ID	% Fill	Cables Contained	Symbol	Cable B/M	Qty	Ref Project ID No.
2307	L120	6.5%	12/C #16 6-STP	XLPSMP	D04-03	2	FLO-8770-292-A
			2/C #16 1-STP	INSTS	D61-05	5	FLO-2998-293-AA
			3/C #16 1-STT	XLPSMP	D04-06	2	FLO-8770-292-A
			2/C #16 (CC)	XLPSMP (TE)	D05-01	1	FLO-8770-292-C
			2/C #14 1-STP	XLPSMP	D04-02	2	FLO-8770-292-A
			4/C #16 SH	XLPP	D04-14	2	FLO-8770-292-C
			2/C #16 (CC)	EPDMHYP	D05-04	1	FLO-8770-292-M
			2/C #14 1-STP	XLPSN	D10-50	2	FLO-8770-292-J
			2/C #16 1-STP	XLPSMP	D04-07	3	FLO-8770-292-A, -H
			4/C #16 DOST	INSTS	D61-08	1	FLO-2998-293-AA
2308	M120	17.7%	3 - 1/C #4/0	XLPP	D02-03	24	FLO-8770-291-A
	C120	2.6%	2/C #12	XLPN	D10-40	1	FLO-8770-292-K
			5/C #16	XLPN	D10-44	1	FLO-8770-292-K
			7/C #12	XLPN	D10-42	1	FLO-8770-292-K
			5/C #12	MCCC	D52-07	1	FLO-2998-292
			2/C #16	XLPPP	D03-12	5	FLO-8770-292-A
	L120	4.8%	12/C #16 6-STP	XLPSMP	D04-03	2	FLO-8770-292-A
			2/C #16 1-STP	INSTS	D61-05	5	FLO-2998-293-AA
			3/C #16 1-STT	XLPSMP	D04-06	2	FLO-8770-292-A
			2/C #16 (CC)	XLPSMP (TE)	D05-01	1	FLO-8770-292-C
			2/C #14 1-STP	XLPSN	D10-50	2	FLO-8770-292-J
			2/C #16 (CC)	EPDMHYP	D05-04	1	FLO-8770-292-M
			2/C #16 1-STP	XLPSMP	D04-07	1	FLO-8770-292-A

7/11/2001 8:59 AM
Prepared by: DERoxas

St. Lucie Plant Unit No. 1
RCB - Cable Trays at Floor El 45.00'

Plan Point	Raceway ID	% Fill	Cables Contained	Symbol	Cable B/M	Qty	Ref Project ID No.
2245	M102	1.2%	3/C #8	XLPP	D02-07	1	FLO-8770-291-A
			3/C #12	XLPN	D10-31	1	FLO-8770-292-K
	C103	10.4%	2/C #16	XLPPP	D03-12	16	FLO-8770-292-A
			2/C #12	XLPPP	D03-08	14	FLO-8770-292-A
			5/C #16	XLPPP	D03-11	7	FLO-8770-292-A
			7/C #12	XLPN	D10-42	1	FLO-8770-292-K
			2/C #12 - Armored cable	XLPE	D03-16	2	-
			5/C #12	XLPN	D10-41	1	FLO-8770-292-J
	L111	13.7%	2/C #16 1-STP	XLPSN (1)	D10-51	11	FLO-8770-292-K
			2/C #14 1-STP	XLPSMP	D04-02	7	FLO-8770-292-A
			3/C #16 1-STT	XLPSMP	D04-06	40	FLO-8770-292-A
			4/C #16 DOST	INSTS	D61-01	1	FLO-2998-293-AA
			4/C #16 SH	XLPSN (1-M/C)	D10-52	2	FLO-8770-292-J
			COAX 1/C #22 & 2/C #20	COA	D10-71	9	FLO-8770-292-J
2247	M102	0.4%	3/C #12	XLPN	D10-31	1	FLO-8770-292-K
	C103	6.3%	2/C #16	XLPPP	D03-12	3	FLO-8770-292-A
			2/C #12	XLPPP	D03-08	6	FLO-8770-292-A
			5/C #16	XLPPP	D03-11	4	FLO-8770-292-A
			7/C #12	XLPN	D10-42	4	FLO-8770-292-K
			2/C #12 - Armored cable	XLPE	D03-16	1	-
			5/C #12	XLPN	D10-41	1	FLO-8770-292-J
	L111	10.6%	2/C #16 1-STP	XLPSN (1)	D10-51	2	FLO-8770-292-K
			2/C #14 1-STP	XLPSMP	D04-02	5	FLO-8770-292-A
			3/C #16 1-STT	XLPSMP	D04-06	38	FLO-8770-292-A
			COAX 1/C #22 & 2/C #20	COA	D10-71	8	FLO-8770-292-J
2221	M127	3.4%	3/C #8	XLPP	D02-07	1	FLO-8770-291-A
			3/C #12	XLPN	D10-31	1	FLO-8770-292-K
			1/C #2/0	XLPN	D10-30	3	FLO-8770-292-J
	C121	18.6%	2/C #16	XLPPP	D03-12	13	FLO-8770-292-A
			5/C #10	XLPPP	D03-02	1	FLO-8770-292-A
			7/C #12	XLPN	D10-42	7	FLO-8770-292-K
			2/C #12	XLPPP	D03-08	17	FLO-8770-292-A
			5/C #12	XLPN	D10-41	6	FLO-8770-292-J
			5/C #16	XLPPP	D03-11	11	FLO-8770-292-A
			2/C #12 - Armored cable	XLPE	D03-16	3	-
	L131	7.4%	3/C #16 1-STT	XLPSMP	D04-06	15	FLO-8770-292-A
			2/C #16 1-STP	XLPSN (1)	D10-51	17	FLO-8770-292-K
			2/C #14 1-STP	XLPSMP	D04-02	8	FLO-8770-292-A
2223	M127	3.4%	3/C #8	XLPP	D02-07	1	FLO-8770-291-A
			3/C #12	XLPN	D10-31	1	FLO-8770-292-K
			1/C #2/0	XLPN	D10-30	3	FLO-8770-292-J
	C121	18.1%	2/C #16	XLPPP	D03-12	13	FLO-8770-292-A
			5/C #10	XLPPP	D03-02	1	FLO-8770-292-A
			7/C #12	XLPN	D10-42	7	FLO-8770-292-K
			2/C #12	XLPPP	D03-08	17	FLO-8770-292-A
			5/C #12	XLPN	D10-41	6	FLO-8770-292-J
			5/C #16	XLPPP	D03-11	11	FLO-8770-292-A
			2/C #12 - Armored cable	XLPE	D03-16	3	-

St. Lucie Plant Unit No. 1
RCB - Cable Trays at Floor El 45.00'

Plan Point	Raceway ID	% Fill	Cables Contained	Symbol	Cable B/M	Qty	Ref Project ID No.
2223	L131	7.6%	RG-71B/U	COA	D10-61	2	FLO-8770-292-J
			3/C #16 1-STT	XLPSMP	D04-06	15	FLO-8770-292-A
			2/C #16 1-STP	XLPSN (1)	D10-51	17	FLO-8770-292-K
			2/C #14 1-STP	XLPSMP	D04-02	8	FLO-8770-292-A
2225	M127	3.4%	3/C #8	XLPP	D02-07	1	FLO-8770-291-A
			3/C #12	XLPN	D10-31	1	FLO-8770-292-K
			1/C #2/0	XLPN	D10-30	3	FLO-8770-292-J
	C121	18.6%	2/C #16	XLPPP	D03-12	13	FLO-8770-292-A
			5/C #10	XLPPP	D03-02	1	FLO-8770-292-A
			7/C #12	XLPN	D10-42	7	FLO-8770-292-K
			2/C #12	XLPPP	D03-08	17	FLO-8770-292-A
			5/C #12	XLPN	D10-41	8	FLO-8770-292-J
			5/C #16	XLPPP	D03-11	11	FLO-8770-292-A
			2/C #12 - Armored cable	XLPE	D03-16	3	-
	L131	7.6%	RG-71B/U	COA	D10-61	2	FLO-8770-292-J
			3/C #16 1-STT	XLPSMP	D04-06	15	FLO-8770-292-A
			2/C #16 1-STP	XLPSN (1)	D10-51	17	FLO-8770-292-K
			2/C #14 1-STP	XLPSMP	D04-02	8	FLO-8770-292-A
2227	M127	0.4%	3/C #12	XLPN	D10-31	1	FLO-8770-292-K
	C121	7.3%	2/C #16	XLPPP	D03-12	4	FLO-8770-292-A
			2/C #12	XLPPP	D03-08	2	FLO-8770-292-A
			5/C #16	XLPPP	D03-11	2	FLO-8770-292-A
			7/C #12	XLPN	D10-42	5	FLO-8770-292-K
			5/C #12	XLPN	D10-41	4	FLO-8770-292-J
			2/C #12 - Armored cable	XLPE	D03-16	1	-
	L131	1.8%	2/C #16 1-STP	XLPSN (1)	D10-51	7	FLO-8770-292-K
			3/C #16 1-STT	XLPSMP	D04-06	1	FLO-8770-292-A
			2/C #14 1-STP	XLPSMP	D04-02	2	FLO-8770-292-A

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Cable Requirement
Sheet No. 3

EBASCO SPECIFICATION 211-69
ELECTRIC CABLES
PART ONE - SPECIFIC REQUIREMENTS

Project Identification
No. FLO-8770-291-A
Issue Date: Sept 18, 1970
Rev 1: Nov 25, 1970
Rev 2: Aug 16, 1971
Rev 3: October 21, 1971
Rev 4: April 11,1973

Symbol - XLPP

Group B2a - Single and Three Conductor 600 Volt Power Cables

Application - For underground and aboveground applications in wet or dry locations and direct burial.

Conductor - Class B, concentric stranded, annealed uncoated copper per ASTM B 3 and ASTM B 8.

Insulation - Carbon-black cross-linked polyethylene insulation meeting the electrical and physical requirements of Interim Standard No. 2, IPCEA Pub. No. S-66-524, NEMA Publication No. WC7. The insulation shall meet the horizontal flame test as indicated in UL No. 44, Rubber-Insulated Wires and Cables. The insulation shall be suitable at conductor temperature of 90° C (194F).

Insulation Thickness - 600 Volts: 14 Awg to 9 Awg = 30 mils, 8 Awg to 2 Awg = 45 mils, 1 Awg to 4/0 Awg = 55 mils, 225 MCM to 500 MCM = 65 mils, 525 MCM to 1000 MCM = 80 mils.

Jacket - 1) For single conductor cable
75 C black polyvinyl chloride jacket meeting physical requirements of Paragraph 3.8. of IPCEA S-61-402. Thickness shall be in accordance with Table 4-6. R3

2) For three conductor cable

a - Jacket over the insulation shall be 75° C black polyvinyl chloride meeting the physical requirements of Paragraph 3.8 of IPCEA S-19-81. Thickness shall be in accordance with Table 4-4. R3

b - Cable shall be made round with nonhygroscopic fillers and binders. R3

c - Overall jacket shall be 75° C black polyvinyl chloride jacket meeting physical requirements of Paragraph 3.8 of IPCEA S-61-402. Thickness shall be in accordance with Table 4-6

Tests - All tests shall meet the Interim Standard No. 2, IPCEA Pub. No. S-66-524, NEMA Pub. No. WC7.

* - Maximum permissible. R2

em	Cable Quan Linear Feet	Conductors No.	Conductors Size	No. of Strands	Nominal * Thickness Insul Mils	Nominal * Thickness Jacket Mils	Maximum * Outside Diameter Inches	Reels Reel No.	Reels Length Feet	
-1	3,000	1	1000 Mcm	61	80	65	1.53	1 thru 3	1000 ea	R2
-2	45,000	1	500 Mcm	37	65	65	1.17	1 thru 15	3000 ea	R4
-3	54,400	1	4/0 Awg	19	55	45	.823	1 thru 17	3200 ea	R4
-4	20,000	1	2/0 Awg	19	55	45	.712	1 thru 7	3000 ea.	R4
-6	99,000	1	#2 Awg	7	45	45	.582	1 thru 33	3000 ea	R4
-5	20,000	3	#2 Awg	7	45 -	25-80	1.25	1 thru 13	1500 ea	R4
-7	30,000	3	#8 Awg	7	45 -	15-60	.846	1 thru 12	2500 ea	R4
-8	75,000	3	#12 Awg	7	30 -	15 - 45	.619	1 thru 25	3000 ea	R4
-9	15,000	1	#6 Awg	7	45	45		1 thru 6	2500 ea	R4

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FROM· (WED) 7. 11'01 15:30/ST. 15:27/NO. 4862005115 P :0

Cable Requirement
Sheet No. 1 of 2 (C1a3)

EBASCO SPECIFICATION 211-69
ELECTRIC CABLES
PART ONE - SPECIFIC REQUIREMENTS

Project Identification
No. FLO-8770-292-A
Issue Date: March 5, 1971
R1: July 6, 1971
R3: October 6, 1971
R4: January 18, 1972
R6: August 16, 197
R7: April 11, 1973

Symbol - XLPPP

Group C1a3 - Multiple Conductor 600 Volt Nonshielded Control Cable and Low Energy Power Circuits

Application - For a-c and d-c control, relay and instrument circuits, and selected low energy power circuits - underground and aboveground applications in wet or dry locations and direct burial.

Conductor - Class B, concentric stranded, 7 strands, tinned or alloy coated annealed copper per ASTM B 33 or ASTM B 8; and ASTM B 189; IPCEA S-61-402, NEMA WC 5, Part 2. R4

Insulation - Carbon - black pigmented cross-linked thermosetting polyethylene meeting electrical and physical requirements of Interim Standard #2 for 600 volts and Interim Standard #1 for 1000 volts of IPCEA S-66-524, NEMA Pub. No. WC 7. The insulation shall meet the horizontal flame test as indicated in UL No. 44, Rubber-Insulated Wires and Cables. The insulation shall be suitable for use at a conductor temperature of 90°C (194).

Insulation Thickness - Nominal Values - 600 volts: 14 Awg - 9 Awg = 30 mils, 8 Awg - 2 Awg = 45 mils.

Jacket Over Insulation - Material: Extruded wall of 75°C polyvinyl chloride jacket meeting physical requirements of Paragraph 3.8 and color coded in accordance with Method 1 (Pigmentation), Paragraph 5.6.3, IPCEA S-61-402.
Thickness: Nominal values - IPCEA S-61-402, Table 4-4.

Cabling - The required number of insulated-jacketed conductors shall be cabled round with nonhygroscopic thermoplastic fillers.

Binder Tape - A binder tape applied over the cabled conductors.

Jacket - 75°C black polyvinyl chloride jacket meeting physical requirements of Paragraph 3.8 of IPCEA S-61-402. Thickness shall be in accordance with Table 7-8. R3

Tests - All tests shall meet applicable standards of IPCEA S-66-524.

Radiation - The completed cable shall withstand a total radiation dose of 3.5×10^5 Rads which is the normal radiation of 1 Rad per hour for a 40 year life.

* - Seller to furnish indicated data.

cables

	Item No.	Quan Feet	Conductors No.	Conductors Size	No. of Strands	Nominal Thickness* Insul Mils	Jacket Over Insul Mils	Jacket Overall Mils	Maximum* Outside Diameter Inches	Reels B/M No.	Reels Reel No.	Reels Length Feet	
	XLPPP-1	70,000	2/C	#10	7	30	15	45	.55	D3-3			R7
7	XLPPP-2	49,500	5/C	#10	7	30	15	60	.74	D3-2			R7
	XLPPP-3	13,000	7/C	#10	7	30	15	60	.81	D3-1			R7
6	XLPPP-4	220,000	2/C	#12	7	30	15	45	.50	D3-8			R7
	XLPPP-5	120,000	5/C	#12	7	30	15	60	.68	D3-7			R4
	XLPPP-6	75,000	7/C	#12	7	30	15	60	.74	D3-6			R4
	XLPPP-7	40,000	9/C	#12	7	30	15	60	.81	D3-5			R7

FROM (WED) 7. 11'01 15:30/ST. 15:27/NO. 4862005115 P 11

Cable Requirement
Sheet No. 2 of 2 (Cla3)

EBASCO SPECIFICATION 211-69
ELECTRIC CABLES
PART ONE - SPECIFIC REQUIREMENTS

Project Identification
No. FLO-8770-292-A
Issue Date: March 5, 197
R1: July 6, 1971
R3: October 6, 1971
R4: January 18, 1972
R6: August 16, 1972
R7: April 11, 1973

Item No.	Quan Feet	Conductors No.	Conductors Size	No. of Strands	Nominal Thickness* Insul Mils	Nominal Thickness* Jacket Over Insul Mils	Nominal Thickness* Jacket Overall Mils	Maximum* Outside Diameter Inches	B/M No.	Reels Reel No.	Reels Length Feet	
LPPP-8	20,000	12/C	#12	7	30	15	80	1.00	D3-4			R6
LPPP-9	220,000	2/C	#16	7	25	15	45	.41	D3-12			R7
PPP-10	186,000	5/C	#16	7	25	15	45	.52	D3-11			R7
PPP-11	80,000	9/C	#16	7	25	15	60	.69	D3-10			R7
PPP-12	20,000	12/C	#16	7	25	15	60	.77	D3-9			R4
PPP-13	8,000	6/C	#16	7	25	15	45	*	D3-13			R6

Cable Requirement
Sheet No. 1 of 2 (E1C)

EBASCO SPECIFICATION 211-69
ELECTRIC CABLES
PART ONE - SPECIFIC REQUIREMENTS

Project Identification
No. FLO-8770-292-A
Issue Date: March 5, 1971
R4: January 18, 1972
R5: March 16, 1972
R6: August 16, 1972

Symbol - XLPSMP(12)

Group E 1c - Twisted Pairs and Three Twisted Conductors - 300 Volt Instrumentation, Communication and Computer Transducer Cable.

Application - For underground and aboveground in wet or dry locations and direct burial.

Conductor - Class B, concentric stranded, 7 strands, tinned or alloy coated annealed copper conductors per ASTM B 33 or ASTM B 8; and ASTM B 189; IPCEA S-61-402, NEMA WC 5, Part 2.

Insulation - 25 mils nominal of carbon - black pigmented cross-linked polyethylene meeting electrical and physical requirements of Interim Standard No. 2 to IPCEA S-66-524, NEMA Pub No. WC7 for 600 Volts. The insulation shall be suitable for use at conductor temperature of 90°C (194 F). R6

Jacket Over Insulation - 15 mils nominal of 75°C polyvinyl chloride jacket meeting physical requirements of Paragraph 3.8 of IPCEA S-61-402. The individual insulated and jacketed conductors shall meet the horizontal flame test as indicated in UL No. 44. R6

Twisted Pairs (Each Pair Individually Shielded) - 1 Pair, 2 Pairs, 3 Pairs and 6 Pairs

Color Code - One pair shall be coded "white" and "black". Additional pairs shall be color coded per Paragraph 7.4.5.3 of IPCEA S-61-402 by Method 1 (full color). R6 R6

Pair - Twisted to maximum lay of 2 in. with a 1 mil, mylar tape helically applied over each pair, providing 100 percent coverage. R5

Drain Wire - Class B, 7 strand, annealed uncoated copper drain wire (not less than two Awg sizes smaller than the insulated conductors) to be laid spirally with the same direction and lay as the twisted pair.

Shielding Tape - 100 percent coverage of 1.7 mil copper-mylar with the metallic face of the tape in continuous contact with the drain wire. The twisted pairs should be isolated from each other by applying an additional tape over the individual pairs.

Cabling - Cable round with nonhygroscopic fillers and a binder tape.

Jacket - 75° C black polyvinyl chloride jacket meeting physical requirements of Paragraph 3.8 of IPCEA S-61-402. Thickness shall be in accordance with Table 7-8.

Three Twisted Conductors

Color Code - Color coded "white", "black" and "red" per IPCEA S-61-402, Paragraph 5.6.3, Method 3 (Printing).

Cabling - Cabled to a maximum lay of 2 in.

Bedding Tape - Cables to be wrapped with one (1) mil thick mylar tape.

Cable Requirement
Sheet No. 1 of 2 (EIC)

EBASCO SPECIFICATION 211-69
ELECTRIC CABLES
PART ONE - SPECIFIC REQUIREMENTS

Project Identification

No. FLO-8770-292-A
Issue Date: March 5, 1971
R4: January 18, 1972
R5: March 16, 1972
R6: August 16, 1972
R7: April 11 1973

Item No.	Type: No. Pairs	Type: Cond	Quan Feet	Conductors Size	No. of Strands	Nominal Thickness*: 1/C Insul Mils	Nominal Thickness*: 1/C Jacket Mils	Nominal Thickness*: Jacket Mils	Maximum* Outside Diameter Inches	Reels: B/M No.	Reels: Reel No.	Reels: Length Feet	
XLPSMP(12)-1	1	2	100,000	#14	7/W	30	15	45	.50	D4-2			R6
XLPSMP(12)-2	3	6	5,000	#14	7/W	25	15	60	.89	D4-1			R6
XLPSMP(12)-3	1	2	190,000	#16	7/W	25	15	45	.41	D4-7			R7
XLPSMP(12)-4	-	3	70,000	#16	7/W	25	15	45	.43	D4-6			R7
XLPSMP(12)-5	2	4	10,000	#16	7/W	25	15	60	.75	D4-5			R6
XLPSMP(12)-6	3	6	5,000	#16	7/W	25	15	60	.79	D4-4			R6
XLPSMP(12)-7	6	12	10,000	#16	7/W	25	15	80	1.10	D4-3			R6

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Cable Requirement
Sheet No. 1 of 1 (72C)

EBASCO SPECIFICATION 211-69
ELECTRIC CABLES
PART ONE - SPECIFIC REQUIREMENTS

Issue Date: March 5, 1971
R1: July 6, 1971
R3: January 4, 1972
R7: April 1?, 1973
R8: Jan 15, 1974
R9: May 20, 1974

Symbol - XLFSMP (TE)

Group 72c - Single Twisted Pair Thermocouple Extension Wire.

Application - For underground and aboveground installation in wet or dry locations.

Conductor - ANSI Type EX, positive wire - Chromel, negative wire - Constantan or ANSI Type KX, positive wire - Chromel, negative wire - Alumel, 16 Awg solid alloy wire matched and calibrated to ANSI C 96.1, latest edition for thermocouple extension wire.

Insulation - 30 mils nominal of filled, nonblack, chemically cross-linked polyethylene meeting electrical and physical requirements of IPCEA S-66-524, Part 3, NEMA Pub. No. WC7 for 600 volts. The insulation shall be covered with flame resistant paint and shall meet the horizontal flame test as indicated in UL No. 44, Rubber Insulated Wires and Cables. The insulation shall be suitable for use at a conductor temperature of 90°C (194 F). R3

Color Code - ANSI color code - Type EX: positive wire - Purple, negative wire - Red; Type KX: positive wire - Yellow, negative wire - Red. R3

Lay of Twist - Maximum of 2-1/4 ± 1/4 inches with nonhygroscopic fillers.

Drain Wire - Class B, 7 strand, annealed uncoated copper drain wire (not less than two Awg sizes smaller than the insulated conductors) to be laid spirally with the same direction and lay as the twisted pair.

Shielding Tape - 100 Percent coverage of 1.7 mil copper-mylar with the metallic face of the tape in continuous contact with the drain wire.

Jacket - 75°C polyvinyl chloride compound meeting requirements of Paragraph 3.8 of IPCEA S-61-402 for both insulation and jacket. Thickness shall be in accordance with Table 7-6, ANSI color: Type EX-Purple, Type KX-Yellow. R3

Tests - 1. Prior to cabling the individual insulated conductors shall be given a 2500 volt a-c spark test.
2. The completed cable shall be given the following tests:
(a) Dielectric test of 1000 volts a-c for five minutes, conductor to conductor, and conductor to shield.
(b) Jacket shall be subjected to an a-c spark of 3000 volts minimum.
(c) Insulation resistance measurements per IPCEA S-61-402, Paragraph 6.12.

Radiation - The completed cable shall withstand a total radiation dose of 3.5 x 10^5 Rads which is the normal radiation of 1 Rad per hour for a 40 year life.

* - Seller to furnish indicated data.

Item No.	Type	Quan Feet	Conductors No.	Conductors Size	Nominal Thickness Insul Mils	Nominal Thickness Jacket Mils	Maximum* Outside Diameter Inches	B/M No.	Reels Reel No.	Reels Length Feet	
TE-1	Chromel-Alumel (KX)	6,000	2/C	#16	30	45	0.35	DS-2			R3
TE-2	Chromel-Constantan (EX)	128,000	2/C	#16	30	45	0.35	DS-1			R3

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Cable Requirement
Sheet No.

ERASCO SPECIFICATION 211-69
ELECTRIC CABLES
PART ONE - SPECIFIC REQUIREMENTS

Project Identification
No. FLO-8770-292D
Issue Date February 7, 1972
Rev 1: April 25, 1972
Rev 2: May 11, 1973

Symbol	-	CZAC
Group	-	600 Volt Multiple Conductor Nonshielded Power Cables.
Application	-	For underground and aboveground applications in wet or dry locations and direct burial.
Conductor	-	Class B, concentric stranded, 7 strands, annealed uncoated copper per ASTM B 3 and ASTM B 8; IPCEA S-61-402, NEMA WC 5, Part 2.
Separator	-	A separator may be used to prevent insulation from sticking to conductor or to prevent insulation from being extruded into strands. If mylar tape is used, it should have a black color.
Insulation	-	Filled, non-black, chemically cross-linked thermosetting polyethylene meeting electrical and physical requirements of IPCEA S-66-524, Part 3. The insulation shall pass the vertical flame test per IPCEA S-19-81, Paragraph 6.19.6. The insulation shall be suitable for use at a conductor temperature of 90 C (194 F).
Insulation Thickness	-	Nominal Valves - 14 Awg - 9 Awg = 30 mils, 8 Awg - 2 Awg = 45 mils, 1 Awg - 4/0 Awg = 55 mils, 225 mcm-500 = 65 mils, 525 mcm-1000 mcm = 80 mils.
Jacket Over Insulation	-	75 C black polyvinyl chloride jacket meeting the physical requirements of Paragraph 3.8 of IPCEA S-61-402 for both insulation and jacket. Thickness shall be in accordance with Table 4 - 4.
Color Code	-	Color coded in accordance with IPCEA S-19-81, Paragraph 5.6.3, Method 1.
Cabling	-	The required numbers of conductors shall be cabled round with nonhygroscopic fillers.
Binder Tape	—	A nonhygroscopic binder tape applied over the cabled conductors.
Jacket	-	Same as over individual insulated conductors except in accordance with Table 7-8.
Radiation	-	The completed cable shall withstand a total radiation of 3.5×10^5 Rads which is the normal radiation of 1 Rad per hour for a 40 year life.
*	-	Seller to furnish indicated data.

Item No.	Cable Quan Circuit Feet	Cable Quan Linear Feet	Conductors No.	Conductors Size	Conductors Metal	No. of Strands	Nominal Thickness * Insul Mils	Color	Nominal Thickness * Jacket Mils	Maximum * Outside Diameter Inches	Reels B/M No.	Reels Reel No.	Reels Circuit Feet	
1	51,000		2/C	#4 Awg	CU	7	45	Blk	80	1.01	D2-10	17		R2
2	5,000		2/C & 8/C	#4* #8*	CU	7	45	Blk	80	1.60	D2-11	5		R1
3	30,000		3/C	#8	CU	7	45	Blk	80	1.17	D2-12	10		R1

* - Combined under the same jacket.

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Issue Date: October 15, 197
R1: March 12, 1974

Part One - Specific Requirements

Cable Requirement
Sheet No. 3 of 4

FLO-8770-292-E

Characteristics (13 Conductor Composite Cable)

a) Number of conductors	AWG (Copper)	Volt Rating	Number of Strands	Insulation Thickness	Type of Insulation	Compound Rating
9	22	300	7/.0096	.025	Silicone Rubber	100°C
2	18	300	16/30	.025	Silicone Rubber	100°C
ONE RG-59/U*	24	2300	19/36	.055	XLPE	90°C
ONE RG-58 A/U*	20	1900	19/.0071	.031	XLPE	90°C
JACKET (all fillers shall be flame retardant glass fiber)				.060	Chloro-sulphonated polyethlene	90°C

b) Completed cable shall pass the IPCEA vertical flame test

c) All tests shall meet applicable standards of IPCEA S-1981

d) RG-59/U has bare copper shield, RG-58A/U has tinned copper shield; all other conductors are identified by printed color code, IPCEA Method 3.

BM NUMBER	QUANTITY (FT)	NOMINAL OD	MAXIMUM OD
D10-17	3,000	0.640	0.675

*NOTE: .010 Mica tape over insulation, #36 AWG copper braided shield, 90% coverage, polyester tape for shield isolation.

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Cable Requirement
Sheet No. 13

EBASCO SPECIFICATION 211-73
ELECTRIC CABLES
PART ONE - SPECIFIC REQUIREMENTS

No. FLO-8770-292J
Issue Date: 2/12/74
R.1: 4/29/74 R.6:10/17/7
R.2: 5/22/74 R.7:11/25/7
R.3: 7/15/74 R.8:12/20/7
R.4: 8/13/74

Symbol . XLPN (600 Volts)

Group D52 . Multiple Conductor - 600 Volt Nonshielded Control Cable and Lower Energy Power Circuits.

Application . For a-c and d-c control, relay and instrument circuits, and selected low energy power circuits - underground and aboveground application in wet or dry locations and direct burial and NESCR condition(s) a,b,c,d

Conductor . Class B, concentric stranded. annealed tin coated copper per ASTM B 33 and ASTM B 8: IPCEA S-66-524, Part 2. (Item D52-1, 1/C #2/0 has Class C Stranding) R1

Separator . A separator may be used to prevent insulation from sticking to the conductor or to prevent insulation from being extruded into the strands. If mylar tape is used, it should have a white color.

Insulation . Flame resistant cross-linked thermosetting polyethylene meeting electrical and physical requirements of IPCEA S-66-524. The insulation is suitable for continuous operation at a conductor temperature not to exceed 90°C(194°F). The individual insulated conductors shall meet the IPCEA S-61-402 vertical flame test (painting to meet flame test not acceptable).

Insulation Thickness . Nominal values - 600 volts = 30 mils.

Color Code . Color coded in accordance with IPCEA S-61-402, Paragraph 5.6.3, Method 1 (Pigmentation).

Cabling . Cabled round with fillers and binder tape which are flame resistant and nonhygroscopic.

Jacket . Highly flame resistant, radiation cross-linked, non-corrosive polyolefin (Flamtrol) meeting requirements of IPCEA S-66-524. R

Tests . All tests shall meet applicable requirements of IPCEA S-66-524. Proof of meeting NESCR condition is required.
is, is not

. Seller to furnish indicated data.

Item No.	Quan Feet	Conductors No.	Size	No. of Strands	Nominal Thickness Insul Mils	Jacket Mils	Maximum Outside Diameter Inches	B/M No.	
D52-1	2,500	1/C	#2/0	37	55	45	.712	D10-30	R3
D52-3	5,000	3/C	#8	7	45	60	.846	D10-32	R3
D52-5	5,000	5/C	#12	7	30	45	.68	D10-41	R3
D52-10	40,000	1/C	#4/0	19	55	45	.824	D2-3	R6
D52-11	15,000	1/C	#2/0	19	55	45	.701	D2-4	R6
D52-12	10,000	3/C	#2	7	45	80	1.06	D2-5	R7
D52-13	3,000	1/C	#4/0	19	55	45	.824	D10-6	R5
D52-14	3,000	3/C	#2	7	45	80	1.06	D10-33	R6
D52-17	20,000	1/C	#6	7	45	30	*	D2-9	R8

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Cable Requirement
Sheet No. 21

EBASCO SPECIFICATION 211-73
ELECTRIC CABLES
PART ONE - SPECIFIC REQUIREMENTS

Project Identificati
No. FLO-8770-2923
Issue Date: 2/12/74
Rev. 1: 4/29/74
Rev 2: 5/22/74
Rev. 3: 7/15/74

Symbol - XLPSN(1-M/C)

Group D68 - Multiple Conductor 600 Volt Control Cable R2

Application - For underground and aboveground in wet or dry locations and direct burial NESCR condition(s) a,b,c & d.

Conductor - Class B, concentric stranded, 7 strands, annealed tin coated copper conductors per ASTM B33 and ASTM B8, IPCEA S-66-524, Part 2. R

Separator - A separator may be used to prevent insulation from sticking to the conductor or to prevent insulation from being extruded into the strands. If mylar tape is used, it should have a white color.

Insulation - 20 Mils nominal of flame resistant cross-linked thermosetting polyethylene meeting electrical and physical requirements of IPCEA S-66-524. The insulation is suitable for continuous operation at conductor temperature not to exceed 90°C (194°F). The individual insulated conductors shall meet the IPCEA S-61-402 vertical flame test (painting to meet flame test not acceptable). R2

Color Code - Color coded in accordance with IPCEA S-61-402 Paragraph 5.6.3, Method 1 (Pigmentation).

Cabling - Cabled round with fillers which are flame resistant and nonhygroscopic. R

Drain Wire - Class B, 7 strands, annealed uncoated copper drain wire(same Awg sizes as the insulated conductors) to be laid longitudinally R2

Shielding Tape - 100 Percent coverage of 1.7 mil aluminum-mylar with metallic face of tape in continuous contact with the drain wire.

Jacket - Highly flame resistant, radiation cross-linked, non-corrosive polyolefin (Flamtrol), meeting requirements of IPCEA S-66-524.

Tests - All tests shall be in accordance with IPCEA S-66-524. Proof of meeting flame test and NESCR condition is required.

* - Seller to furnish indicated data.

Item No.	Quan Feet	Conductor No.	Conductor Size	No of Strands	Nominal Thickness* Insul Mils	Nominal Thickness* Jacket Mils	Maximum* Outside Diameter Inches	B/M No.
D68-1	7,500	4/C	#16	7	20	45	.5	D10-52
D68-2	5,000	7/C	#18	7	20	45	.525	D10-53

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	- COA		
oup Gl	- Coaxial Cables		
plication	- Pressurized Water Reactor - Power Range and Start-Up Range Detectors Inside Nuclear Containment Vessel - Process Radiation Monitoring Instrumentation, NESCR conditions a,b,c,d.		
sign	- Low noise type RG-59/U and RG- 71 B/U, in accordance with MIL-C-17 and specified as follows:		
	RG-59/U		**RG-71 B/U**
) Physical Characteristics			
1) Conductor	#22 Awg stranded tin coated copper		#23 Awg Copper clad steel R
2) Dielectric	Treated for high temperature and radiation		Same as for RG-59/U
3) Shield	Single copper braid, having coverage not less than 90%		Tinned copper, doub[le] braid
4) Jacket	Flame resistant polyolefin radiation, cross-linked, non-corrosive (Flamtrol) *	R1	Same as for RG-59/U
5) Noise free treatment			—
6) Cable outside diameter	.242 ± .008		.272 ± .010
) Electrical Characteristics			
1) Impedance	62 ohms	R1	93 ohms
2) Capacitance	25.7 pico F/ft nominal	R1	13.2 pico F/ft nomi[nal]
3) Dielectric Strength (Bet. cond. & shield)	7000 volt Rms		2000 volt Rms
4) Operating Voltage	2300 volt, Rms, max.		1 000 volt Rms, max.
5) Insulation Resistance	10^{12} ohm/1000 ft, minimum	R1	10^{11} ohm/1000 ft, mi[nimum]
6) Corona Initiation volts	2.3 kV (a-c) Minimum		1.0 kV (a-c) minimum

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PART ONE - SPECIFIC REQUIREMENTS

Issue Date: Feb.12,1974
R2: 5/22/74
R9: 7/31/75

ts:

Insulation resistance shall be measured between cable shield and center conductor with General Radio GR 1230A electrometer, with a CR 1230-P1 component shield applying a 9.2 d-c volt. Other similar instruments may be used, but voltages greater than 10 volts d-c shall not be used. Charging time for the cable shall not exceed one hour. Prior to testing dielectric cable shall be cleaned with a 200-proof denatured anhydrous alcohol. All measurement shall be made under standard conditions of temperature, pressure, and humidity.

* Seller to furnish indicated data.

	Qty (ft)	RG (Type)	No. & Type Shielding Braids	Nominal Diameter of Dielectric (Inch)	Maximum Overall Diameter (Inch)	Weight Lb/Ft	Attenuation in db/100 ft Freq./Atten	B/M No.	
-1.	20000	59/U	Bare Copper	.146	.242±.008	35.5	10 mHz/1.1	D10-60	R9
-2	5000	71B/U	Tin coated CU	.172	.272±.010	44.8	10 mHz/0.9	D10-61	R2

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c Requirement
.ect No. 13

EBASCO SPECIFICATION 211-73
ELECTRIC CABLES
PART ONE - SPECIFIC REQUIREMENTS

Project Identification
No. FLO-8770-292 K
Issue Date: 4/29/74
R1: 5/22/74 R6: 2/4/
R2: 7/17/74 R8 8/20.
R3: 8/13/74 R9: 9/18/
R5: 1/15/75 R10: 10/3

Symbol - XLPN (600 Volts)

Group D52 - Multiple Conductor - 600 Volt Nonshielded Control Cable and Lower Energy Power Circuits.

Application - For a-c and d-c control, relay and instrument circuits, and selected low energy power circuits - underground and aboveground application in wet or dry locations and direct burial and NESCR conditions: a, b, c, d.

Conductor - Class B, concentric stranded, 7 strands, annealed tinned copper per ASTM B33 and ASTM B 8: IPCEA S-66-524, Part 2. R2

Separator - A separator may be used to prevent insulation from sticking to the conductor or to prevent insulation from being extruded into the strands. If mylar tape is used, it should have a white color.

Insulation - Flame resistant cross-linked thermosetting polyethylene meeting electrical and physical requirements of IPCEA S-66-524. The insulation is suitable for continuous operation at a conductor temperature not to exceed 90°C (194°F). The individual insulated conductors shall meet the IPCEA S-61-402 vertical flame test (painting to meet flame test not acceptable).

Insulation Thickness - Nominal values - 600 volts = 30 mils. *

Color Code - Color coded in accordance with IPCEA S-61-402, Paragraph 5.6.3, Method 1 (Pigmentation).

Cabling - Cabled round with fillers and binder tape which are flame resistant and nonhygroscopic.

Jacket - Black heavy duty neoprene jacket meeting the physical requirements of ASTM D 752 and Paragraph 4.13.3 of IPCEA S-19-81 with thickness in accordance with Table 4-18 of IPCEA S-19-81.

Tests - All tests shall meet applicable requirements of IPCEA S-66-524. Proof of meeting NESCR condition is required.
is, is not

- Seller to furnish indicated data.

Item No.	Quan Feet	Conductors No.	Conductors Size	No. of Strands	Nominal Thickness* Insul Mils	Nominal Thickness* Jacket Mils	Maximum* Outside Diameter Inches	B/M No.	
D52-2	30,000	3/C	#12	7			.619	D10-31	
D52-4	135,000	2/C	#12	7			.5	D10-40	R1
D52-6	5,000	7/C	#12	7			.74	D10-42	
D52-7	5,000	9/C	#12	7			.81	D10-43	
D52-8	57,500	5/C	#16	7			.52	D10-44	R
D52-18	250,000	2/C	#16	7				D3-12	R
D52-9	20,000	2/C	#10	7				D3-3	R1
D52-10	65,000	5/C	#12	7				D3-7	R3
D52-15	50,000	9/C	#16	7				D3-10	
D52-16	50,000	5/C	#16	7				D3-11	
D52-19	6,000	7/C	#14	7				D3-15	
	25,000	2/C	#10	7				D10-46	
	100,000	2/C	#16	7				D10-48	

Insulation thickness for Items D52-8, 15, 16 and B/M D10-48 is 25 mils

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Cable Requirement
Sheet No. 18

EBASCO SPECIFICATION 211-73
ELECTRIC CABLES
PART ONE – SPECIFIC REQUIREMENTS

Project Identification
No. FLO-8770-292 K
Issue Date: 4/29/74
R1: 5/22/74
R2: 7/17/74
R7: 3/7/75

Symbol - XLPSN (1)

Group D61 - Twisted Pairs and Conductors 300 Volt Instrumentation, Communication and Computer Input Cable. R7

Application - For underground and aboveground in wet or dry locations and direct burial NESCR condition(s) a, b, c & d

Conductor - Class B, concentric stranded, 7 strands, annealed tinned copper conductors per ASTM B33 and ASTM B 8, IPCEA S-66-524, Part 2. For telephone extension lines use 18 Awg.

Separator - A separator may be used to prevent insulation from sticking to the conductor or to prevent insulation from being extruded into the strands. If mylar tape is used, it should have a white color.

Insulation - 25 Mils nominal of flame resistant cross-linked thermosetting polyethylene meeting electrical and physical requirements of IPCEA S-66-524. The insulation is suitable for continuous operation at conductor temperature not to exceed 90°C (194°F). The individual insulated conductors shall meet the IPCEA S-61-402 vertical flame test (painting to meet flame test not acceptable).

Twisted Pairs (each pair individually shielded)

Color Code - One pair shall be color coded "white" and "black". Additional pairs shall be color coded per Paragraph 7.4.5.3 of IPCEA S-61-402 by Method 1 (Pigmentation).

Pairs/Conductors Twisted to a maximum lay of 2.42 inches. R7

Bedding Tape - Twisted pair to be wrapped with one (1) mil thick mylar tape.

Drain Wire - Class B, 7 strands, annealed tinned copper drain wire (Not less than two Awg size smaller than the insulated conductors) to be laid spirally with the same direction and lay as the twisted pair. R2

Shielding Tape - 100 Percent coverage of 2.0 mil Alum-mylar with metallic face of tape in continuous contact with the drain wire. The twisted pairs shall be isolated from each other by applying an addition tape over the the individual pairs. R2

Cabling - Pairs to be cabled round with fillers and binder tape which are flame resistant and nonhygroscopic.

Jacket - Black heavy duty neoprene jacket meeting the physical requirements of ASTM D 752 and Para. 4.13.3 of IPCEA S-19-81 with thickness in accordance with Table 4-18 of IPCEA S-19-81.

Tests - All tests shall be in accordance with IPCEA S660524. Proof of meeting NESCR condition is required.
is, is not

Seller to furnish indicated data.

Item No.	Quan Feet	No. Pairs	Conductor Size	No. of Strands	Nominal Thickness* Insul Mils	Nominal Thickness* Jacket Mils	Maximum* Outside Diameter Inches	B/M No.	
D61-2	10,000	1	#16	7			.41	D10-51	
D61-3	40,000	1	#14	7				D4-2	R1
D61-4	15,000	1	#16	7				D10-7 -	R1
D61-5	25,000	3/C	#16 —	7				D4 -6	R7
	2000	3	#22	7				D10-79	

Insulation to be 30 Mils R7

3/C Twisted Shielded Cable

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Ebasco Specification
Electric Cables
Part One - Specific Requirements

Project Identification No. FLO 2998.292
Issue Date: 10/28/77

Cable Requirement
Sheet No. 2

Symbol	-	MCCC (600V)
Group D52	-	Multiple Conductor - 600 Volt Nonshielded Control Cable and Lower Energy Power Circuits.
Application	-	For ac and dc control, relay and instrument circuits, and selected low energy power circuits underground and aboveground application in wet and/or dry locations and NESCR condition(s) a,b,c,d. R
Conductor	-	Class B concentric stranded, 7 strands, tinned copper per ASTM B33 and ASTM B8, IPCEA S-66-524, Part II.
Insulation	-	Flame resistant insulation suitable for continuous operation at a conductor temperature not to exceed 90°C (194°F). The individual insulated conductors shall meet the IPCEA S-61-402 vertical flame test (painting or spraying to meet flame test not acceptable). See Table Sheet 2a, page 6 for dimensions.
Color Code	-	Color coded in accordance with IPCEA S-61-402, Paragraph 5.5, Method 3 (printed color name and number).
Cabling	-	Cabled round with fillers and binder tape which are compatible with other components of the cable. R
Jacket	-	Black heavy duty flame resistant jacket. See Table Sheet 2a, page 6, for dimensions.
Tests	-	As per Paragraph 6, Part II of this Specification. Proof of meeting NESCR condition is required.

Project Identification No. FLO 2998.292
Issue Date: 10/28/77
Cable Requirement
Sheet No. 2a

B/M No	Quan Feet	Conductor No.	Conductor Size	No of Strands	Minimum Average Thickness+ Insul Mils	Minimum Average Thickness+ Jacket Mils	Outside Diameter++ Inches
D52-01	14,500	7/C	#10	7	40	65	.76
D52-02	87,000	5/C	#10	7	40	65	.70
D52-03	171,000	2/C	#10	7	40	50	.53
D52-04	22,000	12/C	#12	7	40	80	.99
D52-05	62,000	9/C	#12	7	40	80	.89
** D52-06	66,000	7/C	#12	7	40	65	.69
D52-07	236,000	5/C	#12	7	40	65	.64

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Cable Requirement Sheet No 2(1 of 3)	EBASCO SPECIFICATION 211-73 · ELECTRIC CABLES PART ONE - SPECIFIC REQUIREMENTS	Project Identification No FLO-2998-293AA Issue Date: 1/26/79 Rev. 4: 8/19/80	R4

Symbol	INSTS	
Group D61	Twisted Pairs 600 Volt Instrumentation, Communication and Computer Input Cable.	
Application	Suitable for use in alternate wet and dry locations in exposed conduits, trays, and underground ducts. NESCR condition(s) a, b, c, d .	
Conductor	Class, B concentric stranded, 7 strands, tinned or alloy coated copper per ASTM B33 and ASTM B8, IPCEA S-66-524 Part 2.	R2
Insulation	Kerite Type FR-II thermoseting insulation shall be suitable for continuous operation at the conductor temperature not to exceed 90°C. It shall be radiation, heat, flame, and moisture resistant, meeting the electrical and physical requirements of applicable Kerite Standards. Twisted Pairs (each pair individually shielded). The insulation resistance measurements shall be provided between conductor to conductor and conductor to shield during all conditions of the NESCR	R: R:
Color Code	One pair shall be color coded "white" and "black". Additional pairs shall be color coded per Paragraph 7.4.5.3 of IPCEA S-61-402 by Method 3 (Printed color name and number).	R2
	Quad shall be color coded "black","white","red" and "green" and other conductors of the composite cable to be color coded per ICEA S-61-402 in accordance with method 3 (Printed color name and number) table 5-1 omitting "black","white","red" and "green".	R4
	Multiconductor cable shall be color coded per ICEA S-61-402 in accordance with method 3 (Printed color name and number) table 5-1.	R4
Pairs	Twisted to a maximum lay of 2 inches.	
Quad	Twisted to a maximum lay of 6 inches.	R4
Bedding	Twisted pair/Quad will have an extruded 10 mil polymer layer	R2,R4
Drain Wire	Solid 0.0262 in. tinned copper drain wires. The number of wires used shall be equivalent to not less than two AWG sizes smaller than the insulated conductors (4 for #14 AWG conductors, 3 for #16 AWG conductors) and shall be laid spirally with the same direction and lay as the twisted pair.	R2
Shielding Tape	100 Percent coverage of 2 mil aluminum-mylar with metallic face of tape in continuous contact with the drain wire. The twisted pairs shall be isolated from each other by applying an additional 6 mil glass-mylar tape over the individual pairs.	R2 R2
Cabling	Pairs to be cabled round with fillers and binder tape which are compatible with other components of the cable. Their presence in the cable shall not adversely affect the completed-cable specified flame resistance or water absorption properties.	R2

Cable Requirements Sheet No 2 (2 of 3)	EBASCO SPECIFICATION 211-73 ELECTRICAL CABLES	Project Identification No FLO-2998-293AA Issue Date: 1/26/79

Rev 7: 6/15/81
Rev 8: 8/28/81
Rev 9: 12/29/81
Rev 12: 5/20/82
Rev 14: 7/2/82
Rev 15: 7/8/82

Overall Drain Wire: Same as drain wire when specified R4

Overall Shielding Tape: Same as shielding tape when specified R4

Overall Jacket: Kerite type FR self extinguishing radiation, abrasion, oil and moisture resistant thermosetting jacket meeting the physical requirements of applicable Kerite Standards. The water absorption characteristics of the jacket shall not exceed 20 mg/sq in. when tested per IPCEA Gravimetric Method. R2

Tests: All tests shall be in accordance with Paragraph 6, Part 11. Proof of meeting NESCR condition is required.

R16 See attachment 1 sht 2

Retyped for clarity

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Project Identification
No. FLO-2998-293AA

Rev 16: 10/6/82
Rev 17: 11/5/82
Rev 19: 4/18/84

ATTACHMENT 1

CABLE GROUP D61

B/M No.	Quan Feet	No Pairs	Conductor Size	No. of Strands	Nominal Thickness Insul Mils	Nominal Thickness Jacket Mils	Maximum* Outside Diameter Inches	Reels Reel B/M No.	Reels Length Feet*
D61-01	136,000	1	#14	7	++40	50	0.51	D61-01/ 1-12, 14-36	5,000
								D61-01/13	1,000
D61-02	50,000	3	#16	7	+30	65	0.77	D61-02/ 1 to 10	5,000
D61-03	330,000	2	#16	7	+30	65	0.73	D61-03/ 1 to 66	5,000
!D61-04	210,000	3/C	#16	7	+30	50	0.45	D61-04/ 1 to 36	5,000 R
**D61-05	900,000	1	#16	7	+30	50	0.43	D61-05/ 1 to 193	5,000 R
[illegible]1-06	5,000	3/C	#14	7	++40	50	0.53	D61-06/1	5,000
D61-07	10,000	12	#16	7	+30	80	1.27	D61-07/ 1,2	5,000
!!D61-08	15,000	4/C	#16	7	+30	50	0.51	D61-08/ 1,2,3	5,000
!!D61-09	7,000	4	#16	7	+30	65	0.84	D61-09/1 D61-09/2	5,000 2,000
!!D61-10	5,000	16/C	#16	7	30	65	0.805	D61-10-1	5,000
!!D61-11	1.000	48/C	#16	7	30	80	1.32	D61-11/1	1,000
!!D61-12	1,000	24/C	#16	7	30	80	1.016	D61-12/1	1,000
D61-13	3,000	***	#16	7	30	65	0.754	D61-13/1	3,000
D61-14	1,000	***	#16	7	30	65	0.86	D61-14/1	1,000
! D61-15	10,000	5	#16	7	30	65	later	D61-15/ 1,2	5,000

! D61-04 and D61-06 are shielded twisted triples cables

!! D61-08 is a double overall shielded twisted 4/C cable. Each shield shall have individual drain wire with insulation between shield.

[illegible]Vertical Tray Flame Test to be performed on this cable to qualify all cables of this group. The test shall be as per Paragraph 6, Part 2.

FROM (WED) 7. 11'01 15:34/ST. 15:27/NO. 4862005115 P 28

Rockbestos-Surprenant

172 Sterling Street
Clinton MA 01510
Tel: 978/365-6331
Fax: 978/365-4054

Quote #: 72-1117
Date: 11/20/00
Expiration: 12/20/00

Page 1 Of 1

To: FLORIDA POWER & LIGHT

For: Rfq #
000 24838

Attn: STEVE FRISCHING

Issued By: DOUG SOULLIERE, Customer Service Rep
Tel: (978)365-1220 Voice: (978)365-1225

We are pleased to quote on the following:

Item #	Quantity	Product Code	Description	Delivery ARO Wks	Price Per Mft	Weight Per Mft
1 B/M # D03-16	5,000' Minimum	N/A	2C #12 7/T.C., .030 XLPE/.020 CSPE, Cabled with Fillers, Mylar Wrap, Interlocked Galvanized Steel Armor, Overall .60 Mil Hypalon Jkt 600V 90 C	14-16 Wks	$3,088.00	368
2	2,500' Minimum	N/A	2C #6 7/T.C., .045 XLPE/.030 CSPE, Cabled with Fillers, Mylar Wrap, Interlocked Galvanized Steel Armor, Overall .80 Mil Hypalon Jkt 600V 90 C	14-16 Wks	$6,053.00	790

Additional Notes and Comments: ABOVE ITEMS QUOTED ARE NUCLEAR CLASS IE RATED. CABLE JACKETS TO BE INK PRINTED - NOT INDENT/EMBOSSED PRINTED.

Terms and Conditions for Quotations

Minimum Order:	$500.00
Tolerances:	Shipping and Length Tolerance Plus 10% Minus 10%
Terms of Payment	Net 30 Days Pending Credit Approval.
Quote Validity:	30 Days
Lengths:	Unless otherwise specified herein, quote is based on longest lengths possible.
Metals Escalation:	Prices will be subject to adjustment at time of shipment for changes in the cost of copper from $0.820 per pound Comex. ☐ Firm Price for Immediate Stock Order and Shipment.
Freight & FOB:	FOB Collect our Plant or Warehouse, lowest cost freight allowed to destinations in the US except Alaska and Hawaii for shipments over 5000 pounds
* Certified Test Data:	If required, add $450 per order, plus $75 per line item.

Cutting Charges:

Size	1/C	2/C-5/C	6/C-12/C	13/C & Over
9 AWG & Smaller	$20	$30	$40	$50
8 AWG - 2 AWG	30	60	.	.
1 AWG - 4/0 AWG	45	90	.	.
250 MCM & Larger	75	200	.	.

Lengths 250 feet and Smaller: $100.00 per shipping reel.

Appendix B

Thermal Material Properties used to Calculated Temperature Response of Target Cable Tray System to Incident Heat Flux

B1. Thermal Conductivity

The thermal conductivity for steel as a function of temperature is shown in Table B1. Because the failure threshold for the cable jacket material is less than 400 °C, the thermal conductivity of the copper and PVC jacket material are essentially temperature independent in this analysis.

Copper [Holman, 1990]: 386 W/m-°C
PVC [Marks, 1996]: 0.17 W/m-°C

Table B1 – Temperature Dependent Thermal Conductivity of Steel [Abrams, 1978]

T (°C)	K (W/m-°C)	T (°C)	k (W/m-°C)	T (°C)	k (W/m-°C)	T (°C)	k (W/m-°C)
20.0	46.02	316.0	42.75	649.0	32.84	816.0	29.03
38.0	46.02	371.0	41.04	677.0	32.1	843.0	27.15
73.0	46.4	427.0	39.45	704.0	31.42	871.0	26.40
149.0	45.73	482.0	37.82	732.0	30.92	899.0	26.73
204.0	44.76	538.0	36.44	760.0	30.45	927.0	26.78
260.0	43.84	593.0	34.73	788.0	30.0	1038.0	27.74

B2. Thermal Heat Capacity

The thermal heat capacity for steel as a function of temperature is shown in Table B2. The thermal heat capacity for PVC as a function of temperature over the range of interest is shown in Table B3. The heat capacity for copper is essentially constant of the temperature range expected in the cable core.

Copper [Holman, 1990]: 383 J/kg-°C

Table B2 – Temperature Dependant Heat Capacity of Steel [Abrams, 1978]

T (°C)	c_p (J/kg-°C)	T (°C)	c_p (J/kg-°C)	T (°C)	c_p (J/kg-°C)	T (°C)	c_p (J/kg-°C)
20.0	467	316.0	558	649.0	777	816.0	568
38.0	471	371.0	580	677.0	810	843.0	535
73.0	484	427.0	606	704.0	1098	871.0	522
149.0	501	482.0	641	732.0	1410	899.0	533
204.0	518	538.0	690	760.0	1012	927.0	568
260.0	536	593.0	736	788.0	727	1038.0	584

Table B3 – Temperature Dependant Heat Capacity of PVC [Marks, 1996]

T (°C)	c_p (J/kg-°C)	T (°C)	c_p (J/kg-°C)	T (°C)	c_p (J/kg-°C)
27	950	87	1457	107	1569

B3 Density

The density for the steel, PVC, and copper is constant of the temperature range considered.

Steel [Abrams, 1978]: 7800.0 kg/m^3
Copper [Holman, 1990]: 8954.0 kg/m^3
PVC [Johnson, 1994]: 1500.0 kg/m^3

Appendix C

Cable Tray Fuel Load Calculations

Cable Tray ID	**M100**		
Cable Type	3-1/C #4/0		
Outside Diameter (inches)	0.823	0.020904	meters
Insulation Thickness (mils)	55	0.001397	meters
Jacket Thickness (mils)	45	0.001143	meters
Cable Length (ft)	54,000	16459	meters

XLPP

Insulation Material	Carbon-black cross-linked polyethylene
Insulation Density (kg/m^3)	924.4
Insulation Heat of Combustion (kJ/kg)	23800
Jacket Material	Black polyvinyl chloride (PVC)
Jacket Density (kg/m^3)	1441.8
Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.0104521 m
Total Cable Area (A3)	0.000343208 m^2
Jacket Area	7.09593E-05 m^2
Insulation Area	7.55805E-05 m^2

Total Volume of Jacket (m^3)	1.167934
Total Volume of Insulation (m^3)	1.243994
Total Combustiable Volume (m^3)	2.411928
Total Mass of Jacket (kg)	1683.9
Total Mass of Insulation (kg)	1149.9
Total Combustiable Mass (kg)	2833.9
Number of Cables	24
Total Width of Cables (m)	0.502

Mass of Jacket per meter (kg/m)	0.1023
Mass of Insulation per meter (kg/m)	0.0699
Total Combustiable Mass per meter (kg/m)	0.1722
Jacket heat of combustion energy per meter (kJ/m)	1836.4
Insulation heat of combustion energy per meter (kJ/m)	1662.8
Combustable Fuel Load per meter per cable (kJ/m)	**3499.3**
Combustable Fuel Load per meter (kJ/m)	**83982.6**

Cable Tray ID	**C100**				
Cable Type	7/C #12			XLPN	
Outside Diameter (inches)	0.74	0.018796	meters	Insulation Material	Flame resistant cross-linked polyethylene
Insulation Thickness (mils)	30	0.000762	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	60	0.001524	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	75,000	22860	meters	Jacket Material	Polyolefin (Flamtrol) - *use PVC properties
				Jacket Density (kg/m^3)	1441.8
Outside Radius	0.009398 m			Jacket Heat of Combustion (kJ/kg)	17950
Total Cable Area (A3)	0.000277473 m^2				
Jacket Area	8.26947E-05 m^2				
Insulation Area	3.58749E-05 m^2				

Total Volume of Jacket (m^3)	1.8904	Mass of Jacket per meter (kg/m)	0.1192
Total Volume of Insulation (m^3)	0.8201	Mass of Insulation per meter (kg/m)	0.0332
Total Combustible Volume (m^3)	2.7105	Total Combustible Mass per meter (kg/m)	0.1524
Total Mass of Jacket (kg)	2725.6	Jacket heat of combustion energy per meter (kJ/m)	2140.2
Total Mass of Insulation (kg)	758.1	Insulation heat of combustion energy per meter (kJ/m)	789.3
Total Combustible Mass (kg)	3483.7	Combustible Fuel Load per meter per cable (kJ/m)	**2929.4**
		Combustible Fuel Load per meter (kJ/m)	**11717.7**
Number of Cables	4		
Total Width of Cables (m)	0.075		

Cable Tray ID	**C101**				
Cable Type	2/C #12			XLPPP	
Outside Diameter (inches)	0.5	0.0127	Meters	Insulation Material	Carbon-black cross-linked polyethylene
Insulation Thickness (mils)	30	0.000762	Meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	Meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	220,000	67056	Meters	Jacket Material	Black polyvinyl chloride (PVC)
				Jacket Density (kg/m^3)	1441.8
				Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.00635 m
Total Cable Area (A3)	0.000126677 m^2
Jacket Area	4.14993E-05 m^2
Insulation Area	2.31059E-05 m^2

Total Volume of Jacket (m^3)	2.78278	Mass of Jacket per meter (kg/m)	0.0598
Total Volume of Insulation (m^3)	1.549387	Mass of Insulation per meter (kg/m)	0.0214
Total Combustible Volume (m^3)	4.332167	Total Combustible Mass per meter (kg/m)	0.0812
Total Mass of Jacket (kg)	4012.2	Jacket heat of combustion energy per meter (kJ/m)	1074.0
Total Mass of Insulation (kg)	1432.3	Insulation heat of combustion energy per meter (kJ/m)	508.3
Total Combustible Mass (kg)	5444.5	Combustible Fuel Load per meter per cable (kJ/m)	**1582.4**
		Combustible Fuel Load per meter (kJ/m)	**6329.4**

Number of Cables	4
Total Width of Cables (m)	0.051

Cable Type	2/C #12		
Outside Diameter (inches)	0.5	0.0127	meters
Insulation Thickness (mils)	30	0.000762	meters
Jacket Thickness (mils)	45	0.001143	meters
Cable Length (ft)	220,000	67056	meters

XLPN	
Insulation Material	Carbon-black cross-linked polyethylene
Insulation Density (kg/m^3)	924.4
Insulation Heat of Combustion (kJ/kg)	23800
Jacket Material	Polyolefin (Flamtrol) - *use PVC properties
Jacket Density (kg/m^3)	1441.8
Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.00635 m
Total Cable Area (A3)	0.000126677 m^2
Jacket Area	4.14993E-05 m^2
Insulation Area	2.31059E-05 m^2

Total Volume of Jacket (m^3)	2.78278
Total Volume of Insulation (m^3)	1.549387
Total Combustible Volume (m^3)	4.332167
Total Mass of Jacket (kg)	4012.2
Total Mass of Insulation (kg)	1432.3
Total Combustible Mass (kg)	5444.5

Mass of Jacket per meter (kg/m)	0.0598
Mass of Insulation per meter (kg/m)	0.0214
Total Combustible Mass per meter (kg/m)	0.0812
Jacket heat of combustion energy per meter (kJ/m)	1074.0
Insulation heat of combustion energy per meter (kJ/m)	508.3
Combustible Fuel Load per meter per cable (kJ/m)	**1582.4**
Combustible Fuel Load per meter (kJ/m)	**6329.4**

Number of Cables	4
Total Width of Cables (m)	0.051

Cable Type	5/C #16			XLPN	
Outside Diameter (inches)	0.52	0.013208	meters	Insulation Material	Carbon-black cross-linked polyethylene
Insulation Thickness (mils)	25	0.000635	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	186,000	56693	meters	Jacket Material	Polyolefin (Flamtrol) - *use PVC properties
				Jacket Density (kg/m^3)	1441.8
Outside Radius	0.006604 m			Jacket Heat of Combustion (kJ/kg)	17950
Total Cable Area (A3)	0.000137014 m^2				
Jacket Area	4.33235E-05 m^2				
Insulation Area	2.05217E-05 m^2				

Total Volume of Jacket (m^3)	2.45613	Mass of Jacket per meter (kg/m)	0.0625
Total Volume of Insulation (m^3)	1.16343	Mass of Insulation per meter (kg/m)	0.0190
Total Combustible Volume (m^3)	3.61956	Total Combustible Mass per meter (kg/m)	0.0814
Total Mass of Jacket (kg)	3541.2	Jacket heat of combustion energy per meter (kJ/m)	1121.2
Total Mass of Insulation (kg)	1075.5	Insulation heat of combustion energy per meter (kJ/m)	451.5
Total Combustible Mass (kg)	4616.7	Combustible Fuel Load per meter per cable (kJ/m)	**1572.7**
		Combustible Fuel Load per meter (kJ/m)	**11009.0**
Number of Cables	7		
Total Width of Cables (m)	0.092		

Cable Type	5/C #16			XLPPP	
Outside Diameter (inches)	0.52	0.013208	meters	Insulation Material	Carbon-black cross-linked polyethylene
Insulation Thickness (mils)	25	0.000635	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	186,000	56693	meters	Jacket Material	Black polyvinyl chloride (PVC)
				Jacket Density (kg/m^3)	1441.8
				Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.006604 m
Total Cable Area (A3)	0.000137014 m^2
Jacket Area	4.33235E-05 m^2
Insulation Area	2.05217E-05 m^2

Total Volume of Jacket (m^3)	2.45613	Mass of Jacket per meter (kg/m)	0.0625
Total Volume of Insulation (m^3)	1.16343	Mass of Insulation per meter (kg/m)	0.0190
Total Combustible Volume (m^3)	3.61956	Total Combustible Mass per meter (kg/m)	0.0814
Total Mass of Jacket (kg)	3541.2	Jacket heat of combustion energy per meter (kJ/m)	1121.2
Total Mass of Insulation (kg)	1075.5	Insulation heat of combustion energy per meter (kJ/m)	451.5
Total Combustible Mass (kg)	4616.7	Combustible Fuel Load per meter per cable (kJ/m)	**1572.7**
		Combustible Fuel Load per meter (kJ/m)	**3145.4**

Number of Cables	2
Total Width of Cables (m)	0.026

Cable Type	2/C #16			XLPPP	
Outside Diameter (inches)	0.41	0.010414	meters	Insulation Material	Carbon-black cross-linked polyethylene
Insulation Thickness (mils)	25	0.000635	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	220,000	67056	meters	Jacket Material	Black polyvinyl chloride (PVC)
				Jacket Density (kg/m^3)	1441.8
Outside Radius	0.005207 m			Jacket Heat of Combustion (kJ/kg)	17950
Total Cable Area (A3)	8.51775E-05 m^2				
Jacket Area	3.32907E-05 m^2				
Insulation Area	1.49479E-05 m^2				

Total Volume of Jacket (m^3)	2.23234	Mass of Jacket per meter (kg/m)	0.0480
Total Volume of Insulation (m^3)	1.002344	Mass of Insulation per meter (kg/m)	0.0138
Total Combustible Volume (m^3)	3.234684	Total Combustible Mass per meter (kg/m)	0.0618
Total Mass of Jacket (kg)	3218.6	Jacket heat of combustion energy per meter (kJ/m)	861.6
Total Mass of Insulation (kg)	926.6	Insulation heat of combustion energy per meter (kJ/m)	328.9
Total Combustible Mass (kg)	4145.2	Combustible Fuel Load per meter per cable (kJ/m)	**1190.4**
		Combustible Fuel Load per meter (kJ/m)	**5952.2**
Number of Cables	5		
Total Width of Cables (m)	0.052		

Cable Type	2/C #16			XLPN	
Outside Diameter (inches)	0.41	0.010414	meters	Insulation Material	Carbon-black cross-linked polyethylene
Insulation Thickness (mils)	25	0.000635	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	220,000	67056	meters	Jacket Material	Polyolefin (Flamtrol) - *use PVC properties
				Jacket Density (kg/m^3)	1441.8
Outside Radius	0.005207 m			Jacket Heat of Combustion (kJ/kg)	17950
Total Cable Area (A3)	8.51775E-05 m^2				
Jacket Area	3.32907E-05 m^2				
Insulation Area	1.49479E-05 m^2				

Total Volume of Jacket (m^3)	2.23234	Mass of Jacket per meter (kg/m)	0.0480
Total Volume of Insulation (m^3)	1.002344	Mass of Insulation per meter (kg/m)	0.0138
Total Combustible Volume (m^3)	3.234684	Total Combustible Mass per meter (kg/m)	0.0618
Total Mass of Jacket (kg)	3218.6	Jacket heat of combustion energy per meter (kJ/m)	861.6
Total Mass of Insulation (kg)	926.6	Insulation heat of combustion energy per meter (kJ/m)	328.9
Total Combustible Mass (kg)	4145.2	Combustible Fuel Load per meter per cable (kJ/m)	**1190.4**
		Combustible Fuel Load per meter (kJ/m)	**1190.4**
Number of Cables	1		
Total Width of Cables (m)	0.010		

Combination of Cables

Total heat of combustion energy per meter (kJ/m)	**33956.0**
Total Width of Cables (m)	**0.283**

Cable Tray ID	**L101**				
Cable Type	RG-59/U			COA	
Outside Diameter (inches)	0.242	0.006147	meters	Insulation Material	None
Insulation Thickness (mils)	0	0	meters	Insulation Density (kg/m^3)	0
Jacket Thickness (mils)	96	0.002438	meters	Insulation Heat of Combustion (kJ/kg)	0
Cable Length (ft)	20,000	6096	meters	Jacket Material	Polyolefin (Flamtrol) - *use PVC properties
				Jacket Density (kg/m^3)	1441.8
				Jacket Heat of Combustion (kJ/kg)	46500

Outside Radius	0.0030734 M
Total Cable Area (A3)	2.96748E-05 m^2
Jacket Area	2.8408E-05 m^2
Insulation Area	0 m^2

Total Volume of Jacket (m^3)	0.173175	Mass of Jacket per meter (kg/m)	0.0410
Total Volume of Insulation (m^3)	0	Mass of Insulation per meter (kg/m)	0.0000
Total Combustible Volume (m^3)	0.173175	Total Combustible Mass per meter (kg/m)	0.0410
Total Mass of Jacket (kg)	249.7	Jacket heat of combustion energy per meter (kJ/m)	1904.6
Total Mass of Insulation (kg)	0.0	Insulation heat of combustion energy per meter (kJ/m)	0.0
Total Combustible Mass (kg)	249.7	Combustible Fuel Load per meter per cable (kJ/m)	**1904.6**
		Combustible Fuel Load per meter (kJ/m)	**7618.3**
Number of Cables	4		
Total Width of Cables (m)	0.025		

Cable Type	RG-71B/U			COA	
Outside Diameter (inches)	0.272	0.006909	meters	Insulation Material	None
Insulation Thickness (mils)	0	0	meters	Insulation Density (kg/m^3)	0
Jacket Thickness (mils)	100	0.00254	meters	Insulation Heat of Combustion (kJ/kg)	0
Cable Length (ft)	8,000	2438	meters	Jacket Material	Polyolefin (Flamtrol) - *use PVC properties
				Jacket Density (kg/m^3)	1441.8
				Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.0034544 m
Total Cable Area (A3)	3.74882E-05 m^2
Jacket Area	3.48615E-05 m^2
Insulation Area	0 m^2

Total Volume of Jacket (m^3)	0.085006	Mass of Jacket per meter (kg/m)	0.0503
Total Volume of Insulation (m^3)	0	Mass of Insulation per meter (kg/m)	0.0000
Total Combustible Volume (m^3)	0.085006	Total Combustible Mass per meter (kg/m)	0.0503
Total Mass of Jacket (kg)	122.6	Jacket heat of combustion energy per meter (kJ/m)	902.2
Total Mass of Insulation (kg)	0.0	Insulation heat of combustion energy per meter (kJ/m)	0.0
Total Combustible Mass (kg)	122.6	Combustible Fuel Load per meter per cable (kJ/m)	**902.2**
		Combustible Fuel Load per meter (kJ/m)	**1804.5**

Number of Cables	2
Total Width of Cables (m)	0.014

Cable Type	6/C #18 SH			XLPSN (1-M/C)	
Outside Diameter (inches)	0.525	0.013335	meters	Insulation Material	cross-linked polyethylene
Insulation Thickness (mils)	20	0.000508	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	5,000	1524	meters	Jacket Material	Polyolefin (Flamtrol) - *use PVC properties
				Jacket Density (kg/m^3)	1441.8
				Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.0066675 m
Total Cable Area (A3)	0.000139661 m^2
Jacket Area	4.37795E-05 m^2
Insulation Area	1.68227E-05 m^2

Total Volume of Jacket (m^3)	0.06672	Mass of Jacket per meter (kg/m)	0.0631
Total Volume of Insulation (m^3)	0.025638	Mass of Insulation per meter (kg/m)	0.0156
Total Combustible Volume (m^3)	0.092358	Total Combustible Mass per meter (kg/m)	0.0787
Total Mass of Jacket (kg)	96.2	Jacket heat of combustion energy per meter (kJ/m)	1133.0
Total Mass of Insulation (kg)	23.7	Insulation heat of combustion energy per meter (kJ/m)	370.1
Total Combustible Mass (kg)	119.9	Combustible Fuel Load per meter per cable (kJ/m)	**1503.1**
		Combustible Fuel Load per meter (kJ/m)	**1503.1**

Number of Cables	1
Total Width of Cables (m)	0.013

Cable Type	2/C #16 (CC)		XLPSMP (TE)		
Outside Diameter (inches)	0.35	0.00889 meters	Insulation Material	chemically cross-linked polyethylene
Insulation Thickness (mils)	30	0.000762 meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143 meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	128,000	39014 meters	Jacket Material	polyvinyl chloride (PVC)
			Jacket Density (kg/m^3)	1441.8
			Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.004445 m
Total Cable Area (A3)	6.20717E-05 m^2
Jacket Area	2.78182E-05 m^2
Insulation Area	1.39851E-05 m^2

Total Volume of Jacket (m^3)	1.085312	Mass of Jacket per meter (kg/m)	0.0401
Total Volume of Insulation (m^3)	0.545621	Mass of Insulation per meter (kg/m)	0.0129
Total Combustible Volume (m^3)	1.630933	Total Combustible Mass per meter (kg/m)	0.0530
Total Mass of Jacket (kg)	1564.8	Jacket heat of combustion energy per meter (kJ/m)	719.9
Total Mass of Insulation (kg)	504.4	Insulation heat of combustion energy per meter (kJ/m)	307.7
Total Combustible Mass (kg)	2069.2	Combustible Fuel Load per meter per cable (kJ/m)	**1027.6**
		Combustible Fuel Load per meter (kJ/m)	**3082.9**

Number of Cables	3
Total Width of Cables (m)	0.027

Cable Type	2/C #16 1-STP			XLPSN (1)	
Outside Diameter (inches)	0.41	0.010414	meters	Insulation Material	cross-linked polyethylene
Insulation Thickness (mils)	25	0.000635	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	10,000	3048	meters	Jacket Material	neoprene - *use PVC properties
				Jacket Density (kg/m^3)	1441.8
Outside Radius	0.005207 m			Jacket Heat of Combustion (kJ/kg)	17950
Total Cable Area (A3)	8.51775E-05 m^2				
Jacket Area	3.32907E-05 m^2				
Insulation Area	1.49479E-05 m^2				

Total Volume of Jacket (m^3)	0.10147	Mass of Jacket per meter (kg/m)	0.0480
Total Volume of Insulation (m^3)	0.045561	Mass of Insulation per meter (kg/m)	0.0138
Total Combustible Volume (m^3)	0.147031	Total Combustible Mass per meter (kg/m)	0.0618
Total Mass of Jacket (kg)	146.3	Jacket heat of combustion energy per meter (kJ/m)	861.6
Total Mass of Insulation (kg)	42.1	Insulation heat of combustion energy per meter (kJ/m)	328.9
Total Combustible Mass (kg)	188.4	Combustible Fuel Load per meter per cable (kJ/m)	**1190.4**
		Combustible Fuel Load per meter (kJ/m)	**2380.9**
Number of Cables	2		
Total Width of Cables (m)	0.021		

Cable Type	2/C #14 1-STP			XLPSMP	
Outside Diameter (inches)	0.5	0.0127	meters	Insulation Material	cross-linked polyethylene
Insulation Thickness (mils)	30	0.000762	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	100,000	30480	meters	Jacket Material	polyvinyl chloride (PVC)
				Jacket Density (kg/m^3)	1441.8
Outside Radius	0.00635 m			Jacket Heat of Combustion (kJ/kg)	17950
Total Cable Area (A3)	0.000126677 m^2				
Jacket Area	4.14993E-05 m^2				
Insulation Area	2.31059E-05 m^2				

Total Volume of Jacket (m^3)	1.2649	Mass of Jacket per meter (kg/m)	0.0598
Total Volume of Insulation (m^3)	0.704267	Mass of Insulation per meter (kg/m)	0.0214
Total Combustible Volume (m^3)	1.969167	Total Combustible Mass per meter (kg/m)	0.0812
Total Mass of Jacket (kg)	1823.7	Jacket heat of combustion energy per meter (kJ/m)	1074.0
Total Mass of Insulation (kg)	651.0	Insulation heat of combustion energy per meter (kJ/m)	508.3
Total Combustible Mass (kg)	2474.8	Combustible Fuel Load per meter per cable (kJ/m)	**1582.4**
		Combustible Fuel Load per meter (kJ/m)	**3164.7**
Number of Cables	2		
Total Width of Cables (m)	0.025		

Cable Type	3/C #16 1-STT			XLPSMP	
Outside Diameter (inches)	0.43	0.010922	meters	Insulation Material	cross-linked polyethylene
Insulation Thickness (mils)	25	0.000635	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	70,000	21336	meters	Jacket Material	polyvinyl chloride (PVC)
				Jacket Density (kg/m^3)	1441.8
				Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.005461 m
Total Cable Area (A3)	9.36902E-05 m^2
Jacket Area	3.51148E-05 m^2
Insulation Area	1.59613E-05 m^2

Total Volume of Jacket (m^3)	0.74921	Mass of Jacket per meter (kg/m)	0.0506
Total Volume of Insulation (m^3)	0.34055	Mass of Insulation per meter (kg/m)	0.0148
Total Combustible Volume (m^3)	1.08976	Total Combustible Mass per meter (kg/m)	0.0654
Total Mass of Jacket (kg)	1080.2	Jacket heat of combustion energy per meter (kJ/m)	908.8
Total Mass of Insulation (kg)	314.8	Insulation heat of combustion energy per meter (kJ/m)	351.2
Total Combustible Mass (kg)	1395.0	Combustible Fuel Load per meter per cable (kJ/m)	**1259.9**
		Combustible Fuel Load per meter (kJ/m)	**6299.7**

Number of Cables	5
Total Width of Cables (m)	0.055

Cable Type	4/C #16 SH			XLPSN (1-M/C)	
Outside Diameter (inches)	0.5	0.0127	meters	Insulation Material	cross-linked polyethylene
Insulation Thickness (mils)	20	0.000508	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	7,500	2286	meters	Jacket Material	Polyolefin (Flamtrol) - *use PVC properties
				Jacket Density (kg/m^3)	1441.8
				Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.00635 m
Total Cable Area (A3)	0.000126677 m^2
Jacket Area	4.14993E-05 m^2
Insulation Area	1.58093E-05 m^2

Total Volume of Jacket (m^3)	0.094867	Mass of Jacket per meter (kg/m)	0.0598
Total Volume of Insulation (m^3)	0.03614	Mass of Insulation per meter (kg/m)	0.0146
Total Combustible Volume (m^3)	0.131007	Total Combustible Mass per meter (kg/m)	0.0744
Total Mass of Jacket (kg)	136.8	Jacket heat of combustion energy per meter (kJ/m)	1074.0
Total Mass of Insulation (kg)	33.4	Insulation heat of combustion energy per meter (kJ/m)	347.8
Total Combustible Mass (kg)	170.2	Combustible Fuel Load per meter per cable (kJ/m)	**1421.8**
		Combustible Fuel Load per meter (kJ/m)	**2843.7**

Number of Cables	2
Total Width of Cables (m)	0.025

Cable Type	RG-58A/U			XLPE	
Outside Diameter (inches)	0.675	0.017145	meters	Insulation Material	cross-linked polyethylene
Insulation Thickness (mils)	31	0.000787	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	60	0.001524	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	3,000	914	meters	Jacket Material	[redacted]
				Jacket Density (kg/m^3)	1441.8
				Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.0085725 m
Total Cable Area (A3)	0.000230869 m^2
Jacket Area	7.479E-05 m^2
Insulation Area	3.29238E-05 m^2

Total Volume of Jacket (m^3)	0.068388	Mass of Jacket per meter (kg/m)	0.1078
Total Volume of Insulation (m^3)	0.030106	Mass of Insulation per meter (kg/m)	0.0304
Total Combustible Volume (m^3)	0.098494	Total Combustible Mass per meter (kg/m)	0.1383
Total Mass of Jacket (kg)	98.6	Jacket heat of combustion energy per meter (kJ/m)	1935.6
Total Mass of Insulation (kg)	27.8	Insulation heat of combustion energy per meter (kJ/m)	724.3
Total Combustible Mass (kg)	126.4	Combustible Fuel Load per meter per cable (kJ/m)	**2659.9**
		Combustible Fuel Load per meter (kJ/m)	**2659.9**

Number of Cables	1
Total Width of Cables (m)	0.017

Cable Type	2/C #16 TC (CA)			[redacted]	
Outside Diameter (inches)	0.35	0.00889	meters	Insulation Material	cross-linked polyethylene
Insulation Thickness (mils)	30	0.000762	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	6,000	1829	meters	Jacket Material	Polyvinyl Chloride (PVC)
				Jacket Density (kg/m^3)	1441.8
				Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.004445 m
Total Cable Area (A3)	6.20717E-05 m^2
Jacket Area	2.78182E-05 m^2
Insulation Area	1.39851E-05 m^2

Total Volume of Jacket (m^3)	0.050874	Mass of Jacket per meter (kg/m)	0.0401
Total Volume of Insulation (m^3)	0.025576	Mass of Insulation per meter (kg/m)	0.0129
Total Combustible Volume (m^3)	0.07645	Total Combustible Mass per meter (kg/m)	0.0530
Total Mass of Jacket (kg)	73.4	Jacket heat of combustion energy per meter (kJ/m)	719.9
Total Mass of Insulation (kg)	23.6	Insulation heat of combustion energy per meter (kJ/m)	307.7
Total Combustible Mass (kg)	97.0	Combustible Fuel Load per meter per cable (kJ/m)	**1027.6**
		Combustible Fuel Load per meter (kJ/m)	**2055.3**

Number of Cables	2
Total Width of Cables (m)	0.018

Cable Type	2/C #16 TC (CC)			[redacted]	
Outside Diameter (inches)	0.35	0.00889	meters	Insulation Material	cross-linked polyethylene
Insulation Thickness (mils)	30	0.000762	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	128,000	39014	meters	Jacket Material	Polyvinyl Chloride (PVC)
				Jacket Density (kg/m^3)	1441.8
				Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.004445m
Total Cable Area (A3)	6.20717E-05m^2
Jacket Area	2.78182E-05m^2
Insulation Area	1.39851E-05m^2

Total Volume of Jacket (m^3)	1.085312	Mass of Jacket per meter (kg/m)	0.0401
Total Volume of Insulation (m^3)	0.545621	Mass of Insulation per meter (kg/m)	0.0129
Total Combustible Volume (m^3)	1.630933	Total Combustible Mass per meter (kg/m)	0.0530
Total Mass of Jacket (kg)	1564.8	Jacket heat of combustion energy per meter (kJ/m)	719.9
Total Mass of Insulation (kg)	504.4	Insulation heat of combustion energy per meter (kJ/m)	307.7
Total Combustible Mass (kg)	2069.2	Combustible Fuel Load per meter per cable (kJ/m)	**1027.6**
		Combustible Fuel Load per meter (kJ/m)	**1027.6**

Number of Cables	1
Total Width of Cables (m)	0.009

Cable Type	2/C #14 1-STP			[redacted]	
Outside Diameter (inches)	0.5	0.0127	meters	Insulation Material	cross-linked polyethylene
Insulation Thickness (mils)	30	0.000762	meters	Insulation Density (kg/m^3)	924.4
Jacket Thickness (mils)	45	0.001143	meters	Insulation Heat of Combustion (kJ/kg)	23800
Cable Length (ft)	100,000	30480	meters	Jacket Material	neoprene - *use PVC properties
				Jacket Density (kg/m^3)	1441.8
				Jacket Heat of Combustion (kJ/kg)	17950

Outside Radius	0.00635 m
Total Cable Area (A3)	0.000126677 m^2
Jacket Area	4.14993E-05 m^2
Insulation Area	2.31059E-05 m^2

Total Volume of Jacket (m^3)	1.2649	Mass of Jacket per meter (kg/m)	0.0598
Total Volume of Insulation (m^3)	0.704267	Mass of Insulation per meter (kg/m)	0.0214
Total Combustible Volume (m^3)	1.969167	Total Combustible Mass per meter (kg/m)	0.0812
Total Mass of Jacket (kg)	1823.7	Jacket heat of combustion energy per meter (kJ/m)	1074.0
Total Mass of Insulation (kg)	651.0	Insulation heat of combustion energy per meter (kJ/m)	508.3
Total Combustible Mass (kg)	2474.8	Combustible Fuel Load per meter per cable (kJ/m)	**1582.4**
		Combustible Fuel Load per meter (kJ/m)	**4747.1**

Number of Cables	3
Total Width of Cables (m)	0.038

Combination of Cables

Total heat of combustion energy per meter (kJ/m)	**39187.7**
Total Width of Cables (m)	**0.287**