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APPENDIX R EXEMPTION REQUESTS
TECHNICAL EVALUATION OF DRAFT
SAFETY EVALUATION

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ENCLOSURE 1

DOCKET NOS. 50-266 AND 50-301

APPENDIX R EXEMPTION REQUESTS

POINT BEACH NUCLEAR PLANT, UNITS 1 AND 2

TECHNICAL EVALUATION

OF

DRAFT SAFETY EVALUATION

ENCLOSURE 1

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ENCLOSURE 1

1.0 DRAFT SE TEXT REVIEW

This section contains our review of and our response to items which are noted specifically in Sections 1 and 2 of the draft SE. Also addressed herein are general items which have been noted in the draft SE to be of concern in all plant areas for which exemptions have been requested.

1.1 SE Comment

> "We have determined that the results of the methodology, as applied, do not demonstrate the equivalence of the protection proided for safe shutdown to the specific alternatives set forth in Section III.G of Appendix R." (SE, p. 4)

RESPONSE

Based on this allegedly inadequate demonstration, recommendations are made for denial of various exemption requests.

The draft SE necessarily is based to a significant degree on the analysis by Brookhaven National Laboratory (BNL) of the WE technical approach. BNL stated that Wisconsin Electric has used technically sound and conservative state-of-the-art analytical methods to evaluate the effects of fires on safe shutdown systems at Point Beach Nuclear Plant. However, BNL has identified potential difficulties regarding the uniform application of these models in all fire zones. The BNL questions appear to have been presented in an attempt to achieve a complete understanding of the methodology. BNL also suggests methods of improving the presentation of the analytical results.

Given the nature of the BNL comments, the appropriate response is not to reject the exemption request, but to discuss and resolve on a technical basis the questions raised by BNL. These questions can best be resolved in a technical meeting with the Staff. This is particularly appropriate in light of BNL's summary evaluation of the Point Beach fire hazards analysis:

> "The unit-problem approach employed, together with the correlations and electrical cable damage criterion, can be classified as most current and methodologically consistent with what is being suggested in the open literature as a viable approach for assessing the fire hazard potential associated with cable tray fires."
>
> Thus, in most respects, we find the method employed to be technically sound and the overall approach, if applied properly (as described subsequently) could yield realistic and conservative results for assessing the thermal environment in the fire area."1/ (Emphasis added)

BNL has conducted substantial research into the literature to confirm the methodology's basis and validate the analysis through audit calculations. The positive points contained in BNL's summary evaluation should be factored into the Staff's Safety Evaluation. BNL review comments and questions are addressed in Enclosure 2. It is important that BNL be provided with Enclosure 2 so that these comments and questions can be promptly resolved.

We believe that a technical meeting with the Staff will enable us to resolve the uncertainties contained in the draft SE.

1/ Letter from Mr. John L. Boccio, BNL, to Mr. Randall Eberly, DE/CEB, Subject: "Evaluation of the Analytical Fire Modeling by Wisconsin Electric Power Company Point Beach Nuclear Generating Plant, Units 1 and 2, Response to 10 CFR 50, Appendix R, 'Fire Protection of Safe Shutdown Capability' ", dated December 3, 1982 ("BNL Report") pg. 4.

1.2 SE Comment

"The method does not consider the heat released to the room by secondary fires involving in-situ combustibles. The method uses an electrical failure criteria with the thermal energy release to the room by a single exposure fire. When the cables of concern are at the conditions of electrical failure, other cables within the enclosure are burning and also releasing energy to the room." (SE, p. 4)

RESPONSE

Secondary fires were considered in the analytical method and do not affect the conservative nature of our results. Secondary fires can be postulated either adjacent to the exposure fire or in the stratified layer. The heat release rate of the former is insignificant relative to the heat release rate of the exposure fire. Secondary fires in the stratified layer likewise are not a concern. This effect was not noted in room configuration testing such as the Sandia tests 2/ performed to verify the Appendix R requirements. These tests used a very severe exposure fire in a small enclosure which, in some tests, produced heat fluxes at the target trays as high as 36 kw/m^2. Both qualified (XLPE) and unqualified (PE/PVC) cables were used in the target trays. In no case did ignition occur in the target trays.

Small scale laboratory test data on electrical cables imply that such cables ignite prior to experiencing electrical failure. This apparent discrepancy between the large-scale

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2/ Sandia National Laboratories, "Interim Report: Evaluation of Twenty-Foot Separation Distance, 10 CFR 50 Appendix R", May 1982.

Sandia tests and small-scale laboratory tests for piloted ignition can be understood by a detailed examination of the heat transfer mechanisms in the two cases. The laboratory tests used radiant heating in a small cell with stagnant air surrounding the sample. These conditions are in sharp contrast with the conditions in the hot stratified layer generated by an exposure fire. The heating by the stratification layer is almost entirely by convection. Large convective heat fluxes are always associated with significant convection flow past the object being heated. This flow prevents the accumulation of a combustible mixture near the cables. The process is analogous to blowing out a match.

Consequently, rejection of the methodology for lack of consideration of secondary fires is without basis.

1.3 SE Comment

> "The method does not consider the increased heat release rate of a given fire when it occurs against a wall or in a corner; the method only considers the heat release of a fire as it occurs in an open area." (SE, p. 4)

RESPONSE

The effects of fire placement near a wall or corner were considered in the original analysis and do not affect the conservative nature of our results. The paper by Alpert 3/ on which the comment is based uses an approximate hydrodynamic solution to find the fire height by use of the method of images. This approximation is based on a hypothesis that a wall acts as a plane of symmetry when there is a nearby fire. (Two quarter

3/ R. L. Alpert, "Turbulent Ceiling Jet Induced by Large-Scale Fires", Combustion Science and Technology, 11, 1975, pp. 197-213.

symmetric walls are hypothesized for corner walls.) The method of images captures the effect of symmetry by reflecting the geometry across the plane of symmetry. Alpert, therefore, proposes computing the fire height based on a model fire area twice the area of the actual fire (model area four times the actual area for a corner fire). The important point to remember is that one-half of the model fire is located in an imaginary reflected room. The size of the actual fire in the actual room remains the same. Most importantly, the actual heat release rate is not affected by locating the fire near a wall. Alpert is only seeking to explain the effect of flame stretch on fire <u>height</u>, not the effect on the fire <u>heat release rate</u>.

Moreover, Sandia test results showed:

(1) Flame height increased from 9 to 12 feet (30%) when the exposure fire was moved from the open area to the wall.

(2) Based on burning times (25.4 minutes in the open; 22.1 minutes at the wall), the heat release rate increased only by 13%, not by a factor of two.

As demonstrated above, corner or wall fire location does not significantly affect the fire heat release rate. The postulation of greater effects appears to result from misapplication of Alpert's concept. Further, actual bare wall room configurations seldom exist. Appurtenances typically present at corners and walls would tend to reduce even the effects noted by Alpert. Room appurtenances (piping, ventilation ducts, etc.) typically restrict fire effects upon cable trays along walls as well as in open room areas. Because such items are not uniformly present, the analytical method takes no credit for their presence for conservatism of analysis.

1.4 SE Comment

> "The method does not consider the effects of excess pyrolyzate resulting from the degradation of plastics burning in the stratified layer." (SE, p. 4)

RESPONSE

Excess pyrolyzates were considered. The technical literature shows that this is not a credible hazard in nuclear plants. Burning plastics do not produce pyrolyzate vapors. They are burned as they are produced because they are the fuel for the fire. Pyrolyzate vapors are only released into the stratification layer by heating plastics which are not burning. For the purpose of discussion, we assume that this is the concern of the quoted statement.

This phenomenon appears to occur in locations of combustible construction and interior finishes, e.g., residential structures, plastic/wood finishes, etc. However, Alpert and Ward have stated that excess pyrolyzates are not an issue in the industrial environment. There is no evidence that excess pyrolyzates were a factor in the Brown's Ferry fire. Recent Sandia tests of cable tray installations, designed to examine the stratification effects of a heptane fire in a small enclosure, did not report the phenomenon of pyrolyzate accumulation contributing to damage (energy deposition) at the target cables.5/ Furthermore, full-scale cable fire tests conducted by Factory Mutual Research Corporation (FMRC) on behalf of Electric Power Research Institute (EPRI) failed to show any evidence of the existence of the phenomenon in nuclear power plant configurations.6,7/ Should the Staff have any data contrary to the above, we request that it be provided to us for review and incorporation into our analysis method, if appropriate.

Excess pyrolyzates are not a practical concern. In any event, whatever the possibility for excess pyrolyzate vapors occurring in nuclear construction, it would be equally valid for our approach as for configurations acceptable under III.G.2.b or III.G.2.c. It is inappropriate to reject a showing of equivalence of our configuration based upon a postulated phenomenon which is equally applicable to configurations specified by Appendix R.

1.5 SE Comment

"The method does not consider all of the alternatives set forth in Section III.g, i.e., 3-hour fire barrier, 1-hour fire barrier with suppression system, twenty-feet separation free of combustibles with automatic suppression and alternate or dedicated shutdown capability independent

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5/ L. J. Klamerus, "Evaluation of Twenty-Foot Separation Distance, 10 CFR 50 Appendix R", Interim Report, Sandia National Laboratories, Albuquerque, New Mexico, May 1982.

6/ J. P. Hill, "Fire Tests in Ventilated Rooms", NP-2660, Electric Power Research Institute, Palo Alto, California, December 1982.

7/ J. S. Newman and J. P. Hill, "Assessment of Exposure Fire Hazards to Cable Trays", NP-1675, Electric Power Research Institute, Palo Alto, California, January 1981.

of the area. The method only considers separation without automatic suppression and uses a stratification model which does not include the effects of separation." (SE, p. 4)

RESPONSE

Appendix R does not require consideration of all alternatives; showing equivalence to any one of them is sufficient.

As unequivocally stated in The Connecticut Light and Power Company v. Nuclear Regulatory Commission, the Court delineated the standard as follows:

> "The practical effect of the exemption procedure is thus to give utilities a fourth alternative: if the company can prove that another method works as well as one of the three stipulated by the NRC, in light of the identified fire hazards at its plant, it may continue to employ that method."

> "If the utility can show that some combination of protective meaures provides protection equivalent to that afforded by one of the Commission's three stipulated methods, it will be entitled to an exemption . . ."

In accordance with the Court's decision, the exemption alternative need address only one of the stipulated alternatives of Section III.G. It follows necessarily that the analytical method utilized to substantiate a specific exemption need address only the stipulated alternative from which the exemption is being requested. Therefore, we believe that it is entirely appropriate for our analytical method to address only the separation requirements of Section III.G.2.b from which exemptions have been requested.

Automatic suppression capability has been considered. A fixed automatic suppression system is by nature inflexible. The rule makes no distinction as to access for manual fire fighting when mandating automatic suppression requirements and, therefore, assumes no credit for manual capabilities. Those fire zones which presently do not have full area automatic suppression system coverage have excellent access for manual suppression. Manual fire fighting is by its very nature flexible and able to provide suppression coverage when required. The analytical method is used to determine a level of fire protection which is equivalent to that which is provided by the 20-foot horizontal separation requirement of Section III.G.2.b. Additionally, the Point Beach analysis evaluates the area fire protection provisions in the form of administrative controls, redundant system separation, fire and smoke detection capability, suppression capability and those additional features, which are existing or proposed for implementation, to demonstrate that the resulting fire protection measures are equivalent to the marginal incremental benefit from the addition of standard automatic suppression systems acceptable under Section III.G.2.b. Indeed, as discussed below, the addition of suppression systems could be detrimental to safety in some areas of the plant.

The effects of separation have been considered in development of the stratification model. In a clear open ceiling configuration, some decrease in heat flux with radial distance may occur. However, the perturbations existing in a nuclear power plant fire zone (piping, ventilation ducts, heating system blowers, etc.) may preclude the formation of a uniform stratified gas layer. The conservative philosophy of the Point Beach analytical method takes no credit for these ceiling perturbations and takes no credit for separation distance.

The BNL review appears to agree with this conservative approach. As BNL notes in their review:

> "This correlation (i.e., the stratification model) should be adequate for evaluating the heat flux due to pool exposure fires" (BNL Report, p. 7)

With regard to discounting the effects of separation, BNL states that:

> "... the neglect of the decrease in heat flux with radial distance by Newman and Hill (the stratification model) should yield a conservative result." (BNL Report, p. 7)

1.6 SE Comment

"The licensee has not used the results of this analysis to compare the protective features provided with that specified in Section III.G. The licensee has only stated that the accumulation of the calculated quantity of flammable liquids in the required configuration is an unrealistic condition, and will be prevented by administrative controls. We do not deem this to be a valid argument because there is no positive means of preventing the accumulation of transient materials in individual plant areas. As discussed in Inspection and Enforcement Branch Reports, recent inspections at plants ... have demonstrated that substantial quantities of hazardous substances such as 55-gallon drums of waste oil are located in even highly restricted and controlled entry areas." (SE, p. 4)

RESPONSE

We emphasize that the Point Beach analysis was indeed used to compare the protection provided with that specified in Section III.G. We believe that the Point Beach analysis demonstrates protection equivalent to the acceptable alternative of Section III.G.2.b, i.e., 20-foot horizontal separation plus automatic suppression plus detection. Equivalence to the 20-foot horizontal separation requirement specified by III.G.2.b is demonstrated through our analytical method. Required detection is provided in all zones. In zones without automatic suppression, equivalence is achieved via our defense-in-depth approach. Additionally, we confirm equivalence by assuring in all cases that our protection exceeds that which provides the apparent basis for Section III.G.2.b standard, namely, protection against a fire involving 2-5 gallons of flammable liquid. This 2-5 gallon criterion is specified in an April 24, 1981 memorandum to Mr. R. B. Minogue from Mr. H. R. Denton 8/ which states:

> "The 20-foot separation is considered adequate to provide a safe distance to protect redundant safety divisions exposed to a single, transient exposure fire such as burning 2-5 gallons of flammable liquid. The 20-foot requirement represents the collective judgment of the NRC Staff and its fire protection consultants."

The use of quantities of flammable liquids as a yardstick for purposes of determining relative fire resistance is appropriate. Any method of comparison requires a unit of rating for a specific reference medium in order to be meaningful. For example, accepted ASTM E-119 fire tests provide a fire resistive rating in units of time utilizing a reference medium of constant temperature. In the Point Beach analysis, the fire resistive rating is provided in quantities of flammable liquid utilizing the conservatively calculated heat release rate of a flammable liquid as a reference medium. The expression of fire resistivity in quantities of flammable liquid is consistent with the apparent technical basis for the accepted Section III.G.2.b alternative,

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8/ H. R. Denton, Director, Office of Nuclear Reactor Regulation, letter to R. B. Minogue, Director of Office of Nuclear Regulatory Research, Subject: "User Request for Fire Tests to Verify the Adequacy of the 20-Foot Spatial Separation Requirement Contained in Appendix R to 10 CFR Part 50 (RR-NRR-81)", dated April 24, 1981.

which is also expressed in quantities of flammable liquid. Therefore, we believe that the Point Beach analysis is a valid approach for purposes of demonstration of equivalence.

Methodology in the Point Beach analysis includes both a stratification model and an exposure fire effects model. Other specific analyses are provided for unusual circumstances such as electrical cabinets. When appropriate, modifications are proposed to increase the room fire resistivity so that the required fuel quantities for the exposure fire effects exceed those of the stratification effects. The stratification condition is then the limiting condition for fire resistivity. Because stratification is essentially independent of horizontal separation, as discussed in Section 1.5 of this enclosure, the fire resistivity of the room is equivalent to the accepted Section III.G.2.b alternative.

Each plant area for which an exemption has been requested has been analyzed utilizing these state-of-the-art modeling techniques employing a methodology which is technically sound. The Point Beach analysis demonstrates that the existing and proposed fire protection features in each area exceed the apparent technical basis for the acceptable Section III.G.2.b alternative.

The quoted statement suggests that the Point Beach analysis was performed solely to demonstrate that reasonable protection from likely fires was provided. The objective of the Point Beach analysis is to demonstrate equivalence to Section III.G.2.b as described in the above paragraph. In demonstrating eguivalence, the Point Beach analysis also demonstrates reasonable assurance that adequate protection against fires likely to occur is provided.

The accumulation of the calculated quantity of flammable liquids in the optimum configuration and in the presence of a suitable ignition source is indeed unlikely. The configuration of the fire must be artificially constrained , for purposes of analysis, in order to provide a fire of sufficient duration and intensity to achieve cable failure. These artificial constraints are unrealistic and overly conservative as discussed in Section 1.7.

We are cognizant of the Staff's position not to acknowledge the effectiveness of administrative controls. However, conditions do exist where administrative controls become effective by circumstance. Following an acetone fire several years ago during a refueling outage, in which an employee was seriously burned, Point Beach increased controls over the dispensing and use of acetone. Within the plant structure, acetone is stored in one 5-gallon safety can in a locked flammable liquids storage cabinet. Acetone can be dispensed in a total of approximately six 1-pint safety containers for use. Therefore, the total quantity of acetone within the plant is limited to approximately six to seven gallons by the number of containers available. The calculated fire resistivity of all areas, expressed as gallons of acetone, exceeds the maximum quantity of acetone which can be introduced into the plant (six to seven gallons). The postulated accumulation of larger quantities is certainly an unrealistic condition.

To state that there is no positive means of preventing an accumulation of transient materials in individual plant areas suggests that administrative controls are either non-existent or not effective. This is inconsistent with Section III.G. Section III.G.2.b explicitly takes credit for the existence of effective administrative controls in specifying the absence of intervening combustibles. Sections III.G.2.a and III.G.2.c similarly assume that administrative controls will limit the accumulation of combustibles to a potential fire duration of less than the specified fire barrier rating. These sections further assume that administrative controls will be employed to maintain barrier integrity. Further, the availability of an alternate/dedicated shutdown system or the undamaged train is itself entirely dependent upon administrative controls. The total rejection of credit for administrative controls in the exemption process while affording such credit to Section III.G alternatives is completely inconsistent and inappropriate.

The assumed hazard from the presence of 55 gallons of waste oil in a fire area is invalid. Administrative controls, fuel configuration, location and igniteability are parameters which must be considered in any determination of a fire hazard.

Waste oil is a credible risk only if spilled on a very hot surface or if released from a pressurized system. Neither of these circumstances exists in the fire zones/areas of interest. Further, any postulated exposure fire sufficient to ignite the waste oil would likely be a greater hazard than the waste oil. If ignitability potential is ignored and a 55-gallon waste oil fire is postulated, Section III.G.2 features would not provide adequate protection. To impose a requirement on the exemption process which would cause a Section III.G alternative to fail is totally inappropriate and inconsistent.

1.7 SE Comment

In several instances, the draft SE suggests that the analytical method does not demonstrate equivalence due to a lack of consistent conservatism.

RESPONSE

The analytical method is consistently conservative in accordance with standard licensing practice. The basic approach to performing a bounding calculation on the damage effects due to a postulated exposure fire is to assume worst case conditions where uncertainty exists. We have considered all the important variables inherent in the combustion process and resultant energy deposition onto the target cable. Each variable is assumed to take a value which maximizes the damage process even if the result is a physically contradictory assumption. Some of the conservatisms inherent in the analytical method are discussed below.

The first important assumption in the analytical method is the selection of the fuel type to be used as the postulated floor based exposure fire. The fuel type chosen must pose the greatest hazard to the safe shutdown circuits in order for the calculation to be bounding over all types of exposure fires. The Point Beach facility was first examined to determine what combustible materials were used in various areas and the amounts of such combustibles allowed by administrative controls. In order to pose a realistic fire hazard, the following three criteria must be met:

(1) the combustible must have a relatively high specific energy content,

(2) the combustible must have a specific use at the facility such that a significant quantity of the material can be postulated to occur in the zones of interest, and

(3) the combustible must have a flash point low enough that a credible ignition source can be postulated to be simultaneously present with the material in the zones of interest.

The fuel type selected for analysis at Point Beach is acetone because it is bounding for all other combustibles. Acetone meets the three criteria stated above in that it combines a high energy content with a very low flash point, and small quantities are routinely used in the facility. Materials such as lube oil and gasoline were excluded because of the extreme difficulty of ignition of the former and the absence of use and accumulation of the latter inside the fire zones of interest.

The analytical method utilized in evaluating the Point Beach facility is thoroughly explained in our June, 1982 submittal. We believe it is beneficial to reiterate some of the inherent conservatisms of our method:

(1) No credit is taken for detector actuation and subsequent intervention of the site fire brigade even though documented drills show that brigade response

would be in the order of five minutes in the zones of interest. In addition, no credit is taken for human intervention at the site of the exposure fire even though presence of people would be required to introduce the combustible, release it to the room, and provide the ignition source.

(2) No credit is taken for the actuation of automatic suppression systems except in those areas where a Halon system is installed. The Halon system is credited only because of the fact that the system reliability, quick response and complete area coverage are assured.

(3) No credit is taken for the presence of obstructing equipment. The postulated fire is moved throughout the zone to locate it in the specific position to maximize damage potential. The effects of floor slope and floor drains are assumed to have no effect even though these features would be expected to remove the liquid spill from the worst case location.

(4) No credit is taken for existing configurations which provide fire protection to electrical cables. The target cable is assumed to be suspended in free space and oriented so as to maximize energy deposition, regardless of actual configuration. No benefit is assumed for intervening equipment, cable trays or conduit structures in obscuring the

target cable from plume impingement. No benefit is assumed for the effects of smoke or intervening objects in obscuring the target cable from radiant energy.

(5) The target cable is assumed to remain at ambient temperature throughout the fire in order to maximize energy deposition into the cable. In addition no re-radiation from the cable or conduction along the cable length is credited in removing energy from the limiting segment of the target cable.

(6) The cable failure criterion was selected so as to be the most limiting for all cables at Point Beach All target cables were assumed to be PE/PVC even though a portion of the power cables are in fact IEEE 383 qualified. In addition, the most conservative failure criterion for PE/PVC was uniformly utilized throughout the fire zones of concern.

(7) No credit was taken for the effects of ventilation systems in mitigating the consequences of an exposure fire. In fact, a physically contradictory series of assumptions is made in respect to ventilation. Sufficient ventilation is assumed to occur in a non-mechanistic manner such that the exposure fire is supplied with sufficient oxygen regardless of origin or location. At the same time no benefit is assumed for ventilation systems

removing energy from the room or destabilizing the hot combustion gas layer. Finally sufficient ventilation is assumed to be available to keep the compartment free of smoke at all times to maximize radiant energy damage.

(8) The combustion process and liquid pool fire geometry are defined by a combination of parameters which are unrealistic in actual conditions. The first assumption is that the liquid spill is assumed to instantly confine itself to an ideal, optimum geometry which is usually 10-15 times the expected depth of a thin liquid spill on concrete. No credit is taken for floor slopes or drains which would interfere with the ideal pool configuration. In addition all areas of the fire are assumed to be supplied with sufficient oxygen so that an optimum oxygen/fuel ratio is maintained. In reality, the large liquid hydrocarbon pool fires postulated (6-9 feet in diameter) would become oxygen starved in the center portion of the fire resulting in a decrease in combustion efficiency and subsequent decrease in fire heat release rate. Finally the fuel mass loss rate is fixed at its maximum value regardless of the actual size of the fire. The combined impact of these assumptions is to assume that an ideal fire is postulated which will bound all actual exposure fires.

(9) No credit is taken for soot production providing for a cooler flame. In a non-mechanistic manner soot production is enhanced in order to maximize the radiant energy production while the flame temperature is maintained at an artificial maximum value.

(10) No benefit is assumed for ambient energy loss from the fire zone. Significant energy loss to the intervening equipment and large amount of steel piping and structures in the overhead could provide a substantial head sink. This heat sink would protect the target cables from both direct fire effects and stratification effects.

WE has demonstrated equivalence in those fire zones for which exemptions are requested using the rigorous method described in our submittal. This method is uniformly conservative for many reasons some of which have been described above. WE feels that the demonstration of equivalence cannot be denied on the basis of a lack of conservatism.

1.8 SE Comment

"In our Fire Protection SER, we indicated that separation and safe shutdown capability in the (specific area) was inadequate. By letter dated October 21, 1980, we informed the licensee that to meet the intent of Section III.G of Appendix R, the licensee should provide alternative shutdown capability for this area. (see e.g., SE, p. 6)

RESPONSE

The referenced letter clearly predates the issuance of 10 CFR Part 50.48, Appendix R, Generic Letter 81-12, and our June 30, 1982 submittal of safe shutdown information to meet the requirements of these documents. Since 1980, WE has conducted extensive evaluations, rigorous fire hazards analyses, and proposed additional modifications in response to Appendix R and Generic Letter 81-12. This information is contained in our June 30 submittal. We do not understand how the referenced letter could provide any basis for the Appendix R evaluation. We believe that this reference is inappropriate and should be deleted from the SE.

1.9. SE Comment

> "Modifications such as the installation of an automatic sprinkler system and one-hour fire-rated barriers would provide the requisite levels of safety." (SE, p. 12)

RESPONSE

Similar recommendations are made for other fire zones. Paragraph (c)(6) of 10 CFR Part 50.48 recognizes the potential for conflict existing between fire protection and overall facility safety. Also, fire protection features which are governed by plant Technical Specifications or which may present an unreviewed safety question require a licensee review in accordance with 10 CFR Part 50.59.

We have always considered safety to be of the greatest importance. We have proposed and implemented fire protection measures with the goal of providing high levels of fire protection with minimized impact on plant operability and safety. We believe that the recommended one-hour rated fire barriers, and for some fire zones automatic water suppression systems, cannot, in many cases, be justified in accordance with 10 CFR Part 50.59.

The typical application of fire-rated barriers is in fire wall construction. Qualification requirements preclude the passage of fire or fire ignition on the unaffected side. In typical fire barrier installations, free ventilation exists on the unaffected side which facilitates heat dissipation. Application of rated fire barriers to cable trays requires the tray to be sealed to prevent the entrance of fire from any direction. This precludes ventilation inside the fire barrier. Fire-rated cable tray barriers have been qualified with the cables energized only for continuity. We have found no information which indicates that cables so protected could pass normal operating current within the environment of the ASTM E119 fire curve without severe degradation. With the added absorption of heat from a fire, cable surviveability within a fire-rated barrier cannot be assured. In addition, the typical room in a power plant contains a variety of piping, ventilation ducts, and equipment, as well as conduit and cable trays. Because of the multiple possible configurations of such components and systems, the establishment of fire rating for each configuration would be an insurmountable task.

Barriers which may be constructed of one-hour fire-rated materials installed in an unqualified but carefully engineered configuration to preserve overall facility operating safety would be expected to provide adequate fire protection for approximately 30 to 45 minutes. Documented chronology of unannounced fire drills at Point Beach indicates that normal fire brigade response time is less than five minutes. This does not suggest that five-minute barrier protection is adequate, but does demonstrate that a requirement for one-hour barrier protection is unreasonable.

1.10 SE Comment

The draft SE frequently points out that WE has not delineated the type or rating of proposed barriers.

RESPONSE

We emphasize that it is our intent to provide barriers and thermal shields constructed of materials which are fire rated or have a thermal conductivity equivalent to fire-rated construction. Such barriers and thermal shields would be installed in a configuration which would provide a high level of fire protection for the protected cables and supports within the bounds of maintaining overall facility safety. We believe that it is appropriate to establish a mutually acceptable barrier design as a part of the exemption process. Alternatively, the exemptions could be granted contingent upon mutual agreement and NRC approval of barrier design. As an example, one type of fire barrier which appears to provide the appropriate levels of protection and safety is one of perforated design which includes an intumescent material. The perforations would facilitate ventilation necessary for cable operation. Heat flux from a fire would cause intumescence which would close the ventilation openings in the heat-affected location while allowing continued ventilation in cable locations unaffected by the fire. Intumescent action begins nominally at 250°F. Therefore, the perforated barrier design could enhance the effectiveness of closed head wet pipe automatic suppression systems which actuate nominally at 165°F. We are also considering other types of barriers and will be pleased to discuss these with the Staff.

Given the lack of need for one-hour fire barriers when all aspects of the particular fire zone are considered, and the potential safety concerns, we believe it is inappropriate to adopt one-hour fire barriers.

1.11. SE Comment

The draft SE evaluation of five plant areas for which exemptions have been requested contains the following paragraph:

> "There are generally two mechanisms by which fire damage is propogated; either an exposure fire in close proximity to the redundant equipment or an exposure fire at any point in the room of sufficient magnitude to form a stratified layer of hot gases at the ceiling level, which descends to the floor level at a rate coorelated to the room volume, the burning time and fuel quantity. In the case of a fire which produces a stratified layer of hot gases at the ceiling level, the most severe damage will occur to cables and equipment located within several feet of the ceiling. The redundant cables in each fire zone are installed within three feet of the ceiling. This configuration does not provide reasonable protection from a descending hot gas layer. A local exposure or electrically initiated fire could cause damage to the redundant cables if they are exposed to a heat flux of sufficient intensity." (Emphasis added) (SE, p. 11)

RESPONSE

Concern regarding stratification effects is an inappropriate basis upon which to reject the WE approach. The stratification layer would impact our configuration along with configurations acceptable under III.G.2. Equivalence is all that is required under the regulation and we have demonstrated such equivalence. (See Section 1.6)

While not required by law, the WE approach has demonstrated protection against fire hazards which are greater than credible. This analysis approach has properly included such effects as the formation of a stratified layer of hot combustion gases and has provided protection from this phenomenon. In using undefined terms to reject this analysis, the draft SE precludes our providing specific and detailed clarification. In addition, we are aware that additional fire testing is being considered at Sandia Laboratories which could result in future revisions to the present fire protection regulations. This makes it even more inappropriate to reject exemption requests using imprecise terms.

Additional quantities of combustibles can be postulated to enable a fire of sufficient magnitude or heat flux of sufficient intensity to destroy almost any configuration. Likewise, reduced quantities of combustibles can be postulated to justify minimal protection. The purpose of Section III.G, in specifying design basis protective features by rule, was to preclude such divergent postulations. It is true that redundant cable trays are located within three feet of the ceiling. Section III.G does not specify any vertical configuration requirements and the location three feet from the ceiling is not precluded. The imprecise terms of the draft SE appear to be reintroducing unquantified terms into an evaluation under Appendix R even though the rule was established to preclude such action.

1.12 SE Comment

"Most cables in the plant are polyethelene insulated cables with polyvinylchloride jackets (PE/PVC). These cables have not passed the IEEE 383 test, and therefore an electrically initiated fire may propagate." (SE, p. 3)

RESPONSE

We are not aware of any data which will support the stated contention that PE/PVC cables will sustain an electrically initiated fire. Tests conducted at Sandia Laboratories attempted to generate electrically initiated cable tray fires using optimum cable configuration not typical of actual nuclear power plant cable installation. The test personnel were able to initiate a fire, but not of a sufficient magnitude to be self-sustaining once the electrical fault condition was removed. Sandia had to resort to an exposure fire in order to establish a deep-seated tray fire. Should the Staff posess any data which would indicate that there is an actual concern for PE/PVC cables, we request that such data be made available for our review and incorporation into the fire hazards analysis, as appropriate.

2.0 REQUESTED EXEMPTION REVIEW

This section contains our review and our response to the evaluations of individual fire zones for which exemptions have been requested which are contained in Sections 3 through 10 of the draft SE.

2.1 FIRE ZONE 10 Unit 1 Containment Southeast Sector Elevation 21 Feet

2.1.1 Basis for Exemption Request

Fire Zone 10 contains redundant conduits for pressurizer level and pressure instrumentation and pressurizer heater cables.

The exemption request for Fire Zone 10 is justified because:

(1) The conservative quantitative fire hazards analysis described in Section 5.11 of the Point Beach analysis demonstrates that additional modifications necessary to achieve compliance with Section III.G.2.b of Appendix R would not enhance fire protection safety in Fire Zone 10.

(2) At least one division of safe shutdown circuits will be protected from floor-based exposure fires by the proposed modifications; and

(3) A limited combustible loading consisting almost entirely of cable insulation is present in the

zone. This insulation is confined primarily to horizontal trays which are a minimum of 14 feet above the floor;

(4) Extensive smoke detection exists in the area;

(5) Manual fire suppression equipment is provided convenient to the area;

(6) The area is unoccupied during normal operation;

The defense-in-depth protection summarized in the Point Beach analysis combined with the additional passive protection provided by the proposed modifications provides a level of fire protection safety which is at least equivalent to that which would be provided by Section III.G.2.b of Appendix R.

2.1.2 Analysis Summary

The requirement for pressurizer heaters to enable plant shutdown is an operations consideration. It is the opinion of the Point Beach operating staff that pressurizer heaters are desirable to facilitate safe plant shutdown. In the interest of overall facility safety, pressurizer heater cables will be protected to ensure that safe plant shutdown can be accomplished in accordance with operating practice.

The relative fire resistivity of the elevation 21 foot general area in terms of flammable liquid quantity was determined to be in excess of 20 gallons. This is more than sufficient to demonstrate equivalence to III.G.2.b. The pressurizer cubicle is essentially devoid of fixed combustibles other than the pressurizer heater cables. Radiation levels within the cubicle during periods of normal operation preclude personnel traffic and the introduction of transient combustibles. Therefore, analysis of the cubicle was determined to be unncessary.

2.1.3 Draft SE Discussion

2.1.3.1 SE Comment

"The containment building is one large common area." (SE, p. 22)

RESPONSE

The containment can generally be interpreted to be one large common area. However, primary system components of a pressurized water reactor unit are surrounded by concrete shield walls of varying thickness. The minimum shield wall thickness in the Point Beach containment is 30 inches. The floor, ceiling, and shield wall construction provides effective separation of general areas from primary coolant system components at intermediate containment elevations. The general area at elevation 21 feet and the pressurizer heater cubicle are separated in this manner. The SE evaluation does not appear to recognize this separation.

2.1.3.2 SE Comment

"By letter dated October 21, 1980, we informed the licensee that to meet the intent of Section III.G of Appendix R, the licensee should provide alternate shutdown capability for this area." (SE, p. 22)

RESPONSE

We believe this statement should be deleted from the draft SE. See Section 1.8 above.

2.1.4 Draft SE Evaluation

2.1.4.1 SE Comment

> "The licensee did not consider electrically initiated fires in cables. The cable insulation on cables is not qualified in accordance with the IEEE 383 flame test. As discussed in Section 1.0, nonqualified electrical cabling is susceptible to electrically initiated fires. Therefore, an electrically initiated fire in a single cable tray containing the redundant pressurizer heater cables would result in fire damage to the redundant cables." (SE, p. 23)

RESPONSE

We do not consider electrically initiated fires to be a credible occurrence. See Section 1.12. The discussion in SE Section 1.0 does not include a referenced basis which should have been provided.

Because Point Beach Nuclear Plant contains a mixture of qualified and unqualified cabling, the Point Beach analysis conservatively assumed all cable to be PE/PVC for analytical purposes. However, certain cables for specific safety related equipment have been positively identified as part of our environmental qualification program. The pressurizer heater cables are 600V Kerite HTK insulated FR jacketed power cable qualified for class 1E application at Point Beach. This cabling has been verified to meet the qualification requirements of IEEE 383.

2.1.4.2 SE Comment

> "Modifications such as rerouting redundant cables to provide twenty feet of separation would provide the requisite level of safety." (SE, P. 24)

RESPONSE

Each Point Beach containment is constructed with one pressurizer heater cubicle having dimensions of approximately 12 feet by 15 feet by 53 feet high. The pressurizer has an internal diameter of 7 feet amd cables must terminate at the pressurizer. Therefore, it is not possible to implement the SE recommendations to provide 20 feet of separation.

2.1.5 Conclusion

The Point Beach analysis has demonstrated that the fire resistivity of Fire Zone 10 is at least equivalent to the requirements of the Section III.G.2.b alternative of Appendix R. The evaluation has been clarified to verify that pressurizer heater cables are 1EEE 383 qualified. We have complied with the directives of Generic Letter 81-12 and demonstrated equivalence to the Section III.G.2.b alternative. We believe we have also satisfied the concerns stated in the draft SE. Therefore, the exemption should be granted.

2.2 FIRE ZONE 11 Unit 2 Containment Southeast Section Elevation 21 Feet

2.2.1 Basis for Exemption Request

Fire Zone 11 contains redundant conduits for pressurizer level and pressure instrumentation and pressurizer heater cables.

The exemption request for Fire Zone 11 is justified because:

(1) The conservative quantitative fire hazards analysis described in section 5.12 of the Point Beach analysis demonstrates that additional modifications necessary to achieve compliance with Section III.G.2.b of Appendix R would not enhance fire protection safety in Fire Zone 11;

(2) At least one division of safe shutdown circuits will be protected from floor-based exposure fires by the proposed modifications;

(3) A limited combustible loading consisting almost entirely of cable insulation is present in the zone. The insulation is confined primarily to horizontal trays which are a minimum of 14 feet above the floor;

(4) Extensive smoke detection exists in the area;

(5) Manual fire suppression equipment is provided convenient to the area; and

(6) The area is unoccupied during normal operation;

The defense-in-depth protection summarized in the Point Beach analysis combined with the additional passive protection provided by the proposed modifications provides a level of fire protection safety which is at least equivalent to that which would be provided by Section III.G.2.b of Appendix R.

2.2.2 Analysis Summary

The requirement for pressurizer heaters to enable plant shutdown is an operations consideration. It is the opinion of the Point Beach operating staff that pressurizer heaters are desirable to facilitate safe plant shutdown. In the interest of overall facility safety, pressurizer heater cables will be protected to ensure that safe plant shutdown can be accomplished in accordance with operating practice.

The relative fire resistivity of the elevation 21 foot general area in terms of flammable liquid quantity was determined to be in excess of 20 gallons. This is more than sufficient to demonstrate equivalence to III.G.2.b. The pressurizer cubicle is essentially devoid of fixed combustibles other than the pressurizer heater cables. Radiation levels within the cubicle during periods of normal operation preclude personnel traffic and the introduction of transient combustibles. Therefore, analysis of the cubicle was determined to be unncessary.

2.2.3 Draft SE Discussion

2.2.3.1 SE Comment

"The containment building is one large common area." (SE, p. 25)

RESPONSE

The containment can generally be interpreted to be one large common area. However, primary system components of a pressurized water reactor unit are surrounded by concrete shield walls of varying thickness. The minimum shield wall thickness in the Point Beach containment is 30 inches. The floor, ceiling, and shield wall construction provides effective separation of general areas from primary coolant system components at intermediate containment elevations. The general area at elevation 21 feet and the pressurizer heater cubicle are separated in this manner. The SE evaluation does not appear to recognize the separation provided.

SE Comment

2.2.3.2 "By letter dated October 21, 1980, we informed the licensee that to meet the intent of Section III.G of Appendix R, the licensee should provide alternate shutdown capability for this area." (SE, p. 25)

RESPONSE

We believe this statement should be deleted from SE. See Section 1.8 above.

2.2.4 Draft SE Evaluation

2.2.4.1 SE Comment

(2) "As discussed in Section 8.3, an electrically initiated fire could cause damage to the redundant pressurizer heaters cables in the pressurizer heaters cubicle where they are separated by approximately one foot." (SE, p. 25)

RESPONSE

We do not consider electrically initiated fires to be a credible occurrence. See Section 1.12. Certain cables for specific safety related equipment have been positively identified as part our environmental qualification program. The pressurizer heater cables are 600V Kerite HTK insulated FR jacketed power cable qualified for class 1E application at Point Beach. This cabling has been verified to meet the qualification requirements of IEEE 383.

2.2.5 Conclusion

The Point Beach analysis has demonstrated that the fire resistivity of Fire Zone 11 is at least equivalent to the requirements of the Section III.G.2.b alternative of Appendix R. The evaluation has been clarified to verify that pressurizer heater cables are IEEE 383 qualified. We have complied with the directives of Generic Letter 81-12 and demonstrated equivalence to the Section III.G.2.b alternative. We believe we have also satisfied the concerns stated in the draft SE evaluation. Therefore, the exemption should be granted.

2.3 Halon Systems

Automatic Halon 1301 gaseous suppression systems are proposed for Fire Areas 5, 6, and 8. In subsequent Fire Zone analysis sections, we demonstrate equivalence to Section III.G.2.b. In this section, we describe the Halon system characteristics and demonstrate its equivalence to III.G.2.c.

In accordance with the guidance in Appendix R, overall area fire safety is achieved through the defense-in-depth approach to fire protection which includes administrative controls, passive protection, and active suppression. Equivalence of Halon systems to Section III.G.2.c is demonstrated by using an approach to fire protection consistent with the NFPA Systems Approach to Fire Protection (SPP-36). The following decision tree actions are employed by SPP-36.

A. Achieve Fire Safety Objective

1. Prevent Fire Ignition, or
2. Manage Fire Impact
    a. Manage Exposed, or
    b. Manage Fire
        1) Control Combustion Process, or
        2) Control Fire by Construction, or
        3) Suppress Fire
            a) Manually Suppress Fire, or
            b) Automatically Suppress Fire
                (1) Detect Fire (Threshold), and
                (2) Initiate Action, and
                (3) Control Fire

Under the decision tree approach, 2.b.1), 2), or 3) are equivalent for achieving the fire safety objective. Thus, equivalent fire safety can be reached in any fire area by using any one of the following:

1) Controlling the combustion process (i.e., administrative controls), or
2) Controlling the fire by construction (i.e., passive protection), or
3) Suppressing the fire (i.e., active suppression).

Experience has demonstrated that the number of personnel who require access to safe shutdown areas of a nuclear power plant is such that the first NFPA alternative, administrative controls should not be the sole means of achieving the fire safety objective, even though the effectiveness of administrative controls can be demonstrated.

The objectives of Section III.G and the second NFPA alternative can be satisfied by provision of passive protection alone in accordance with the Section III.G.2.a alternative. However, the required construction to satisfy this alternative cannot be accommodated in the areas of interest.

The third NFPA alternative by which the objectives of Section III.G can be satisfied is active suppression. While Section III.G.2 partly credits active suppression in alternatives b and c, no III.G.2 alternative is provided which uses active suppression alone. This alternative should remain available in the exemption process.

The three SPP-36 requirements for effective automatic fire suppression are:

(1) Threshold fire detection

(2) System initiation

(3) Fire control

The WE Halon system satisfies these requirements. The first requirement is satisfied by a high quality detection system already designed and being installed in the areas of interest.

To meet the second criterion of SPP-36, a reliable means to assure system actuation is required. In order to provide the requisite level of safety, redundant components and power supplies independent of off-site power are provided. The concept of separation into "trains" which is utilized for nuclear safety systems in order to accommodate a single failure is used to ensure operability of the Halon suppression system.

Main and reserve banks of Halon storage containers are provided. All containers are monitored and each bank includes a spare container which will be discharged should any one of the containers within the bank fail to discharge. Redundant pairs of Halon release valves are provided. Should a single valve fail to operate, the redundant pair of valves is actuated. System flow is monitored downstream of the release valves. Should one train of the system fail to actuate, the redundant train will be actuated. The system is continuously supervised with alarm annunciation provided in the control room. The system is designed for a total single train discharge time of ten seconds and a minimum concentration holding time of ten minutes in accordance with NFPA 12A. This will be verified by a system acceptance test. Therefore, positive actuation of the Point Beach Halon system is assured. We believe that no higher standard for fire protection systems is existent or has ever been required.

The third requirement, fire control is achieved through the use of Halon. Halon is a suppressant which is compatible with electrical components in the areas and results in minimal hazard to personnel. The total flooding Halon suppression system is best suited to provide rapid total area coverage. The effectiveness of Halon as a fire suppressant is well documented. Exhibit B in the Point Beach analysis documents the suppression of a fire in an operational switchgear room. The effectiveness of Halon in suppressing flammable liquid fires is documented in a Dupont test, recorded on film, for Amoco Oil Company. The

Halon system is designed in accordance with nuclear safety system design philosophy and achieves the objectives of Section III.G. By satisfying the requirements of SPP-36, the equivalence of the Halon system to the III.G.2.c alternative is demonstrated.

2.4 FIRE AREA 5 Auxiliary Feedwater Pump Room

2.4.1 Basis for Exemption Request

Fire Area 5 contains:

(1) Four auxiliary feedwater pumps (two 100%-capacity unit dedicated steam-driven, two 50%-capacity shared electric motor-driven);

(2) Remote shutdown panels for operation of the motor-driven auxiliary feedwater pumps and containment cooling fans;

(3) Redundant safe shutdown cables; and

(4) Room ventilation equipment.

The exemption request for Fire Area 5 is justified because:

(1) A single-failure-proof Halon 1301 automatic suppression system will provide fast total area suppression capability;

(2) The conservative, quantitative fire hazards analysis, described in Section 5.6 the Point Beach analysis demonstrates that additional modifications necessary to achieve compliance with Section III.G.2.b or III.G.2.c of Appendix R would not enhance fire protection safety in Fire Area 5;

(3) Division "B" circuits are protected from floor-based exposure fire effects by the proposed modifications described in Section 5.6 of the Point Beach analysis;

(4) A limited combustible loading consisting almost entirely of cable insulation is present in the area. This insulation is confined primarily to horizontal trays which are at least 12 feet above the floor. Portions of the trays are located above an enclosed three-hour rated passageway which precludes an exposure fire location beneath the tray sections. The cable tray location and configuration reduce the probability of significant involvement due to an exposure fire;

(5) Extensive smoke detection exists in the area; and

(6) Excellent access and equipment are provided for rapid manual fire suppression.

The defense-in-depth protection summarized in the Point Beach analysis combined with the additional passive and active protection provided by the proposed modifications provides a level of fire protection safety which is at least equivalent to that which would be provided by Sections III.G.2.b or III.G.2.c of Appendix R.

2.4.2 Analysis Summary

The Point Beach analysis for Fire Area 5 was performed to demonstrate that fire protection features within this area are equivalent to the Section III.G.2 alternative. The configuration of Fire Area 5 is somewhat unusual having an overall length of approximately 80 feet. The area contains certain common safe shutdown cables for which divisional separation in excess of 20 feet is achieved. The area also contains certain unit specific redundant cables which are located approximately in the north and south sections of the room. Sufficient separation exists such that a common exposure fire would not affect redundant cabling of both units. Therefore, separate analyses were performed for the Units 1 and 2 sections of the area. Fire resistivity was analyzed relative to the effects of exposure fires and stratified hot gas layers in each section. For the Unit 1 section, the fire resistivity, in terms of quantity of flammable liquid, was determined to be 12.7 gallons for exposure fires and 12.9 gallons for stratified hot gas layers. The essentially equal fire resistance of this section indicates that essentially equal potential for degradation of redundant cables exists due to exposure fires or stratification, regardless of horizontal separation. For the Unit 2 section, the fire resistivity, in terms of quantity of flammable liquid, was determined to be 15.2 gallons for exposure fires and 11.5 gallons for stratified hot gas layers. The effects from a stratified layer of hot gases pose the greatest potential for the degradation of redundant cables.

2.4.3 Draft SE Discussion

2.4.3.1 SE Comment

(1) "The licensee has proposed to wrap Division "B" conduit 1P2C1 with a one-hour fire-rated barrier over its entire length through the area." (SE, p. 13)

RESPONSE

The statement committing to a one-hour fire barrier for conduit 1P2C1 which contains charging pump power cables was made in the Point Beach analysis. This statement was a typographical error. Consistent with our concern for overall facility safety, we cannot commit to a one-hour fire barrier for conduit 1P2C1. Our approach to fire barriers is discussed in Sections 1.9 and 1.10. Appropriate fire barriers will be provided.

2.4.3.2 SE Comment

> "By letter dated October 21, 1980, we informed the licensee that to meet the intent of Section III.G of Appendix R, the licensee should provide alternate shutdown capability for this area." (SE, p. 14)

RESPONSE

We believe that this statement should be deleted from the SE. See Section 1.8 above.

2.4.4 Draft SE Evaluation

2.4.4.1 SE Comment

> "Except for the above compensatory features, the configuration of the area, the quantity of in-situ combustibles, the type of cable insulation, the potential for the accumulation of combustible materials, and the installed fire protection systems are what is typically found in auxiliary feedwater pump rooms." (SE, p. 14)

RESPONSE

The fire protection features of the Point Beach auxiliary feedwater pump room are not typical. The unusual configuration of the auxiliary feedwater pump room is described in Section 2.4.2 above and in the Point Beach analysis.

The three-hour fire-rated tunnel through the area is also an unusual feature. One purpose for provision of the tunnel was the recognition that combustible materials are required in the performance of normal operating duties. The tunnel contains an auxiliary operator station and space for the storage of operating personnel supplies. A second purpose of the tunnel is to provide a direct personnel access path between Units 1 and 2 independent of the auxiliary feedwater pump room. The isolation of the auxiliary feedwater pump room from personnel traffic has a positive effect in reducing the potential for the accumulation of combustible materials.

The Halon automatic fire suppression system is a continuously monitored single-failure-proof system provided with an emergency battery backup power supply having an eight-hour capacity. The Halon system alone provides protection equivalent to that of Section III.G.2.c. See Section 2.3 above.

2.4.4.2 <u>SE Comment</u>

> "Because of the configuration of cables and components in this area, an exposure or electrically initiated fire could cause damage to both trains of shutdown equiment." (SE, p. 15)

<u>RESPONSE</u>

The Point Beach analysis demonstrates that adequate separation distance necessary to satisfy Section III.G.2.b requirements between required components is achieved.

Regulatory Guide 1.75 requirements specify electrical separation. Appendix R requirements specify separation from exposure fires. We are not aware of any data which support the conclusion that PE/PVC cables will support continuous combustion due to an electrical fault condition. See Section 1.12 above.

2.4.4.3 SE Comment

> "Although these mitigating features may retard somewhat the onset of fire damage, they do not provide an equivalent level of protection as Section III.G." (SE, p. 15)

The Point Beach analysis has demonstrated that passive features of the auxiliary feedwater pump room provide a level of fire protection equivalent to the III.G.2.b alternative. The single-failure-proof Halon suppression system alone provides a level of fire protection equivalent to Section III.G.2.c. In addition, our approach has demonstrated that fire protection is provided against fire hazards which are greater than credible.

2.4.4.4 SE Comment

> "The automatic Halon 1301 extinguishing system will mitigate the fire hazard but may not provide fast total coverage of cabling and/or the floor area." (SE, p. 15)

The Halon 1301 system in the auxiliary feedwater pump room is designed and being installed in accordance with NFPA 12A. The system is designed to achieve total discharge within 10 seconds and to maintain required concentration for 10 minutes. These conditions will be verified by an acceptance test. See Section 2.3 above.

2.4.4.5 SE Comment

> Without the required separation distance, or the installation of a one-hour fire-rated barrier, as required by Section III.G.2, we would not have reasonable assurance that damage to redundant trains would not occur pending activation of the suppression systems." (SE, p. 15)

The Point Beach analysis has demonstrated equivalence to Section III.G.2.b. One-hour fire-rated barriers are discussed in Section 1.9 above.

The rapid assured actuation of the Halon suppression system described in Section 2.3 above provides reasonable assurance that damage to redundant trains will not occur.

2.3.5 Conclusion

The Point Beach analysis has demonstrated that the fire resistivity of Fire Area 5 is at least equivalent to the III.G.2.b alternative and more than adequate to protect against fires which may be likely to occur. The Halon suppression system alone provides fire protection equivalent to the Section III.G.2 alternative. We have complied wth the directives of Generic Letter 81-12 and demonstrated equivalence to one of the alternatives of Section III.G.2. Therefore, the exemption should be granted.

2.5 FIRE AREA 6 4160V Switchgear Room

2.5.1 Basis for Exemption Request

Fire Area 6 contains safeguards switchgear for both trains A and B of Units 1 and 2, safety-related cable trays, conduit, distribution panels and battery chargers for the station ESF batteries.

The exemption request for Fire Area 6 is justified because:

(1) A single-failure-proof Halon 1301 automatic suppression system will provide fast total area suppression capability;

(2) The conservative, quantitative fire hazards analysis, described in Section 5.7 of the Point Beach analysis demonstrates that additional modifications necessary to achieve compliance with Section III.G.2.b or Section III.G.2.c of Appendix R would not enhance fire protection safety in Fire Area 6;

(3) At least one division of safe shutdown circuits will be protected from floor-based exposure fire effects by the proposed modifications;

(4) A limited combustible loading consisting almost entirely of cable insulation is present in the area. This insulation is confined primarily to horizontal trays which are a minimum of 8.5 feet above the floor;

(5) Extensive smoke detection exists in the area; and

(6) Excellent access and equipment is provided for rapid manual fire suppression;

The defense-in-depth protection summarized in Section 5.7 of the Point Beach analysis combined with the additional passive and active protection provided by the proposed modifications provides a level of fire protection safety which is at least equivalent to that which would be provided by Section III.G.2.b or Section III.G.2.c of Appendix R.

2.5.2 Analysis Summary

The Point Beach analysis for Fire Area 6 was performed to demonstrate that fire protection features within this area are equivalent to the Section III.G.2 alternative. Fire resistivity was analyzed for several existing room cable configurations relative to the effects of exposure fires and a layer of descending stratified hot gas. The minimum resistivity, in terms of quantity of flammable liquid, was determined to be 13.6 gallons for exposure fires and 13.3 gallons resulting from stratification effects. Resistivity to the effects from exposure fires was greater in all analyzed cases. Therefore, the effects of a stratified layer of hot gases poses the greatest potential for redundant cable degradation. These stratification effects are independent of horizontal separation. The results of the analysis also demonstrated that the cabinets could withstand a fire of a magnitude equivalent to the technical basis of the Section III.G.2.b alternative (i.e., 2-5 gallons flammable liquid) with no degradation of internal components. Thus, the fire resistance of the switchgear room is equivalent to the Section III.G.2.b alternative and provides protection greater than that needed against credible fires.

2.5.3 Draft SE Discussion

2.5.3.1 SE Comment

> "By letter dated October 21, 1980, we informed the licensee that to meet the intent of Section III.G of Appendix R, the licensee should provide alternate shutdown capability for this area." (SE, p. 16)

RESPONSE

We believe that this statement should be deleted from the SE. See Section 1.8 above.

2.5.3.2 SE Comment

> "The licensee has now proposed the following modifications." (SE, p. 16)

RESPONSE

The proposed barrier modifications include wrapping the total length of certain conduits in the switchgear room with one-hour fire-rated barriers. Our concern for safety relative to one-hour rated fire barriers is stated in Section 1.9 of this report. Because most cabling in the switchgear room is power cabling, a review a our proposed modifications is necessary to ensure that the degree of barrier protection to be provided will not be detrimental to overall facility safety.

We have also proposed barrier protection for sections of certain conduits and cable trays. The extent of proposed modifications was determined by the Point Beach analysis to be equivalent to the Section III.G.2.b alternative.

2.5.4 Draft SE Evaluation

2.5.4.1 SE Comment

> "In regard to exposure fires, the licensee's analysis demonstrates that a fire of only 5 gallons of acetone for 30 seconds duration will not cause fire damage to the internal parts of the redundant switchgear. Because an exposure fire from the accumulation of transient combustibles could be of significantly longer duration than 30 seconds, the metal electrical cabinets do not provide protection equivalent to twenty feet of separation free of combustibles, or a one-hour fire barrier, or an alternate shutdown capability independent of the area." (SE, p. 18)

RESPONSE

The representative five-gallon fire used in the Point Beach analysis demonstrates equivalence to the Section III.G.2.b alternative. The Point Beach analysis does not purport to specify a design basis fire size of five gallons or a maximum acceptable fire duration of thirty seconds.

The analysis of exposure effects on electrical components mounted inside and on the surface of electrical cabinets in the switchgear room has been repeated using a longer duration fire in response to concerns stated in the draft SE.

The analysis used a representative fire of 12.7 gallons burning for a duration of 120 seconds. See Enclosure 2, Section 13. This analysis demonstrates that under these greater than credible conditions, component failure will not occur. The additional protective measures included in the analysis will be provided. As a result, the level of fire protection of the switchgear room is conclusively demonstrated to be above that which is required by the Section III.G.2.b alternative and that which would be necessary to protect against a credible fire event.

2.5.4.2 <u>SE Comment</u>

> "The existing protection in this fire area does not provide a level of fire protection equivalent to Section III.G." (SE, p. 18)

<u>RESPONSE</u>

This fire area is protected by a continuously monitored, single-failure-proof, automatic Halon fire suppression system provided with an eight-hour capacity emergency battery backup power supply. The Halon system alone provides protection equivalent to that of Section III.G.2.c. See Section 2.3 above.

2.5.5 Conclusion

With proper consideration of the above clarifications, the existing and proposed features for the 4160V switchgear room have been demonstrated to provide a level of fire protection equivalent to the Section III.G.2.b or Section III.G.2.c alternatives of Appendix R and the exemption should be granted.

2.6 Fire Area 8 Cable Spreading Room

2.6.1 Basis for Exemption Request

Fire Area 8 contains safety-related control and instrument cable, transformers, distribution panels and relay cabinets for Units 1 and 2.

The technical justification for the exemption request is as follows:

(1) A single-failure-proof Halon 1301 automatic suppression system will provide fast total area suppression capability;

(2) The conservative quantitative fire hazards analysis described in Section 5.9 of the Point Beach analysis demonstrates that additional modifications necessary to achieve compliance with Sections III.G.2.b or III.G.2.c of Appendix R would not enhance fire protection safety in Fire Zone 8;

(3) At least one division of safe shutdown circuits will be protected from floor-based exposure fire effects by the proposed modifications described in Section 5.9 of the Point Beach analysis;

(4) A limited combustible loading consisting almost entirely of cable insulation is present in the area. The insulation is confined primarily to horizontal trays which are a minimum of seven feet above the floor. All cable trays are of totally enclosed, all steel construction;

(5) Extensive smoke detection exists in the area;

(6) Excellent access and equipment is provided for rapid manual fire suppression; and

(7) A dedicated smoke exhaust system enhances manual fire fighting capability.

The defense-in-depth protection summarized in the Point Beach analysis combined with the additional active protection provided by the proposed modifications provides a level of fire protection safety which is at least equivalent to that which would be provided by Sections III.G.2.b or III.G.2.c of Appendix R.

2.6.2 Analysis Summary

The Point Beach analysis for Fire Area 8 was performed to show that fire protection features within this area meet or exceed the requirements of Sections III.G.2.b or III.G.2.c. The III.G.2.c analysis is provided in Section 2.3. This section provides a discussion of Section III.G.2.b analyses. All cable trays and risers to the control room above are totally enclosed in metal enclosures and contain kaowool blankets. This configuration precludes the potential for direct involvement of in-situ combustibles in a fire.

The WE approach for Fire Area 8 includes many features in excess of those required by III.G.2.b. For instance, our system includes enhanced fire suppression through the use of the Halon suppression system. All cable trays are totally enclosed in sheet metal and a one-half inch Kaowool blanket is placed on the top of each cable tray. These added features provide fire protection at least equivalent to the 20-foot separation feature of III.G.2. This is demonstrated in three ways. First, the III.G.2 configuration would fail due to stratification effects from a fire of 9.6 gallons assuming identical ceiling height (see Fire Zone 2). Our configuration on the other hand will not fail due to stratification effects due to the assured intervention of the Halon suppression system in conjunction with the passive cable tray protection already installed. Secondly, in Section 14 of Enclosure 2, an analysis is provided which demonstrates that our configuration will withstand an exposure fire well in excess of twelve gallons. This is substantially in excess of quantities which could fail acceptable III.G.2.b configurations from stratification effects. Finally, the lowest fire resistivity of our configuration is well in excess of the apparent basis for the selection of the III.G.2.b separation requirements, namely 2-5 gallons.

2.6.3 Draft SE Discussion

2.6.3.1 SE Comment

"Most cable trays are installed approximately 6 feet above the floor." (SE, p. 19)

RESPONSE

Page 5-136 of the Point Beach analysis indicates that the minimum cable tray height in the cable spreading room is 7 feet above the floor.

2.6.3.2 SE Comment

> The licensee has not provided information on the location of redundant equipment." (SE, p. 19)

RESPONSE

We acknowledge that the specific location of redundant equipment is not shown in the Point Beach analysis. Equipment location within the cable spreading room is shown on Figure 1.2-4 of the Point Beach Final Safety Analysis Report which is available to the Staff. The Staff has not requested additional information other than a listing of vertical cable trays which was provided with our October 11, 1982 letter. Should the Staff need further information, we will be pleased to provide such information upon request.

2.6.3.3 SE Comment

> "By letter dated October 21, 1980, we informed the licensee that to meet the intent of Section III.G of Appendix R, the licensee should provide alternate shutdown capability for this area." (SE, p. 19)

RESPONSE

We believe that this statement should be deleted from the SE. See Section 1.8 above.

2.6.4 Draft SE Evaluation

2.6.4.1 SE Comment

> "These areas are not in compliance with Section III.G because the minimum separation distance free of intervening

combustibles between redundant trains of cables is four feet, ..." (SE, p. 20)

RESPONSE

The noted separation exists between riser trays which carry trains of redundant control through the ceiling to the control board. The riser trays begin a minimum of seven feet above the floor and are provided with full width kaowool blankets inside the tray covers which face each other. Section 14 of Enclosure 2 describes an analysis of the effects of an exposure fire on a floor-to-ceiling vertical cable tray typical for cable trays installed in the cable spreading room.

This analysis is considered to be a bounding condition applicable to the partial height riser trays. The analysis demonstrates that fire protection safety equivalent to that of the Section III.G.2.b alternative is provided.

2.6.4.2 SE Comment

"The cable spreading room contains the majority of control and instrumentation cable necessary for operation and for shutdown of both units. Without adequate protection, a single fire of significant magnitude would damage cables of redundant divisions. If such a fire occurred, there is no capability to achieve shutdown independent of the cable spreading room." (SE, p. 20)

RESPONSE

The Point Beach analysis, including the clarification of Section 14 of Enclosure 2, demonstrates that adequate cable protection is provided. For this reason, shutdown capability independent of the cable spreading room is not required. By using undefined terms, the draft SE precludes our providing further specific and detailed clarification.

2.6.4.3 SE Comment

> "Except for the above compensatory features, the configuration of the room, the quantity of in-situ combustibles, the type of cable insulation, the potential for the accumulation of combustible materials, and the installed fire protection systems are what is typically found in cable spreading rooms." (SE, p. 20)

RESPONSE

The fire protection features of the cable spreading room are not typical. The cable trays in the cable spreading room are totally enclosed with solid bottoms as well as kaowool blankets and tight-fitting tray covers. All cable trays are located a minimum of seven feet above the floor. Therefore, seven feet of head room and free access to all floor areas exists throughout the room. These are not typical configurations for either cable trays or for cable spreading rooms.

The cable spreading room is an area of controlled access. The non-vital switchgear area to the east of and outside of the cable spreading room has a diked entrance with step-over stair treads which prevents the wheeling of large quantities of combustibles into the area. An open area of unrestricted access is provided east of the non-vital switchgear area to accommodate personnel and material traffic. The controlled isolation of the cable spreading room from personnel traffic between plant areas has a positive effect in reducing the potential for the accumulation of combustibles and introduction of potential ignition sources.

The Halon automatic suppression system is a continuously monitored system provided with an emergency battery backup power supply having an eight-hour capacity. The Halon system alone provides protection equivalent to that of Section III.G.2.c of Appendix R. See Section 2.3 above.

2.6.4.4 SE Comment

> "Because most, if not all, safety and shutdown systems could be affected by a single fire in this area, the compensatory features do not provide equivalent protection to an alternate shutdown system independent of this area." (SE, p. 20)

RESPONSE

The Point Beach analysis demonstrates that the fire resistance of the cable spreading room is at least equivalent to that of Section III.G.2.b. The Halon suppression system provides protection equivalent to that of Section III.G.2.c. See Section 2.3. Therefore, demonstration of equivalence to an alternate shutdown system is not required. See Section 1.5 above.

2.6.4.5 SE Comment

> " 'Recent tests' conducted at Underwriters Laboratories for the NRC showed that in a configuration similar to that in this area, ..." (SE, p. 20)

RESPONSE

We have reviewed the Sandia Interim Report and note the following significant differences in room features:

Item	Sandia Test Room	Point Beach Cable Spreading Room
Room length	25 feet	78 feet
width	14 feet	49 feet
height	10 feet	16.5 feet
floor area	350 sq. ft.	3,822 sq. ft.
volume	3,500 cu. ft.	63,063 cu. ft.
Vertical cable trays	1	4

Item	Sandia Test Room	Point Beach Cable Spreading Room
Horizontal separation	NA	12 feet, 9 feet, 12 feet
Location	In pool fire	6 inches behind face of 1 in. high solid concrete pedestal
Protection	None	Totally enclosed with kaowool blanket inside exposed face cover

A review of the above parameters indicates that insufficient similarity exists between the two rooms to justify use of the referenced test data as a basis for evaluation.

2.6.4.6 SE Comment

"The automatic Halon 1301 extinguishing system will mitigate the fire hazard but may not provide fast total coverage of cabling and/or the floor area." (SE, p. 21)

RESPONSE

The Halon suppression system assured fast actuation is described in Section 2.3 above. Fast total coverage is assured by the features of the system.

2.6.5 Conclusion

The Point Beach analysis demonstrates that the fire resistive features of the cable spreading room are equivalent to those of the Section III.G.2.b alternative. The Halon suppression system provides protection equivalent to Section III.G.2.c. We also believe that the above clarifications satisfy the concerns stated in the draft SE.

2.7 AUXILIARY BUILDING FIRE ZONES

2.7.1 Fire Zone 1 Unit 1 Motor Control Center Room

A shield wall has been installed in Fire Zone 1 as part of post-TMI-2 modifications. The location of the shield wall restricts the potential for redundant cable trays to become directly involved in a single flammable liquid spill fire. The shield wall location is shown on the attached marked-up copy of Figure 5.2-1 from the Point Beach analysis.

We evaluated the possibility of modifying the design of the newly installed shield wall into a one-hour fire-rated barrier and determined that it could not be done without impairing plant operability and maintenance. Although the barrier offers some measure of protection from potential exposure fires, no credit is taken for its presence in conformance with the conservatism of our methodology. See Section 1.7 above.

2.7.1.1 Basis for Exemption Request

Fire Zone 1 contains safe shutdown cables for both Division "A" and "B" Unit 1 charging system. The only safe shutdown equipment located within this zone is MCC 1B32 which has a redundant component, MCC 1B42, located outside the fire zone. The exemption request for Fire Zone 1 is justified because:

(1) A limited combustible loading consisting almost entirely of cable insulation is present in the zone. This insulation is confined primarily to

horizontal cable trays which are a minimum of 12 feet above the floor. Some trays are shielded by ventilation ducts;

(2) Extensive smoke detection exists in the area;

(3) Excellent access and equipment is provided for rapid manual suppression of any fire;

(4) At least one division of safe shutdown circuits will be protected from floor-based exposure fire effects by the proposed modifications which are described in Section 5.2 of the Point Beach analysis; and

(5) The conservative, quantitative fire hazards analysis which is described in Section 5.2 of the Point Beach analysis demonstrates that additional modifications necessary to achieve compliance with Section III.G.2.b of Appendix R would not enhance fire protection safety in Fire Zone 1.

The defense-in-depth protection summarized in the Point Beach analysis combined with the additional passive protection provided by the proposed modifications provides a level of fire protection safety which is at least equivalent to that which would be provided by Section III.G.2.b of Appendix R.

2.7.1.2 Analysis Summary

The Point Beach analysis for Fire Zone 1 was performed to demonstrate that fire protection features within this zone are at least equivalent to the Section III.G.2.b alternative.

Fire protection features of Fire Zone 1 were analyzed to determine relative fire resistivity. The fire resistivity was analyzed relative to the effects of exposure fires and stratified hot gas layers. The Point Beach analysis postulated an exposure fire location which would have the most severe impact on redundant cable trays. The relative fire resistivity in terms of flammable liquid quantity was determined to be 17.4 gallons for an exposure fire and 14 gallons due to combustion gas stratification effects.

Therefore, the effects of a stratified layer of hot gases pose the greatest potential for redundant cable degradation. These stratification effects are independent of horizontal separation distance and the actual room configuration is equivalent to the separation criterion of Section III.G.2.b.

The feasibility for automatic fire suppression was also evaluated. Total area water suppression coverage was considered to be detrimental to facility safety because safeguards motor control center 1-B32 is located in the zone and could be adversely affected by direct water impingement. Partial area suppression or local spray capability was not proposed on the basis that such applications probably could not satisfy NFPA or NRC requirements. The effectiveness of an automatic suppression system is also significantly reduced in areas where a large quantity of barriers are installed. A suppression system could also adversely affect waste disposal system capability. The fire resistance of Fire Zone 1 is more than two times that of the technical basis for the of Section Section III.G.2.b alternative (i.e., 2-5 gallons of flammable liquid), or that required to accommodate the total possible introduction of acetone in the zone. For the above reasons, automatic water suppression would not enhance fire protection safety in Fire Zone 1 and could be detrimental to overall facility safety.

2.7.1.3 Draft SE Discussion

2.7.1.3.1 SE Comment

"The licensee has not delineated the location of all the cable trays in the area." (SE, p. 6)

RESPONSE

This information was not required as part of the Point Beach analysis nor has it been requested by the Staff during the Appendix R evaluation. Should such information be necessary for satisfactory resolution of the exemption request, we will furnish this information as soon as possible upon request.

2.7.1.3.2 SE Comment

"The licensee has not indicated the type or fire rating of the barrier." (SE, p. 6)

RESPONSE

A thorough discussion of this item is provided in Sections 1.9 and 1.0 above.

2.7.1.3.3 SE Comment

"By letter dated October 21, 1980, we informed the licensee that to meet the intent of Section III.G of Appendix R, the licensee should provide alternate shutdown capability for this area."

RESPONSE

We believe that this statement should be deleted from the SE. See Section 1.8 above.

2.7.2 Fire Zone 2 Safety Injection and Containment Spray Pump Room

2.7.2.1 Basis for Exemption Request

Fire Zone 2 contains safe shutdown cables for Division "A" and "B" Unit 1 charging system, pressurizer heater and safety-related MCC's. There is no safe shutdown equipment located within this zone. The exemption request for Fire Zone 2 is justified because:

(1) A limited combustible loading consisting almost entirely of cable insulation and small amounts of lubricating oil is present in the zone. The cable insulation is confined primarily to horizontal cable trays which are a minimum of 12 feet the floor. The small sections of vertical cable trays are at the ceiling level and not subject to local exposure fire effects. The approximately eight gallons of lubricating oil is contained within the pumps and no hot surfaces exist within the zone to cause ignition of this oil;

(2) Extensive smoke detection exists in the area;

(3) Excellent access and equipment are provided for rapid manual suppression of any fire;

(4) An automatic wet pipe sprinkler system provides partial zone coverage in the eastern section of the zone which contains the highest concentration of fixed combustibles.

(5) At least one division of safe shutdown circuits will be protected from floor-based exposure fire effects by the proposed modifications described in Section 5.3 of the Point Beach analysis; and

(6) The conservative quantitative fire hazards analysis which is described in Section 5.3 of the Point Beach analysis demonstrates that additional modifications necessary to achieve compliance with Section III.G.2 of Appendix R would not enhance fire protection safety in Fire Zone 2.

The defense-in-depth protection summarized in the Point Beach analysis combined with the additional passive protection provided by the proposed modifications provides a level of fire protection safety which is at least equivalent to that which would be provided by Section III.G.2.b of Appendix R.

2.7.2.2 Analysis Summary

The Point Beach analysis for Fire Zone 2 was performed to demonstrate that fire protection features within this zone are at least equivalent to the Section III.G.2.b alternative. The fire resistivity of Fire Zone 2 was analyzed relative to the effects of exposure fires and stratified hot gas layers. The fire resistivity, in terms of quantity of flammable liquid, was determined to be 20.7 gallons for exposure fires and 9.6 gallons for the effects of stratified hot gas layers. Therefore, the effects of a stratified layer of hot gases pose the greatest potential for redundant cable degradation.

These stratification effects are independent of horizontal separation distance and the actual room configuration is equivalent to the separation criterion of Section III.G.2.b.

The feasibility for total area automatic water fire suppression was also evaluated. The partial automatic suppression system was provided in accordance with Staff Position PF-7. This system covers that portion of Fire Zone 2 which contains a high combustible fuel load. The system was designed to protect the safety injection pumps specifically and does not cover completely both trains of redundant cable. No credit was taken for the suppression system, which provides protection for one train of redundant cables, on the basis that it probably could not satisfy NFPA or NRC requirements. A total area suppression system could also adversely affect waste disposal system capability. The relative fire resistance of Fire Zone 2 is 1-1/2 times that needed to satisfy the Section III.G.2.b alternative or any credible fire in Zone 2. For the above reasons, total area automatic fire suppression would not enhance the fire protection safety in Fire Zone 2 and could be detrimental to overall facility safety.

2.7.2.3 <u>Draft SE Discussion</u>

2.7.2.3.1 <u>SE Comment</u>

"The safety injection pumps are protected by a wet pipe automatic sprinkler system; however, the system does not extent to where the redundant cables are installed." (SE, p. 7)

RESPONSE

We have reinspected the fire zone and verified that the wet pipe suppression system provides sprinkler protection for all Division "A" circuits and Division "B" circuits with the exception of Tray PS and conduit 1P2C. Even these circuits could be indirectly protected from ceiling hot gas stratification effects by the installed water suppression system. A copy of Figure 5.3-1 marked to show the area of automatic water suppression system protection is attached.

2.7.2.3.2 SE Comment

> "The combustibles comprise a fuel load of 55,800 BTU/sq. ft. which, if totally consumed, would correspond to a fire severity of about forty minutes on the ASTM E-119 standard time temperature curve." (SE, p. 7)

RESPONSE

The stated combustible fuel load exists only in the safety injection pump area of the room which is protected by the automatic fire suppression system. The remaining approximately sixty percent of the room has a combustible fuel load of less than 8,000 BTU/sq. ft.

2.7.2.3.3 SE Comment

> "By letter dated October 21, 1980, we informed the licensee that to meet the intent of Section III.G of Appendix R, the licensee should provide alternate shutdown capability for the area." (SE, p. 7)

RESPONSE

We believe that this statement should be deleted from the SE. See Section 1.8 above.

2.7.3 Fire Zone 3 Component Cooling Water Pump Room

2.7.3.1 Basis for Exemption Request

Fire Zone 3 contains safe shutdown cables for Division "B" Unit 1 charging system and safety-related MCC, along with Unit 2 Divisions "A" and "B" charging system, pressurizer heaters and Division "A" safety-related MCC. The only safe shutdown equipment which is located within this zone are all four component cooling water pumps which are only required for cold shutdown. The exemption request for Fire Zone 3 is justified because:

(1) A limited combustible loading consisting almost entirely of cable insulation is present in the zone. This insulation is confined to horizontal trays which are a minimum of twelve feet above the floor. Some trays are shielded by ventilation ducts;

(2) Extensive smoke detection exists in the area;

(3) Excellent access and equipment are provided for rapid manual suppression of any fire;

(4) An automatic wet pipe system provides complete local area coverage for the northern section of Fire Zone 3;

(5) At least one division of safe shutdown circuits will be protected from floor-based exposure fire effects by the proposed modifications described in Section 5.4 of the Point Beach analysis; and

(6) The conservative quantitative fire hazards analysis which is described in Section 5.4 of the Point Beach analysis demonstrates that additional modifications necessary to achieve compliance with Section III.G.2 of Appendix R would not enhance fire protection safety in Zone 3.

The defense-in-depth protection summarized in the Point Beach analysis combined with the additional passive protection provided by the proposed modifications provides a level of fire protection safety which is at least equivalent to that which would be provided by Section III.G.2.b of Appendix R.

2.7.3.2 Analysis Summary

The Point Beach analysis for Fire Zone 3 was performed to demonstrate that fire protection features within this zone are at least equivalent to the Section III.G.2.b alternative. The fire resistivity of Fire Zone 3 was analyzed relative to the effects of exposure fires and stratified hot gas layers. The fire resistivity in terms of quantity of flammable liquid was determined to be 17.4 gallons for exposure fires and 9.6 gallons for stratified hot gas layers. Therefore, the effects of a stratified layer of hot gases pose the greatest potential for redundant cable degradation. These stratification effects are independent of horizontal separation distance and the actual room configuration is equivalent to the separation criterion of Section III.G.2.b.

The feasibility for total area automatic water fire suppression was also evaluated. The partial automatic suppression system was provided in accordance with Staff Position PF-9. Although the system was installed to provide protection for the component cooling water pumps, it also provides protection for all of the Unit 2 redundant cables located in this fire zone. For clarification, we note that only one train of Unit 1 redundant cables are located in Fire Zone 3. No credit was taken for the suppression system on the basis that it probably could not satisfy NFPA or NRC requirements. A total area suppression system could also adversely affect waste disposal system capability. The relative fire resistance of Fire Zone 3 is 1-1/2 that needed to satisfy the Section III.G.2.b alternatives or that necessary to protect against any credible fire. For the above reasons, total area automatic fire suppression would not enhance the fire protection safety in Fire Zone 3 and could be detrimental to overall facility safety.

2.7.3.3 Draft SE Discussion

2.7.3.3.1 SE Comment

"Automatic sprinkler protection has been installed to protect the component cooling water pump area; however, the system does not extend to protect the redundant cables in the area." (SE, p. 8)

RESPONSE

We have reinspected the fire zone and verified that the wet pipe suppression system provides complete sprinkler protection for all Divisions "A" and "B" circuits with the exception of a small portion of cable tray CK. Even this tray is indirectly protected from ceiling hot gas stratification effects by the installed local suppression system. A copy of Figure 5.4-2 marked to show the area of automatic water suppression is attached.

2.7.3.3.2 SE Comment

"The combustible in the area is cable insulation comprising a fuel loading of 52,800 BTU/sq. ft..." (SE, p. 8)

RESPONSE

Page 5-38 of the Point Beach analysis correctly states the fire loading for this area of 5.6 lb/sq. ft. The value of 6.6 lb/sq. ft. stated on page 5-45 is an error. The total combustible fuel load is 44,800 BTU/sq. ft.

2.7.3.3.3 SE Comment

"By letter dated October 21, 1980, we informed the licensee that to meet the intent of Section III.G of Appendix R, the licensee should provide alternate shutdown capability for this area. (SE, p. 8)

RESPONSE

We believe that this statement should be deleted from the SE. See Section 1.8 above.

2.7.4 Fire Zone 4 Unit 2 Motor Control Center Room

2.7.4.1 Basis for Exemption Request

Fire Zone 4 contains safe shutdown cables for both Division "A" and "B" Unit 2 charging system. The safe shutdown equipment located within this zone is the Division "B" charging system MCC and transformer and MCC 2B32 which has a redundant component, MCC 2B42, located outside the fire zone. The exemption request for Fire Zone 4 is justified because:

(1) A limited combustible loading consisting almost entirely of cable insulation is present in the zone. This insulation is confined to horizontal trays which are at a minimum of twelve feet above the floor. Some trays are shielded by ventilation ducts;

(2) Extensive smoke detection exists in the area;

(3) Excellent access and equipment is provided for rapid manual suppression of any fire;

(4) At least one division of safe shutdown circuits will be protected from floor-based exposure fire effects by the proposed modifications described in Section 5.5 of the Point Beach analysis; and

(5) The conservative, quantitative fire hazards analysis which is described in Section 5.5 of the Point Beach analysis demonstrates that additional modifications necessary to achieve compliance with Section III.G.2.b of Appendix R would not enhance fire protection safety in Zone 4.

The defense-in-depth protection summarized in the Point Beach analysis combined with the additional passive protection provided by the proposed modifications provides a level of fire protection safety which is at least equivalent to that which would be provided by Section III.G.2.b of Appendix R.

2.7.4.2 Analysis Summary

The Point Beach analysis for Fire Zone 4 was performed to demonstrate that fire protection features within this zone are at least equivalent to the Section III.G.2.b. alternative. The fire resistivity of Fire Zone 4 was analyzed relative to the effects of exposure fires and stratified hot gas layers. The fire resistivity, in terms of quantity of flammable liquid, was determined to be 12.3 gallons for the effects of stratified hot gas layers. The proposed modifications increase the resistance to exposure fire effect above this quantity because of the configuration in this area. A barrier beneath either tray would cause the effects of stratification to become limiting. Therefore, the effects of a stratified layer of hot gases pose the greatest potential for redundant cable degradation. These stratification effects are independent of horizontal separation distance and the actual room configuration is equivalent to the separation criterion of Section III.G.2.b.

The feasibility for automatic fire suppression was also evaluated. Total area water suppression coverage was considered to be detrimental to facility safety because safeguards MCC 2B32 is located in the zone and could be adversely affected by direct water impingement. Partial area suppression or local spray capability was not proposed on the basis that such applications probably would not satisfy NFPA or NRC requirements. The effectiveness of an automatic suppression system is also significantly reduced in areas where a large quantity of barriers are installed. A suppression system could also adversly affect waste disposal system capability. The relative fire resistance of Fire Zone 4 is more than two times that needed to satisfy the Section III.G.2.b alternative or that required to protect against any credible fire. For the above reasons, automatic suppression would not enhance fire protection safety in Fire Zone 4 and could be detrimental to overall facility safety.

2.7.4.3 Draft SE Discussion

2.7.4.3.1 SE Comment

> By letter dated October 21, 1980, we informed the licensee that to meet the intent of Section III.G of Appendix R, the licensee should provide alternate shutdown capability for this area." (SE, p. 9)

RESPONSE

We believe that this statement should be deleted from the SE. See Section 1.8 above.

2.7.4.3.2 SE Comment

> "The licensee has not delineated the type or fire rating of the barrier." (SE, p. 9)

RESPONSE

A thorough discussion of this item is provided in Sections 1.9 and 1.10 above.

2.7.4.3.3 SE Comment

> "The licensee is not separating the Division "B" Motor Control Center and Transformer which contain termination of redundant Division "B" cables." (SE, p. 10)

RESPONSE

We believe that this statement is in reference to the Division "B" charging pump MCC and transformer separation from Division "A" charging cable tray HA01 which is approximately ten feet horizontally. Cable tray HA01 is ten feet above the floor and 6.5 feet below the ceiling. No credible exposure fire would fail both divisions. The MCC is floor-mounted and not subject to hot gas stratification effects. Therefore, these components are suitably separated.

2.7.5 Fire Zone 7 Containment Spray Additive Tank and Monitor Area

2.7.5.1 Basis for Exemption Request

Fire Zone 7 contains safe shutdown cables for both Unit 1 and 2 Division "A" and "B" charging system and pressurizer heaters. The only safe shutdown equipment located within this zone is MCC 1B42 and 2B42 which have redundant components, MCC 1B32 and 2B32, located outside the fire zone. The exemption request for Fire Zone 7 is justified because:

(1) A limited combustible loading consisting almost entirely of cable insulation is present in the zone. This insulation is confined principally to vertical cable trays located against one wall of the zone. The vertical cable trays are protected by a 42" wide, solid concrete curb 6" high which would prevent direct exposure to fire impingement. The location and configuration of these cables reduces the probability of significant involvement due to an exposure fire;

(2) Extensive smoke detection exists in the area;

(3) Excellent access and equipment is provided for rapid manual suppression of any fire;

(4) At least one division of safe shutdown circuits will be protected from floor-based exposure fire effects by the proposed modifications described in Section 5.8 of the Point Beach analysis; and

(5) The conservative, quantitative fire hazards analysis which is described in the Point Beach analysis demonstrates that additional modifications necessary to achieve compliance with Section III.G.2.b of Appendix R would not enhance fire protection safety in Fire Zone 7.

The defense-in-depth protection summarized in the Point Beach analysis combined with the additional passive protection provided by the proposed modifications provides a level of fire protection safety which is at least equivalent to that which would be provided by Section III.G.2.b of Appendix R.

2.7.5.2 Analysis Summary

The Point Beach analysis for Fire Zone 7 was performed to demonstrate that fire protection features within this zone are equivalent to the Section III.G.2.b alternative. Fire protection features of Fire Zone 7 were analyzed to determine relative fire resistivity. The analysis and the draft SE are in agreement that exposure fires or stratified hot gas layers are generally the two mechanisms for causing fire damage.

Exposure fires can be postulated to occur in various room locations and the potential for fire damage can be affected by cable separation distance. The Point Beach analysis postulated an exposure fire location which would have the most severe impact on redundant cable trays. The relative fire resistivity in terms of flammable liquid quantity was determined to be greater than 20 gallons for an exposure fire and 14.5 gallons due to combustion gas stratification effects. Therefore, the effects of a stratified layer of hot gases pose the greatest potential for redundant cable degradation. The stratification effects are independent of horizontal separation distance and the actual room configuration is equivalent to the separation criterion of Section III.G.2.b.

The feasibility for automatic fire suppression was also evaluated. Total area water suppression coverage was considered to be detrimental to facility safety because safeguards motor control centers IB42 and 2B42 are located in the zone and could be adversely affected by direct water impingement. Partial area suppression or local spray capability was not proposed on the basis that such applications probably could not satisfy NFPA or NRC requirements in all respects. The effectiveness of an automatic suppression system is also significantly reduced in areas where a large quantity of barriers are installed. The suppression system could adversely affect radioactive waste disposal system capability. The relative fire resistance of Fire Zone 7 is more than two times that of the technical basis for the of Section III.G.2.b alternative (i.e., 2-5 gallons of flammable liquid) and that required to accommodate the total possible introduction of acetone into the zone (approximately six gallons), For the above reasons, automatic water suppression would not enhance fire protection safety in Fire Zone 7 and could be detrimental to overall facility safety.

2.7.5.3 Draft SE Discussion

SE Comment

2.7.5.3.1 "By letter dated October 21, 1980, we informed the licensee that to meet the intent of Section III.G of Appendix R, the licensee should provide alternate shutdown capability for this area." (SE, p. 10)

RESPONSE

We believe that this statement should be deleted from the SE. See Section 1.8 above.

2.7.5.3.2 SE Comment

"The licensee states that the shields will assure that at least one train of safe shutdown cables for each unit will not fail due to the radiation effects from an exposure fire. The licensee has not provided the information necessary to substantiate such a claim. The licensee has not discussed the effects of convection from exposure fire on the vertical cable trays enclosed with radiant energy shields." (SE, p. 11)

RESPONSE

The shields provide sufficient protection from an exposure fire such that the stratification effects are limiting in Fire Zone 7. The licensee has considered the effects of convection in specifying protection for these cable trays. Because these trays are protected by the existent 6" and 42" wide high concrete curbing, it is not necessary to provide a barrier whose construction must withstand the intense convective heat transfer which exists in the exposure fire plume. We acknowledge that at higher elevations the inevitable diffusion of the fire plume will result in some convective heat transfer to the protected tray. However, for failure of both trains to occur, this exposure fire must also damage redundant circuits which are horizontally separated by a minimum distance of 3'-8". Clearly an exposure fire located so as to maximize energy transfer to the protected cable tray would be expected to have minimal effect on the unprotected redundant tray.

2.7.6 <u>Auxiliary Building Evaluation</u>

The draft SE contains a single evaluation section for all auxiliary building fire zones.

2.7.6.1 <u>SE Comment</u>

> "In the case of a fire which produces a stratified layer of hot gases at the ceiling level, the most severe damage will occur to cables and equipment located within several feet of the ceiling. The redundant cables in each fire zone are installed within three feet of the ceiling. This configuration does not provide reasonable protection from a descending hot gas layer." (SE, p. 11)

<u>RESPONSE</u>

This statement is equally applicable to configurations which meet the specified separation criterion in III.G.2.b for which an exemption request would not be necessary. Section III.G does not specify any vertical configuration requirements and the location three feet from the ceiling is not precluded. For these reasons, we do not believe that the vertical separation of cable trays from the ceiling presents a justifiable basis for the denial of exemption requests.

2.7.6.2 SE Comment

> "A local exposure or electrically initiated fire could cause damage to the redundant cables if they are exposed to a heat flux of sufficient intensity." (SE, p. 11)

RESPONSE

We do not consider electrically initiated fires to be a credible occurrence. See Section 1.12.

The Point Beach analysis shows that, with the proposed modifications in place, the size of the exposure fire required to generate the heat flux necessary for cable failure exceeds the size of fire required to cause cable failure by stratified hot gases and further modifications will not enhance fire protection safety. Thus, equivalence to III.G.2.b has been demonstrated.

2.7.6.3 SE Comment

> "These (radiant energy shields) cannot be considered equivalent to a one-hour rated barrier as they may only inhibit fire damage for several minutes." (SE, p. 12)

RESPONSE

The draft SE does not reference data which supports the contention that such barriers would "only inhibit fire damage for several minutes". In a January 1981 EPRI study (NP-1675), a single cable tray with a barrier similar in function to that proposed by WE (but with a fire rating of less than one hour) was placed six feet above a 17-gallon, four-foot diameter lube oil fire. The flames of this fire were twelve feet high and the fire burned at steady state for at least fifteen minutes. The temperature below the tray baffle was in excess of 1290°F for greater than twelve minutes, while above the tray the temperature was 210°F. After the test was completed, the cables in the tray showed no signs of distress. The cable trays in the Point Beach auxiliary building fire zones are at least twice as high above the floor as the EPRI test configuration. Thus, the radiant energy shields proposed by WE are expected to provide even greater protection. We believe that these barriers provide adequate protection to electrical cables from exposure fires.

2.7.6.4 SE Comment

"The existing protection does not provide reasonable assurance that the redundant cables of both trains will not be damaged in this time interval (fire brigade response). Cable trays which the licensee proposes to install radiant energy shields on will provide some resistance to exposure fires; however, an incident heat flux of sufficient magnitude will cause the thermal degradation and ultimate failure of the cable in the trays." (SE, p. 12)

RESPONSE

The Point Beach analysis has demonstrated that, with the proposed modifications, the fire protection features for the areas of interest are equivalent to Section III.G.2.b. The analytical methods take no credit for detector actuation time or fire brigade response. See Section 1.7 above. In demonstrating equivalence, the Point Beach analysis also demonstrates reasonable assurance that adequate protection against fires likely to occur is provided. See Section 1.6 above.

2.7.7 Conclusions

The Point Beach analysis has demonstrated that the fire resistivity of Fire Zones 1, 2, 3, 4, and 7 is at least equivalent to the requirements of the Section III.G.2.b alternative and also that adequate protection against fires likely to occur is provided. We have complied with the directives of Generic Letter 81-12 and demonstrated equivalence to one of the alternatives of Section III.G.2. Therefore, the exemptions should be granted.

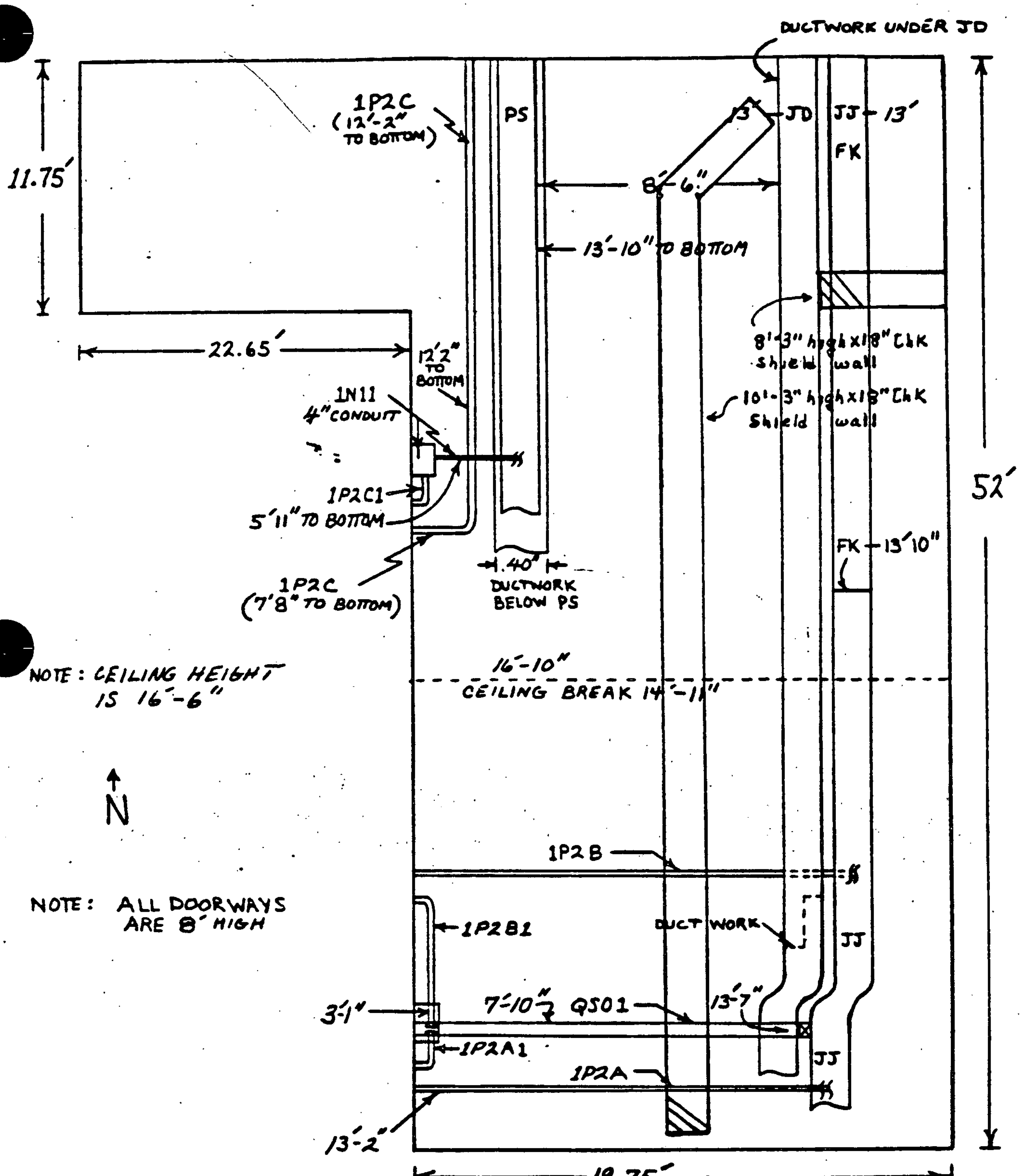

Figure 5.2-1. Fire Area 1 - Unit 1

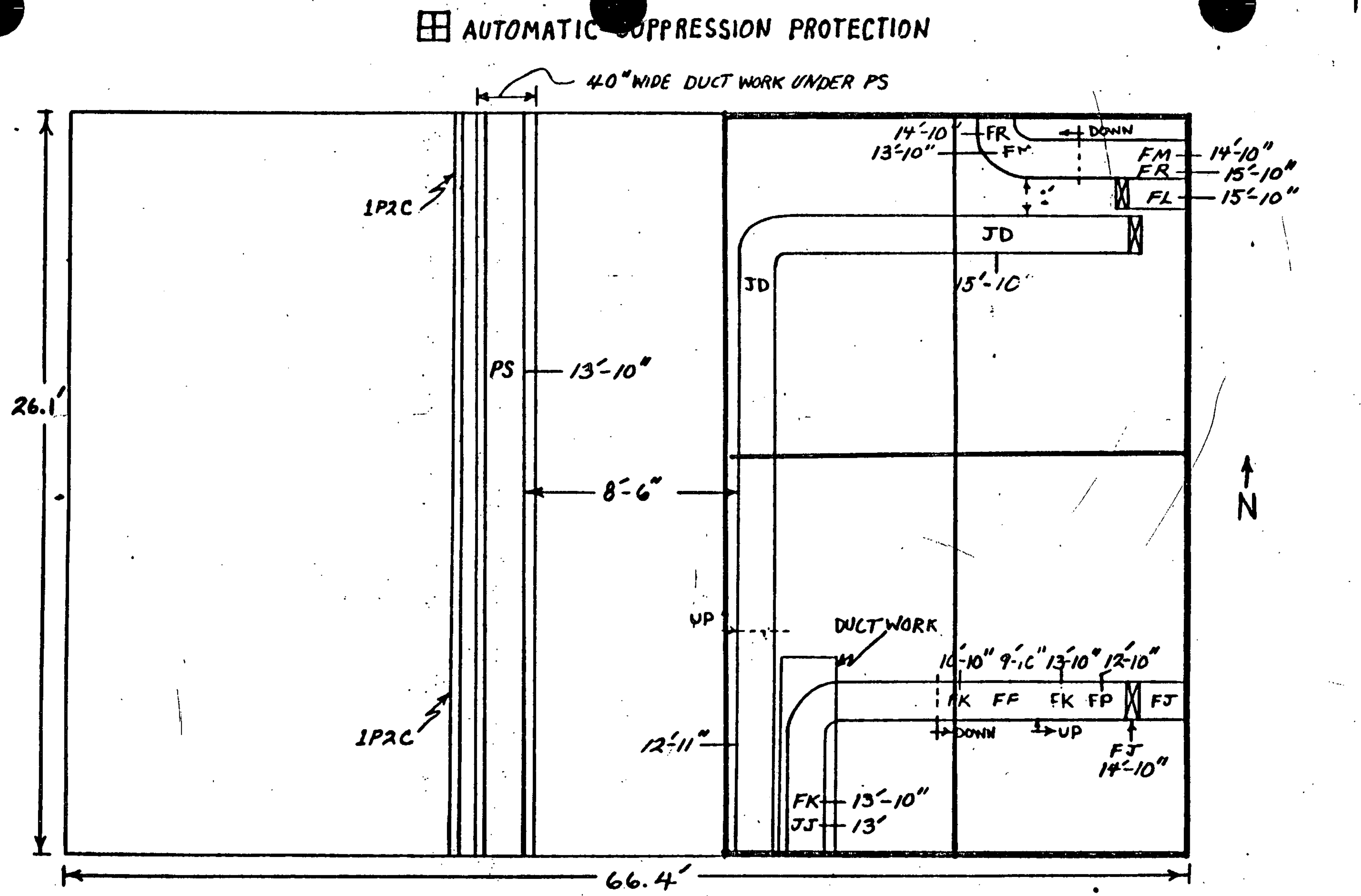

Figure 5.3-1. Fire Area 2 - Unit 1

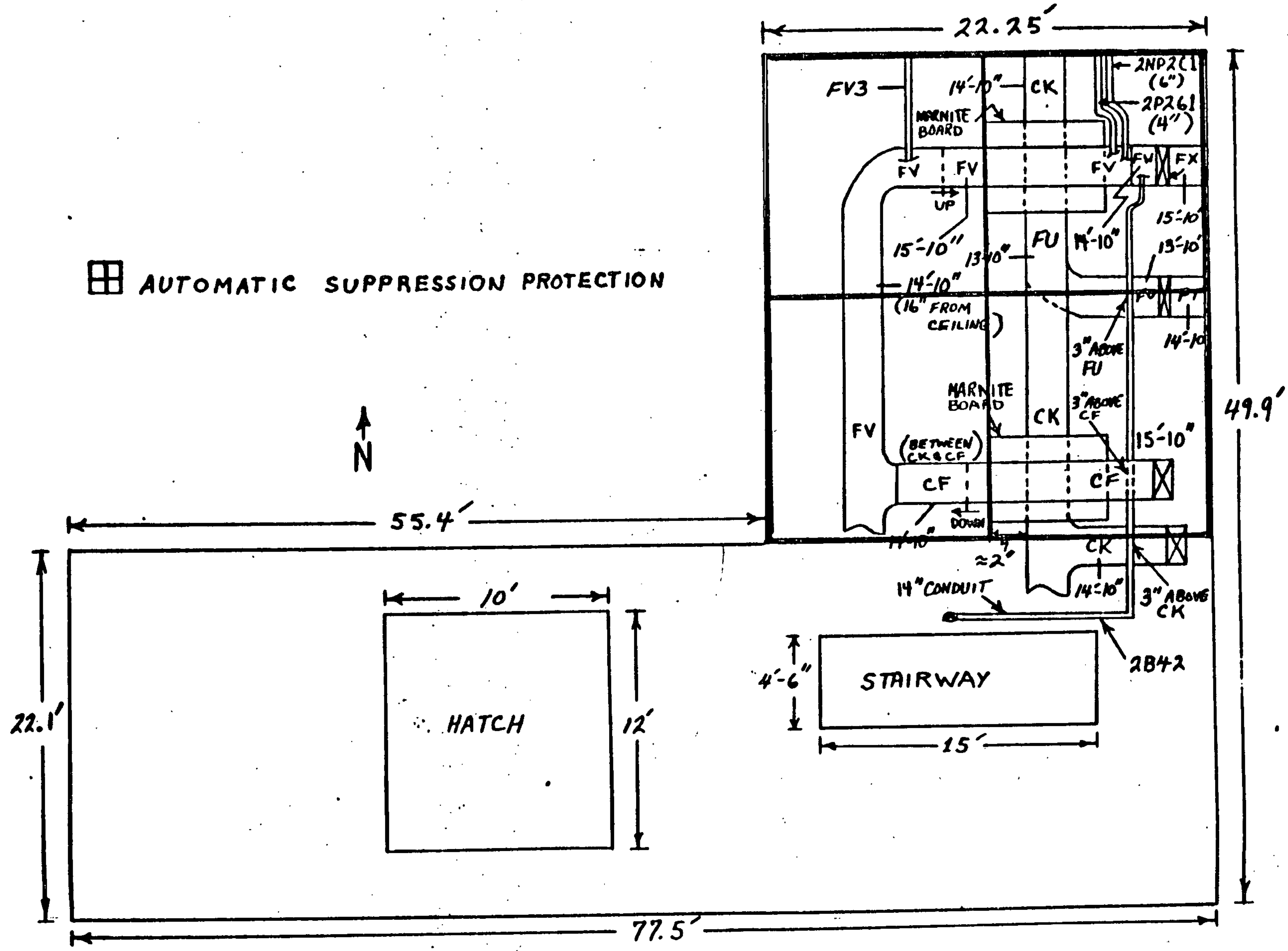

Figure 5.4-2. Fire Area 3 - Unit 2

ENCLOSURE 2

DOCKET NOS. 50-266 AND 50-301

APPENDIX R EXEMPTION REQUESTS

POINT BEACH NUCLEAR PLANT, UNITS 1 AND 2

TECHNICAL EVALUATION

OF

BNL EVALUATION

SUMMARY RESPONSE TO BNL REVIEW

In their evaluation of the Point Beach analysis, BNL outlined the features of a "state-of-the-art" approach to fire modeling as embodying a unit-problem concept addressing seven basic features:

(1) burning object,
(2) combusting plume,
(3) hot layer,
(4) cold layer,
(5) targets,
(6) enclosure geometry, and
(7) ventilation.

BNL then assessed the features of the Point Beach analysis in the context of these seven elements to determine the overall validity of the modeling approach and its implementation. In this summary, BNL concluded:

> "The unit-problem approach employed [by WEPCo], together with the correlations and electrical cable damage criterion, can be classified as most current and methodologically consistent with what is being suggested in the open literature as a viable approach for assessing the fire hazard potential associated with cable tray fires."

BNL continues:

> "Thus, in most respects, we find the method employed to be technically sound and the overall approach, if applied properly (as described subsequently) could yield realistic and conservative results for assessing the thermal environment in the fire area."

BNL concludes:

> "However, we do give credit to WEP for utilizing current modeling techniques (as we have defined); we give credit for their use of reasonable physical data, and, in some respects, the degree of conservatism employed. To editorialize for the moment, we feel hard-pressed to judge the overall conservatism. In some fire phenomena factors, the models and assumptions lead to over-conservatism; in others, non-conservatism prevails."

BNL's review also identified a number of issues related to the application of the model to particular circumstances. These issues are essentially concerned with "overall traceability" and related difficulties in quickly reproducing all of the results. No judgment is made by BNL as to the accuracy of the analysis as a result of these traceability issues. In fairness to BNL, these difficulties ought not to be either surprising or unsettling since the Point Beach models required approximately one year to develop. That BNL could accomplish as much in their review in the few weeks available to them is itself an achievement.

The comments presented by BNL in their review may be addressed without a great deal of difficulty. It should be emphasized that, as comments, they represent valid questions raised on the particular application and are indicative of uncertainties which may have been developed in the review process. The responses presented below are directed at the detailed evaluation portion of the BNL letter.

1.0 General Observations

BNL makes several observations in its introductions. Each of these is answered below.

BNL Comment

> "Accordingly, the model/damage criterion is not uniformly valid when cables, either in the fire plume or in the stratified layer, are in the process of burning, thereby adding thermal energy to the enclosure."

RESPONSE

As noted in Enclosure 1, no experimental evidence has been cited in support of this contention. The recent Sandia tests have shown that cables are not ignited by stratification layer heating even for heat fluxes of 30 to 35 kW/m^2. The motion of gas past the cable surface appears to be sufficient to prevent the accumulation of a localized combustible mixture.

BNL Comment

> "An intrinsic limitation of the stratification model in attempting to show equivalency in protection provided is the independency of the correlation to lateral separation distance."

RESPONSE

The assumption of a uniform stratification layer is not a limitation of the analytical techniques. It assures that conservative results are consistently obtained when assessing the fire safety of a particular cable and room geometry. In contrast, the 20 feet separation option of Section III.G.2 does not account for cable location relative to the ceiling, a variable which all experimental studies agree is of great importance in assessing the hazard posed by an enclosure fire.

BNL Comment

> "Neither the models employed, nor the methodology used, consider the increased heat flux that exposure fires can generate when located near walls and corners."

RESPONSE

As discussed in Enclosure 1, this issue arises from a misreading of Alpert's paper9/ and is not supported by the results of the recent Sandia test.

BNL Comment

> "The possibility of excess pyrolyzate resulting from insulation degradation or from initiating fires resulting from the burning of solid combustibles, which could enter into and subsequently burn within the stratified layer, has not been investigated."

RESPONSE

As discussed in Enclosure 1, the combustion of excess pyrolyzate vapors has not been observed in either the EPRI/FMRC or Sandia tests.

BNL Comment

> "Errors in the data listed, needed in establishing the hazards associated with high fire-point liquid hydrocarbons, provides significant doubts when used with the

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9/ Alpert, op. cit.

analyses described, as to conclusions drawn that such liquid spills do not present a significant fire hazard when spilled on concrete."

RESPONSE

Errors were made in the original submittal. However, we point out that the corrected heat fluxes for ignition of a thin spill of lubricating oil (24.62 kW/m^2), calculated in Section 10.0 below, could only be obtained from a very substantial, pre-existing fire or from a piece of equipment at a 1000°F temperature located very close to the spill. Moreover, experimental results submitted to the NRC on another docket demonstrated that a lube oil spill could not be ignited even when acetone was poured on top of the oil.10/ Consequently, thin spills of high-fire-point fluids do not present a significant fire hazard when spilled on concrete.

BNL Comment

"Fires initiated at locations other than on the floor have not been addressed".

RESPONSE

Fires other than on the floor could only occur as follows:

(1) Electrical failure in trays. Sandia was unable to achieve sustained and propagating fires by this method and was forced to use a flammable liquid exposure fire.

10/ Florida Power and Light Company, "Turkey Point Units 3 and 4 10 CFR 50 Appendix R Fire Protection Review", Appendix F, 1982.

(2) Spills of small quantities of fluids (perhaps cleaner or paint) by workers using ladders to reach the elevated locations. These were not considered because:

(a) The quantities of liquids would be small and not constitute the degree of fire threat as the floor-based spills used in the analyses;

(b) This type of work would usually be performed during unit outages.

BNL Comment

"The non-linear optimization methodology used to determine the minimum amount of liquid fuel required to cause electrical damage to both redundant and safe-shutdown systems is not presented in sufficient detail to allow for audit calculations or appraisal."

RESPONSE

Discussions with BNL on other dockets indicate that they now understand the mathematical techniques utilized.

BNL Comment

"The Rayleigh numbers of the postulated fires are far beyond the range for which the plume impingement model is valid."

RESPONSE

The Rayleigh number extension refers to the You and Faeth correlation11/ which was not used directly for any detailed fire

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11/ H.Z. You and G.M. Faeth, "Ceiling Heat Transfer During Fire Plume and Fire Impingement", Fire and Materials, Vol. 3, No. 3, 1979, pp. 140-147.

hazards analysis. This correlation was only used to demonstrate that the results of the stratification model are conservatively based.

BNL Comment

> "An error has been found on the thermal shield analysis, which, if corrected, would alter the limits placed on the wake velocity and temperature defects incorporated in establishing the size of shield required for protecting cables immersed within the fire plume."

RESPONSE

BNL's assertion of square root scaling of heat transfer in the wake of a thermal shield is not supported by a more detailed analysis or experimental results (see Section 6.0 below).

BNL Comment

> "It is not clear which radiation heat transfer model is used in the analysis or from where the configuration factor is obtained."

RESPONSE

The fire was modeled as a right circular cylinder with a uniform flame temperature of 1800°F. The configuration factor is based on Appendix C-17, C-18, and C-24 of Siegel and Howell.12/ In their more general remarks, it is clear that BNL does not take issue with the overall approach used in the radiation model.

12/ R. Siegel and J. R. Howell, Thermal Radiation Heat Transfer. 2nd Edition. McGraw-Hill, New York, 1981.

2.0 Appendix A.1 - Heat Release Rate

BNL notes that conservative limits are used to define the physics of the combustion process and ventilation effects. No questions or issues appear to be taken by BNL with the propriety of these assumptions.

RESPONSE

None deemed necessary.

3.0 Appendix A.2 - Stratification

BNL's review of the stratification model identifies conservatism in not taking credit for the variation of heat flux relative to horizontal separation:

> "...the neglect of the decrease in heat flux with radial distance by Newman and Hill should yield a conservative result."

The Point Beach analysis takes the Newman-Hill correlation and modifies it to treat the sensitivity to ventilation more consistently. The conservative nature of this modified correlation is acknowledged by BNL:

> "The modified correlation is more conservative than the original."

However, BNL does comment on the effect of walls and corners on the behavior of fire:

> "On the other hand, References 3 and 5 show that if the exposure fire is near a wall or in a corner, the ceiling temperatures increase as if the fire heat release rate is increased by a factor of 2 and 4 respectively. Therefore, care must be taken in

> applying the Newman and Hill correlation for exposure fires in the vicinity of walls or corners so that non-conservative results are not obtained."

RESPONSE

BNL's comments concerning the conservatisms in the stratification model are noted and no response is deemed necessary. Regarding the so-called "corner and wall" effect, BNL is misinterpreting the results of Alpert.13/ As described in Enclosure 1, Alpert is only seeking to explain the effect of flame stretch on fire height, NOT the effect on the heat release rate.

Since the Newman and Hill correlation which forms the basis for the stratification model is a function of the fuel's heat release rate and is independent of the coherency of the plume geometry, the presence of walls or corners is not considered to be a concern in the behavior of a stratified ceiling layer. BNL's comment is, therefore, not applicable to the stratification model.

4.0 Appendix A.3 - Diffusion Plumes

BNL notes the following comment concerning the Point Beach diffusion model:

> "These models represent the more recent correlations for hydrocarbon pool-fire plumes. However, there are several errors, most likely typographical, which should be corrected."

13/ Alpert, op. cit.

BNL then presents several examples and presumed corrections based, apparently, on a review of the original papers in the literature.

With regard to heat flux correlations derived from the literature for the stagnation point, BNL comments:

> "The heat flux correlations of You and Faeth for the stagnation region (r/H <0.2) and the ceiling jet are also presented. The correlations are for Rayleigh numbers of 10^9 to 10^{14}, whereas the fires discussed in Section 6 of the submittal have Rayleigh numbers of about 10^{18}. There should be some defense of this extension."

RESPONSE

BNL's comments concerning the typographical errors and recommended corrections are appropriate. Regarding the question concerning the You and Faeth correlation14/, the question is moot in this instance since the stagnation heat fluxes were not used in the Point Beach analysis. The purpose of providing this information in the exemption submittal was merely to demonstrate that the stratification model is conservative in discounting the effect of horizontal separation for cables at that elevation.

From a phenomenological perspective, it is noted that the perceived limitations in the Rayleigh number are applicable only to the stagnation region at the ceiling. They are not valid where cylindrical cross-flow heat transfer is used, as was actually employed in the exemption analysis. In response to the BNL comment, no defense of the inferred extension is deemed necessary.

14/ You and Faeth, op. cit.

5.0 Appendix A.4 - Radiation

In this section BNL summarizes the radiation model and concludes:

> "These classical expressions and assumptions are acceptable as present state of knowledge in radiant heat transfer."

BNL then notes a minor documentation error and recommends a correction based on their review of the literature.

RESPONSE

BNL's comments are noted and no response is deemed necessary. Their identification of the minor typographical error and its correction are appropriate.

6.0 Appendix A.5 - Thermal Shields

> "In Appendix A.5 of the submittal, an analysis is presented which is used to provide a basis for determining the required size of baffles used to protect a vertical stack of trays from convective heating due to direct impingement of an exposure fire plume. A data correlation[10] based on the turbulent wake behind a blunt body is used to obtain an expression for the required baffle width in terms of the downstream extent of the zone to be protected. The condition that the velocity be reduced to 20 percent of the free stream value was used as a protected zone boundary definition. However, it is then implied that the temperature reduction (defect) in the wake is linearly proportional to the velocity defect. A closer review of reference 10 indicates that experimental data and theoretical results based on Taylor's assumption of turbulence, rather than Prandtl's theory of free turbulence, results in the wake temperature defect being equal to the square root of the velocity defect. Therefore, a shield which limits the velocity

to 20% of the free stream velocity, will only reduce the temperature to 45% of its free stream value. This is less conservative than implied in Appendix A.5."

RESPONSE

BNL is correct in noting that the effects of turbulence on gas temperature are non-linear. However, their conclusion suggesting the potential for non-conservatism in the Point Beach analysis is not supported either by analysis or full-scale tests.

Two calculations are presented herein for the effects of baffles in disrupting an 1800°F (1255°K) gas flowing at the rate of 31.2 ft/sec (9.1 m/sec) characteristic of immersion in a fire. The first case is for a bare cable in space while the second assumes the presence of a baffle. BNL's assumption of 20% free stream gas velocity and 45% free stream excess gas temperature is used to represent the baffled conditions. The calculations and all intermediate steps are presented below:

UNBAFFLED	BAFFLED
$T = 1255.6^{o}K$	$T = 0.45\ (1255.6 - 294.4) + 294.4 = 726.9^{o}K$
$V = 9.5$ m/sec	$V = (0.2)(9.5$ m/sec$) = 1.9$m/sec
$T_{amb} = 294.4^{o}K$	$T_{amb} = 294.4^{o}K$
$nu = 1.7 \times 10^{-4}\ m^2/sec$	$nu = 7.0 \times 10^{-5}\ m^2/sec$
$Re = 848$	$Re = 416$
$h = 6.06 \times 10^{-2}\ kW/m^2K$	$h = 2.82 \times 10^{-2}\ kW/m^2K$
$q_c = h(T-294.4)$	$q_c = h(T-294.4)$
$= \underline{58.3}\ kW/m^2$	$= \underline{12.2}\ kW/m^2$

As may be evident, under the most severe fire conditions within the flames, a baffle which reduces the gas temperatures and velocities as defined by BNL does indeed lead to an 80% reduction in incident heat flux to an exposed electrical cable as suggested in the Point Beach analysis.

These results are further supported by tests performed at Factory Mutual Research Corporation under EPRI sponsorship.15/ In two tests where cable tray impingement baffles were employed, electrical cables were shown to be completely protected and unaffected following immersion in the flames of a fire involving 17 gallons of #2 fuel oil contained in a 3.9 feet (1.2 m) diameter pan located 5.9 ft (1.8 m) below the trays. When the same configuration of electrical cables was exposed to the same

15/ J.S. Newman and J.P. Hill, "Assessment of Exposure Fire Hazards to Cable Trays", NP-1675, Electric Power Research Institute, Palo Alto, CA., January 1981.

fire conditions without the benefit of the impingement baffle, severe cable damage was rapidly incurred.

On the basis of the EPRI tests and the analysis presented herein, the efficacy of baffles in protecting against impinging fires is conclusively demonstrated.

7.0 Appendix A.6 - Internal Component Model

BNL's comments on this model are directed at their difficulty in understanding how the modeling process was structured and its boundary conditions.

As BNL notes:

> "However, the issue is not how to solve the equation, but rather, how WEP should demonstrate that the complex heat conduction processes taking place during a fire can be adequately modeled by the equation."

RESPONSE

BNL's difficulty in tracing the finite-element analysis deserves a more detailed explanation. This discussion intends to respond to that issue.

The MERLIN code was used in the Point Beach analysis to obtain a numerical solution to a series of partial differential equations. Its accuracy was validated prior to its use by comparison with a series of problems for which analytical solutions can be obtained. These test problems were chosen to investigate all combinations of boundary conditions and geometry which can be handled by MERLIN's heat conduction elements. These test problems were also used to study the effects of time step choice and element aspect ratio on accuracy. It was found that the maximum error is in the order of 2 percent or less.

In response to the Staff's concern that a postulated 30-second unconfined acetone fire is not a sufficiently severe postulated fire, the MERLIN applications have been recalculated using a longer fire duration. A detailed description of the boundary conditions applied is contained in the following sections for the fire zones where MERLIN is used.

Five generic types of boundary conditions are available for use by the analyst. An adiabatic boundary condition is the default if no boundary condition is specified. A constant fixed temperature boundary condition may be assigned to any boundary. A constant heat flux may be imposed on a boundary. A linear convection boundary condition may be imposed with heat transfer coefficient and source or sink temperature defined by the analyst. The last type of boundary condition defined is for radiation. For the radiation boundary condition the analyst specifies the magnitude of the impinging radiation and the surface emissivity. The non-linear Stefan-Boltzmann radiation law is used. These boundary condition types may be applied to steady state and transient models made up of both triangular and quadrilateral elements. Complex boundary conditions can also be created using additive sums of the five basic types.

A three-dimensional model was not developed since the two-dimensional model indicated that the significant features of the switch response to a short-lived intense fire are one-dimensional in nature. The model indicated that the only portions of the switch potentially at risk due to exposure to such a fire are the switch knob and mounting plate. These components are made of a heat-resistant phenol plastic which has a low thermal diffusivity. Because of this low diffusivity, the component's outer surface heats up rapidly while the inside of the component remains cool. Since the penetration depth of this effect is so thin, it could be modeled using a simple one-dimensional model.

The question of applicability of finite element modeling to study the effects of a fire on panel components is not nearly so complex as implied by the reviewer. The use of Laplace's equation to model heat conduction has been well established for over two centuries. The use of this equation in determining the internal response of the switch due to the imposed boundary conditions can be accepted with confidence. The applicability question should focus on the choice of boundary conditions. For the purposes of the present application, it is sufficient that the boundary conditions be chosen conservatively.

To meet this goal, no credit is taken for convective heat loss from the rear surfaces of the component into the interior of the cabinet. This tends to maximize the component temperatures resulting from the MERLIN models.

In summary, a proven modeling technique was used with a conservative choice of boundary conditions to show that only the outermost surface of the panel components would be damaged by an unlikely large fire. Moreover, it is shown that this damage is confined to the outer surface and would not impede the component's proper function after the end of the fire, thereby demonstrating that it be free of fire damage as required by Appendix R.

8.0 Appendix A.7 - Macroscopic Equipment Analysis

BNL's only comments are for a more involved discussion of the model's limitations and a notation of some typographical errors.

RESPONSE

BNL's corrections of the typographical errors are noted without comment. With regard to possible model limitations, the simplicity and conservatism of the one-dimensional approach leads to a bounding analysis consistent with the conservatisms presented elsewhere in the models.

9.0 Appendix A.8 - Console Analysis

The Console model was not used in the Point Beach fire hazards analysis. No response is deemed necessary.

10.0 Chapter 4 - Analytical Methods

BNL's comments in this area are along three dimensions:

(1) ventilation,
(2) excess pyrolyzate, and
(3) liquid spill ignitibility.

BNL notes the following concerning the ventilation assumptions:

> "The assumption is made that there is always sufficient ventilation to support an optimum

> stoichiometric fuel/air ratio and to maintain the compartment desmoked. This results in conservative estimates of the heat release rates. Also conservatism is imparted in the analysis as a result of the neglect of attenuation of radiant energy due to smoke."

BNL also comments on the potential for excess pyrolyzate igniting in an enclosure. Finally, BNL identifies errors in the spill ignitibility analysis.

RESPONSE

BNL's comments regarding the ventilation assumptions in the Point Beach analysis are noted and no response is deemed necessary. The concept of excess pyrolyzate is addressed in Enclosure 1 and Section 1.0 to Enclosure 2 of this letter.

Concerning the spill ignitibility analysis, BNL identification of this error in the hand calculation is correct. A recalculation of the heat flux necessary to achieve ignition for substrate at 70^{o}F has been re-performed and results are presented below.

MAGNITUDE OF EXTERNAL HEAT FLUX NECESSARY TO ACHIEVE DESIRED TEMPERATURE FOR SPILL ON CONCRETE

	Thin Spill	Thick Spill (>20mm)
Lubricating Oil - Flash Point (489°K)	13.29 kW/m^2	3.33 kW/m^2
-Ignition (650°K)	24.62 kW/m^2	6.17 kW/m^2

These results indicate that a thin spill of lubricating oil would have to receive radiant heat from a source having a steady state surface temperature of at least 836°K (1045°F) for a period of at least ten minutes for ignition to occur. It is unlikely that any piece of equipment in the affected areas at Point Beach Nuclear Station would have a surface temperature of this magnitude. Any other heat source capable of achieving this temperature for this duration would have to be a pre-existing, substantial fire. A thick spill would require a heat source with a steady state surface temperature of 591°K (604°F) to be located directly above the surface of the spill for a minimum of ten minutes to result in ignition of the spill. It must be remembered that radiation is diffuse and non-directional and that the amount of heat transferred to a nearby object is dependent upon the configuration factor, which is a geometric function of the spatial relationship between the heat source and the receiving element. Displacing the heat source horizontally or vertically from direct thermal contact with a spill increases the energy requirements for the potential ignition source dramatically.

These fire tests and analyses support the Staff's own conclusion that high fire point liquid hydrocarbons are not significant fire hazards when spilled on concrete that is not near hot surfaces.

11.0 Chapter 5 - Analysis and Exemption Requests

BNL provides a series of general comments regarding the detailed fire zone analysis. A response to each significant comment which has not been dealt with above follows.

BNL Comment

> "... it would be more conservative to use the insulation/jacket degradation mode as a cable damageability criterion."

RESPONSE

Jacket degradation is not a well-defined failure mode. EPRI research on this subject16/ describes the critical heat flux obtained by linear extrapolation of data on the inverse time to failure-exposed heat flux diagram. According to this data, the initiation of jacket degradation occurs at any imposed heat flux value including those well below the critical heat flux values for insulation degradation. In fact, for such reasons, Sandia rejects insulation degradation as a failure criteria on the basis of extensive testing and notably urges the NRC to base cable damage on functionability.17/ Accordingly, the concept of insulation degradation as a failure threshold is inappropriate in an

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16/ Lee, op. cit.
17/ L.L. Lukens, "Nuclear Power Plant Electrical Cable Damageability Experiments", NUREG/CR-2927, US Nuclear Regulatory Commission, Washington, DC, October 1982.

intense fire environment of relatively short duration. The choice of piloted ignition is also not realistic .

BNL Comment

> "However, referring to Fig. 3-15 of Reference 13, (Lee op. cit.), it should be noted that for external heat fluxes of 70 kW/m^2 or less, the trend of the data indicates that Sample 5 exhibits earlier electrical failure that that shown for Sample 6 for the same incident heat flux. Accordingly, the use of Sample 6 as the referenced cable would yield non-conservative estimates within the aforenoted heat flux range."

RESPONSE

A sensitivity analysis was performed to investigate this issue using the analysis performed for Fire Zone 1 as an example problem. Since the curve for Sample 5 does not intercept the positive abscissa, a small critical heat flux of 1 kW/m^2 was assigned to this sample. A non-zero critical heat flux is required for compatibility with the optimization algorithm used in the analysis. The absorbed energy required for failure was calculated for each of the test points using the formula:

$$E = (Q-1)\ t$$

where E = absorbed critical energy (kJ/m^2)

Q = imposed heat flux (kW/m^2)

t = time to electrical failure (sec)

The assumed critical heat flux is subtracted from the imposed heat flux Q so that E corresponds to the usual definition of critical absorbed energy. The usual method of calculating E from the slope of the curve does not apply in this case because a proper abscissa intercept does not exist. The two methods are equivalent.

Fire Zone 1 was re-analyzed using the latest revision of the computer code which implements the standard fire hazards analysis. For the stratification analysis, the minimum volume of acetone required for failure goes from 13.96 gallons for Sample 6 to 14.60 gallons for Sample 5. This is an increase of 4.6 percent. For the radiation analysis, assuming the installation of radiation shields, the minimum acetone volume goes from 17.39 gallons for Sample 6 to 23.13 gallons for Sample 5. This is an increase of 33 percent. Clearly, the use of Sample 6 failure criterion, which is the criterion used in the Point Beach analysis, is the conservative choice.

The above results show that the vital failure parameter is the absorbed critical energy. The critical heat flux criterion can be met by simply altering the postulated fire diameter. As a result the calculated minimum fuel volume is principally a function of the critical energy. Therefore, choice of the sample whose failure curve has the largest slope is conservative when determining minimum fuel volumes required for failure, because the curve slope is inversely related to the critical energy.

Another conservatism is added in the manner in which the critical energy is calculated using the fire models. The standard method of defining critical energy involves subtracting the critical heat flux from the applied heat flux when computing the integrated critical energy. When the applied heat flux is calculated from the fire models, the entire applied heat flux is used in calculating the integrated critical energy. The integration starts when the applied heat flux exceeds the critical heat flux. Therefore, this change in the method of calculating critical energy means that a very conservative estimate of critical energy is used in a failure determination.

BNL Comment

> "The submittal states that a "back calculation" approach is used which calculates the smallest quantity of fuel to cause both redundant divisions to just exceed the damage criteria. It is stated that "classical optimization techniques for non-linear functions" are used. However, this methodology is not explained sufficiently to be reproducible. The methodology description does not state which equations and minimization techniques are used."

RESPONSE

The optimization technique is focused on the determination of the minimum quantity and associated geometry. The incident heat flux on a cable depends on the size of the fire while the damage energy is a function of both the exposure heat flux and the burn time. The optimization takes advantage of a simple iteration process. The process begins with consideration of a very small size fire and calculates the exposure heat flux. If the incident heat flux is greater than the critical heat flux of the cable, the exposure time to deposit the required damage energy on the cable is then calculated. The exposure time or the burn time is converted to the depth of the spill through the burn rate of the selected hydrocarbon. Assuming the spill to be in the form of a right cylinder, the corresponding combustible quantity may be obtained. Repeating the same process for a fire size slightly larger than the previous one and comparison of end results determines the optimum quantity and geometry of the combustible to cause failure.

This process of determining the minimum quantity of a liquid combustible to just achieve the selected failure criterion for a cable of interest is called the "back calculation" method.

BNL Comment

> BNL points out that radiation from the fire plume and the stratification layer is not included in the model.

RESPONSE

BNL is correct in noting that only radiation from the combustion zone of the postulated fire is included in the model. It should be pointed out that the use of a right circular cylinder as a model for the combustion zone geometry grossly over-estimates the fire radiation as compared with the actual conical shape of the fire. Radiation from this flame zone is included when analyzing trays with baffles. It should be further noted that gas temperatures in the plume and stratification layer are much cooler than those of the fire itself. Newman and Hill report that, for their largest enclosure fire, the radiation from the stratification layer to calorimeters directly under the ceiling was a maximum of 2.34 kW/m^2.18/ The radiation heat flux

18/ Newman and Hill, op. cit., Table 3-4.

delivered to a cable below the stratification layer will be much less than this and therefore can reasonably be neglected as compared to the flame zone radiation. This radiation effect is included in the stratification model for target cables within the stratification layer.

BNL Comment

> BNL summarizes the individual fire area analyses and presents a number of issues concerning the methodology used in the analysis of Fire Zone 8.

RESPONSE

The analysis of Fire Zone 8, as identified by BNL, takes advantage of a simple one-dimensional heat transfer model using the HOTBOX computer code. The analysis first determines that the optimum quantity of acetone necessary to cause failure of a single cable due to impingement of the fire plume on the cable is approximately 4.4 gallons. The imposed heat flux on the cable is 24.8 kW/m^2, while the exposure time is 260 seconds at an elevation of 12 feet. In order to ensure the safety of the cables under proposed modification conditions, the one-dimensional HOTBOX code is used. The incident heat flux is conservatively assumed to be 40 kW/m^2. The temperature of cables ignoring the presence of the insulation blanket after 260 seconds is 188^{o}F.

It should be noted that the critical heat flux and surface temperature of a cable are interchangeable through the use of the Stefan-Boltzmann Constant as suggested by Lee.

12.0 Fire Hazards Analysis

BNL has reviewed the analysis on an area by area basis. It is apparent that further description of models used in the analysis is necessary to clarify the steps taken in the course of analysis. This section describes the radiation and stratification models in detail and considers Fire Zone 1 for the purpose of demonstration of the computational process.

12.1 Descriptions of Models and Criteria Used in the Analysis

Heat Release From Fuels

References:

(1) A. Tewarson, "Heat Release Rate in Fires", Fire and Materials, v. 4, pp. 185-191, FMRC, 1980.

(2) A. Tewarson, "Psysico-Chemical and Combustion/Pyrolysis of Polymeric Materials", RC80-T-9, FMRC, 1980.

(3) A. Tewarson, "Fire Behavior of Transformer Dielectric Insulating Fluids", DOT-TSC-1703, FMRC, 1979.

Assumptions:

The fire heat transfer models require specification of fuel thermal performance. The fuel data of Tewarson was used to create a single set of bounding fuel parameter values for an unconfined turbulent combustion plume above a large pool for each fuel. The set of fuel performance parameters is used in all heat transfer computations to describe the heat release characteristics of that particular fuel.

Acetone Pool Fire Performance Parameters

fuel vaporization rate	=	40.0 $g/(m^2.s)$
actual total heat release	=	936.0 kW/m^2
convective heat release rate	=	477.0 kW/m^2

Cable Failure Criteria

Reference:

> J. L. Lee, "A Study of Damageability of Electrical Cables in Simulated Fire Environments", NP-1767, FMRC, 1981.

Assumptions:

The assessment of fire hazards requires specification of cable damage and failure criteria. — The model for cable response to imposed heat fluxes employs the test results presented by Lee. Damage energy accumulation commences when and if the imposed heat flux is greater than or equal to the specified cable critical heat flux (qcrit). The failure mode occurs when the accumulated damage energy reaches the corresponding specified cable critical energy (Ecrit). The full imposed heat flux is used for damage energy accumulation (not the difference between the imposed and critical heat fluxes as implied by Lee). The ability of armor to protect cable from degradation is ignored in the analyses. Cable armor is assumed to protect against piloted and auto-ignition of cables. Cable failure criteria are associated with cable jacket and insulation material types, such as PE/PVC cables. The electrical failure criterion for Sample 6 was used for the analyses.

PE/PVC Cable Failure Criteria

Failure Mode	Sample No.	qcrit (kW/m^2)	Ecrit (kJ/m^2)
Initiation of Insulation Degradation	5	18.0	530.0
	6	18.0	1000.0
Piloted Ignition of Cable	5	18.0	460.0
	6	23.0	690.0
Electrical Failure of Cable	5	--	9070.0
	6	24.0	6530.0
Auto-Ignition	5	5.0	6010.0
	6	15.0	9480.0

Heat Transfer from Stratification Layer

Reference:

J. S. Newman and J. P. Hill, "Assessment of Exposure Fire Hazards to Cable Trays", NP-1675, FMRC, 1981.

Assumptions:

The combined convective and radiative heat transfer to cables immersed in the stratification layer that develops in a room containing a fire is modeled by correlations of data presented by Newman and Hill. The fire enclosure is empty except for the fire and target cable. The room has dimensions of H x H x 2H, where H is the ceiling height. There is no reduction of imposed heat flux at the cable surface due to room ventilation. There is no variation of imposed heat flux with respect to radial separation within the enclosure. The stratification layer model utilizes a different correlation of data presented by Newman and Hill for the steady state heat flux because their correlation behaved poorly with ventilation rate.

Stratification Layer Heat Transfer Model

t	=	time after start of fire (s)
Z	=	elevation of target cable (m)
D	=	fire diameter (m)
H	=	ceiling height (m)
B	=	fuel transient burn parameter = 51.0 (for acetone)
t_c	=	time constant = D**(-0.5)*B seconds
Q	=	fire heat release rate (kW)
t_{ss}	=	time to steady state = B/(D**0.5*(0.52*(Z/H)**0.5)**1.111) seconds
q_{ss}	=	steady state heat flux = (Q/H**2)*(0.5585/(1.193-Z/H)**0.5)/(0.01161-0.01031/(2.13-Z/H)**0.5)**0.153 kW
q_t	=	transient heat flux (for $t<t_{ss}$) = $(0.52*q_{ss}*(Z/H)**0.5*(t/t_c)**0.9$ kW

Thermal Radiation from Flames

References:

(1) H. C. Hottel and A. F. Sarofim, Radiative Transfer, McGraw-Hill, N.Y., 1967.

(2) S. Hadvig, "Gas Emmissivity and Absorbtivity: A Thermodynamic Study", Journal of the Institute of Fuel, 1970.

(3) R. Siegel and J. R. Howell, Thermal Radiation Heat Transfer, 2nd Edition, McGraw-Hill, N.Y., 1981.

Assumptions:

Thermal radiation from the fire is modeled by the radiative flux from a steady, luminous right circular cylinder of 1800°F gases with partial pressures of both CO_2 and H_2) equal to 0.131 atm (complete combustion). The cylinder is defined by the fire diameter and the critical height of the plume, the height above which the plume flow relations apply and the plume gas temperatures are signficantly less than 1800°F (plume flow and gas temperatures are treated in the convection model). The total gas emissivity is calculated using an expression developed from results of Hadvig, whose work was based on the original gas emissivity charts of Hottel. An emissivity increment of 0.1, as recommended by Hottel for furnaces, is included to account for the presence of soot. The radiation configuration factors for exposure to disk and cylindrical surfaces are developed from the standard expressions presented in Siegel. Re-radiation from target cables was not considered since the cable failure criteria are based on imposed heat flux, not net heat flux.

Thermal Radiation Model

D	=	fire diameter (m)
T	=	gas temperature = 1800°F = 1255.6°K pCO_2 = partial pressure of CO_2 = 0.131 atm
S	=	Stefan-Boltzmann Constant = 5.67E-11 kW/(m^2.K^4)
es	=	soot emissivity increment = 0.1
CF	=	configuration factor for radiation from top disk and cylinder walls
eg	=	gas emissivity = 600.0*(0.94*pCO_2*D)**0.412/T

= 253.2*D**0.412/T

q_r = radiative heat flux = CF*(eg+*es)*s*T**4
= CF*(1.435E-08*D**0.412*T**3+5.67E-12*T**4)kW/m^2

Heat Convection from Flames and Plume

References:

(1) F. Kreith, Principles of Heat Transfer, 3rd Edition, Intext Press, N.Y., 1973.

(2) W. M. Rohsenow and H. Choi, Heat, Mass, and Momentum Transfer, Prentice-Hall, Englewood Cliffs, N.J., 1961.

(3) P. Stavrianidis, "The Behavior of Plumes above Pool Fires", Master of Science Thesis in Department of Mechanical Engineering, Northeastern University, Boston, MA, August 1980.

Assumptions:

The convective heat transfer computation uses a cylinder cross-flow model presented by Kreith to calculate an average surface heat transfer coefficient for the flow of hot air around an object, with air properties correlated with temperature. The kinematic viscosity values for air were obtained from Rohsenow and Choi and were also correlated with temperature to be used in the heat transfer calculations. The gas temperatures and velocities in a fully-developed fire plume are computed using relations developed by Stavrianidis. The cable surface temperature is maintained at 70^{o}F and the cable is completely exposed to the plume flow to maximize convective heat transfer, unless a flow baffle is placed below the cable to prevent its exposure to the plume gases.

Heat Convection Model

d	=	outer diameter of cable (m)
r	=	radial distance of target cable from fire axis (m)
z	=	elevation of target cable (m)
T_a	=	ambient temperature = 70^oF = 294.4^oK
Q_c	=	convective heat release rate of fire (kW)
ac	=	fire efficiency parameter = 0.39 (for acetone)
z_v	=	plume virtual source height = (0.11274/ac**0.6-0.15)*Qc**0.4 meters
z_c	=	plume critical height = 0.13*Qc**0.4+zv meters
T	=	plume gas temperature = Ta + Ta*(0.092*Qc** 0.667/(z-zv)**1.667)*exp(-71.0*(r/z)**2) [for plume center-line temperature, T_o (1255.6^oK)]
V	=	plume gas velocity = 1.2*Qc**0.333/ (z-zv)**0.333)*exp(-96.0*(r/z)**2) [for plume centerline velocity, V_o (2.1*Qc**0.5 m/s)]
nu	=	kinematic viscosity of air = 6.721E11*T**2 + 5.765E-08*T - 7.762E-06 m^2/s
Re	=	Reynolds number = d*V/nu
h	=	heat transfer coefficient for cylinder cross-flow = (0.4*Re**0.5 + 0.06*Re**0.67)*(3.174E-08*T)/d = 1.402E-05kW/(m^2.K)
q_c	=	convective heat flux = h*(T - 294.4^oK) kW/m^2

12.2 Sample Calculations

Stratification Analysis

This portion of the analysis examines the effects of stratification on redundant electrical cables. The fuel used in this analysis is acetone with the assumed properties:

q_f = total heat release rate per unit area = 936 kW/m^2

B = Build-up factor = 51 for acetone (Newman and Hill, 1981)

BR = pool recession rate (born rate) = 3.0 mm/min

The primary geometric dimensions are:

Z = Cable above the floor = 156 in. = 3.96 m

H = Ceiling height = 198 in. = 5.03 m

The cable is PE/PVC with

E_{crit} = critical energy = 6530 kJ/m^2

q_{crit} = critical heat flux = 24 kW/m^2

Using these assumptions, the DRAGON code predicts the optimum acetone quantity required to just fail the above cable is:

D = acetone pool diameter = 89.76 in. = 2.28 m

V = acetone quantity = 13.96 gal

These results may be duplicated by hand using the following expressions:

$$t_{ss} = \frac{B}{D^{0.5}\,[0.52\,(Z/H)^{0.5}]^{1.111}} \quad (1)$$

$$q_{ss} = (Q/H^2)[0.05585/(1.193 - Z/H)^{0.5}]/ [(0.01161 - 0.01031)/(2.13 - Z/H)^{0.5}]^{0.153} \quad (2)$$

$$q_t = 0.52\,q_{ss}\,(Z/H)^{0.5}\,(t/t_c)^{0.9} \quad (3)$$

where t_{ss} = time to reach steady state (s)

q_{ss} = steady state heat flux (kW/m^2)

q_t = start of fire transient heat flux (kW/m^2)

t_c = heat flux time constant = $B/D^{0.5}$ = 33.8 sec

Q = fire heat release rate

= $3.14\ D^2\ q_f/4$ = 3821 kW

Substituting the required data into Equations 1 and 2 yields:

t_{ss} = 78.8 sec

q_{ss} = 32.7 kW/m^2

To determine the time at which the cable fails, the integrated energy absorbed by the cable must be found. The first step in this calculation is to find the time, t_{crit}, at which q_t = $_{crit}$. It is easy to check using Equation 3 and the specified data that,

t_{crit} = 56.6 sec

The total integrated absorbed energy is the sum of two terms. The first term is the integral of that energy absorbed from the time that damage begins at t_{crit} until the steady state solution is reached at t_{ss}. Integration of Equation 3 between t_{crit} and t_{ss} gives the first energy term as:

$$E_1 = (0.52/1.90)(Z/H)^{0.5}\ [(t_{ss}/t_c)^{0.9}t_{ss} - (t_{crit}/t_c)^{0.9}t_{crit}]q_{ss} \quad (4)$$

The second energy term is the integral of that energy absorbed from time t_{ss} until failure occurs at time t_{fail}. Since q_{ss} is a constant, the second term is:

$$E_2 = q_{ss}\ (t_{fail} - t_{ss}) \quad (5)$$

The total integrated absorbed energy at failure is then by definition:

$$E_{crit} = E_1 + E_2 \qquad (6)$$

Note that the total q_t or q_{ss} is used in computing E_{crit}, not the usual definition which uses $E - E_{crit}$. This adds an extra energy term:

$$E_{conservatism} = E_{crit} (t_{fail} - t_{crit})$$

in the calculation of Equation 6. The standard definition of critical energy E'_{crit} is:

$$E'_{crit} = E_1 + E_2 - E_{conservation} \qquad (7)$$

Using the specified data:

$$E_1 = 625.6 \text{ kJ}$$

$$E_2 = E_{crit} - E_1 = 5904 \text{ kJ}$$

$$t_{fail} = t_{ss} + E_2/q_{ss} = 259 \text{ sec}$$

The volume of fuel consumed by the fire at t_{fail} is:

$$V = \frac{BR}{1000 \text{ mm/min}} \cdot \frac{3.14}{4} D^2 \frac{t_{fail}}{60 \text{ sec/min}} \qquad (8)$$

$$= 0.05285 \text{ m}^3 = 13.96 \text{ gal } (1 \text{ gal} = 0.003785 \text{ m}^3)$$

If the standard definition of E_{crit} is used, the corresponding time to failure may be computed as:

$$t'_{fail} = \frac{E_{crit} - E_1 + E_{ss} t_{ss} - E_{crit} t_{crit}}{(q_{ss} - E_{crit})} \qquad (9)$$

$$= 818 \text{ sec}$$

The corresponding fuel volume is:

$V' = 44.1$ gallons

Direct substitution in the above equations will demonstrate that a minimum fuel volume for stratification has been found. If the standard E_{crit} definition is used, it can be shown that the corresponding minimum fuel volume is 21.5 gallon in a pool 3.95 m in diameter.

Radiation

The other failure mechanisms for cable are radiation and plume impingement. Installation of impingement baffles as proposed in the Fire Zone 1 analysis will eliminate plume impingement as a failure mode and will substantially reduce the amount of fire radiation absorbed by the cable. Computer analysis of these effects indicates that a pool containing 17.39 gallons of acetone in a 2.7 m diameter fire is required to fail both redundant cables in trays PS and JD.

The optimization procedure is to search iteratively over possible pool diameters to minimize the fuel volume required to cause cable failure. The remainder of this section will demonstrate the calculation of the failure fuel volume given an assumed pool diameter. The pool diameter used will be that given above as the optimal.

The basic geometric data for this example is taken from the Fire Zone 1 analysis:

Z = cable elevation = 166 in. = 4.216 m

D = fire diameter = 2.7 m

R = target radius from fire centerline = 51 in. = 1.295m

The fuel is acetone with:

q_c = convective heat flux = 477.4 kW/m^2

alpha = ratio of convective heating value to theoretic heating value = 0.39

The first step in this calculation is to compute the fire height. The correlation of Stavrianidis for the critical height of liquid pool fires is used to determine the fire height, H.

$$H = [0.11274/(alpha)^{0.6} - 0.02]\ Q_c^{0.4} \qquad (10)$$

where Q_c = total fire convective heat release rate (kW)

$= (3.14*D^2/4)\ q_c = 2733$ kW

Substituting the given data yields:

H = 4.226 m

The next step is to calculate the configuration factor, F, between the fire and the target. The fire is assumed to have the shape of a right circular cylinder. If the target is located within this cylinder, it is moved out horizontally to the edge of the cylinder. This is done so that standard analytical configuration factor formulae may be employed. Because a radiation shield is assumed to be located directly below the cable, only that portion of the fire cylinder above the horizontal plane of the target is visible to the target. The configuration factor for this cylinder is calculated using Equation 24 from Appendix C of Siegel and Howell. This equation is repeated below:

$$F = \frac{1}{3.14\,M}\tan^{-1}\frac{L}{(M^2-1)^{0.5}} + \frac{L}{3.14}\left[\frac{X-2M}{M(XY)^{0.5}}\tan^{-1}\left(\frac{X(M-1)}{Y(M+1)}\right)^{0.5} - \frac{1}{M}\tan^{-1}\left(\frac{M-1}{M+1}\right)^{0.5}\right] \quad (11)$$

where $M = 2R/D = 1.002$ (by definition in moving target to fire edge)

$L = 2(H-Z)/D = 0.010$

$X = (M+1)^2 + L^2 = 4.008$

$Y = (M-1)^2 + L^2 = 104 \cdot 10^{-6}$

Using the specified data,

$F = 0.490$

If the target was located above the plane of the fire top, an additional factor due to the disk of the fire top would be added to F. This additional factor would be computed using Equation 17 or 18 from Appendix C of Siegel and Howell depending on the location of the target inside or outside the fire radius, respectively. Finally, if the radiation shield is not present, an additional factor would be added for the fire cylinder below the target level.

An equivalent surface emissivity for the gray gas cylinder is computed using:

$$e_g = 253.2\, D^{0.412}/T \quad (12)$$

which is derived from the work of Hadvig, and Hottel and Sarofim. Using the given data and an assumed flame temperature of 1255.6°K (1800°F):

$e_g = 0.304$

An assumed soot emissivity, e_s, of 0.1 is added to bring the total emissivity to:

$$e = 0.304 + 0.10 = 0.404 \quad (13)$$

The radiative heat flux can now be computed using the standard grey surface radiation law:

$$q_r = (F)(e)(s)(T^4) \quad (14)$$

where s = the Stefan-Boltzmann Constant ($5.67 \cdot 10^{-11}$ kW/m^{2}K^4)

Using all of the above results and an assumed flame temperature of 1255.6°K,

$q_r = 27.9$ kW/m^2

The time required for cable failure is calculated by assuming that the fire starts instantly and burns constantly in steady state. With this assumption, the time to cable failure is:

$$t_{fail} = E_{crit}/q_r \quad (15)$$

Using the above results and $E_{crit} = 6530$ kJ/m^2,

$t_f = 234$ sec

The volume of fuel consumed in this time is computed using Equation 8 above and is:

$V = 17.7$ gallons

The error between the fuel volume calculated above using a hand calculator and V = 17.4 gallons computed in the computer analysis is primarily due to the effect of numerical precision on the computation of the configuration factor. It can be verified by repeating the above computation for different valves of D that D = 2.7 m provides the minimum fuel value required for cable failure. (Remember when trying other fire diameters that q_r is reduced to zero when the fire height is less than the height of the cable and its radiation shield.)

13.0 Passive Fire Protection of Electrical Cabinet Components

BNL and Staff reviewers have questioned the adequacy of fire protection for electrical cabinets located in the 4160V Switchgear Room and the Cable Spreading Room. Their principal concern is that a fire might occur with a larger duration than the postulated 30-second, 5-gallon acetone fire. The purpose of this section is to demonstrate that these cabinets, with the addition of radiation shields for selected components on their exterior panels, will not be damaged by a 120-second exposure to an extremely large pool fire. The 120 second time limit was determined to be bounding for any postulated exposure fires which could occur in these areas due to the presence of the Halon 1301 suppression system. The installed Halon system will achieve a Halon concentration sufficient to extinguish the exposure fire in less than 100 seconds. This time estimate includes 60 seconds for detection response and system initiation, 30 seconds built-in time delay for personnel evacuation, and 10 seconds for full area flood. Another 20 seconds was added for conservatism to obtain a total exposure fire duration of 120 seconds.

13.1 Postulated Fire

The pool fire is assumed to be an acetone spill occurring in the access alley between rows of electrical cabinets. The cabinets will confine such a spill into a rectangular pool with a width equal to the width of the alley. The resulting fire would have the shape of a rectangular slab extending up from the floor to the ceiling. A pool width of 2 meters was used for this analysis. The length of the pool is not constrained by the alley floor. However, because a configuration view factor of 1.0 was used in computing the fire radiation, the length of the postulated fire has no effect on the analysis described below. The pool length only effects the total amount of fuel consumed. Assuming a pool length of 4 meters and a pool recession rate of 3 mm/min, 12.7 gallons of acetone will be consumed by the postulated fire.

The equivalent surface emissivity, e, of the fire is computed using a formula devised from Hadvig.19/

$$e = \frac{259.9\, L_m^{0.412}}{T} + 0.1$$

where L_m = mean beam length = 1.76d (for an infinite slab)

d = slab thickness (m)

The additive 0.1 term accounts for flame soot and is recommended by Hottel and Sarofim.20/ Assuming a view factor of 1.0, the

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19/ Hadvig, op. cit.
20/ Hottel and Sarofim, op. cit.

radiation from the fire, q_r, is computed using the usual law forgrey body radiation:

$$q_r = e\ s\ T^4$$

where s = Stefan-Boltzmann Constant

= $5.67 \cdot 10^{-8}$ W/m^2 ^{o}K^4

Using the specified data and an assumed flame temperature of 1255.6^{o}K (1800^{o}F),

e = 0.448

q_r = 63.1 kW/m^2

The heat transfer coefficient, h, for convection from the fire was estimated using the standard correlation for cross-flow past a cylinder:

$$h = 1.1(0.174) R_e^{.618}\ P_r^{.31}\ k/d$$ (Kreith, Equation 9-3b)

where R_e = Reynold's Number

P_r = Prandtl Number

k = air conductivity

d = cylinder diameter

Air properties were evaluated at a film temperature of 778^{o}K assuming a flame temperature of 1255.6K and a surface temperature of 300^{o}K. These air properties are:

Density = 0.453 kg/m^3

Specific heat = 1089 J/kg - ^{o}K

Viscosity = $3.578 \cdot 10^{-5}$ Ns/m^2

Conductivity = 0.0536 W/mK

Using a typical diameter of 0.1 m and a fire plume velocity of 10 m/s,

$$R_e = 12660$$

$$P_r = 0.727$$

$$h = 31.88 \text{ W/m}^2 \, {}^{o}\text{K}$$

An h of 32 W/m^2 ^oK was used for all of the analyses below. For comparison, h based on flow past a flat plate was also computed. Its value of 16.76 W/m^2 ^oK is roughly half that computed above, indicating that the above computation is probably a conservative estimate of h.

13.2 <u>Cabinet Analysis</u>

Heating of the air and contents within an electrical cabinet was modeled using the HOTBOX program. An incident heat flux of 100 kW/m^2 for 120 seconds was assumed. This is greater than the maximum fire heat transfer which is:

$$q_{fire} = 63.1 + 0.032(1255-300) = 93.7 \text{ kW/m}^2$$

The simulation demonstrated that the maximum air temperature will be 339^{o}F (410^{o}K) at the end of 120 sec. This temperature will not damage components contained within the cabinet.

13.3 <u>Radiation Shield</u>

Three types of electrical components are mounted on the front panel of these electrical cabinets. These are switches, relays and breakers. The switches and relays are located on cabinets in the Switchgear Room while the breaker handles are for cabinets in the Cable Spreading Room. The first two are vulnerable to fire damage because of features in their design. The switch housing containing the electrical contacts and cams is mounted directly against the exterior panel surface. This makes them vulnerable to damage as the panel is heated by the fire. The relays are mounted within boxes with glass faced covers. The glass covers permit visual verification of the proper operation of the relays. These also permit fire radiation to directly heat the relay mechanism, perhaps damaging it. It is proposed that radiation shields will be constructed for these types of components associated with one train of safety-related equipment for each unit. As will be demonstrated in the next section below, the construction of the breakers has sufficient passive fire protection to prevent damage without modification.

The proposed modification is the construction of a radiation shield around each component to be protected. The shield will be a non-conducting box fabricated from intumescent-type material having a hinged door on the front to permit access. This enclosure is sufficient to prevent direct radiation or plume impingement on the component or the panel within the enclosure. The only remaining mechanism for heat transfer to the component is by conduction along the cabinet panel into the enclosure. The enclosure can be made large enough so that heat conduction will not damage the component. The purpose of the analysis below is to determine the minimum spacing between the edge of the enclosure and the edge of the component required to prevent damage from the postulated fire.

Only conduction along the panel is modeled in this analysis. A short 5-inch long section of panel is modeled using the MERLIN finite element program. The model layout is shown in Figure 1. On the fire side of the panel, the model is exposed to the fire over a 2-inch span. The boundary conditions for this surface include 63.1 kW/m^2 radiation from the fire, convection from the fire using a heat transfer coefficient of 32 $W/m^2\ ^oK$ and a flame temperature of 1255.6^oK, and re-radiation from the surface. The surface emissivity is assumed to be 0.95. The remainder of the fire side surface is assumed to be protected by the enclosure. This surface is assumed to be adiabatic. The cabinet side of the panel is assumed to be "looking" at the air temperature generated by the HOTBOX simulation from the previous section. These temperatures are treated as a radiation boundary condition. The fire period is broken into two pieces with an average cabinet air temperature and incident radiation defined to be:

TIME	AIR TEMPERATURE	INCIDENT RADIATION
0-60 sec	338^oK	738 W/m^2
60-120 sec	410^oK	1598 W/m^2

The panel ends are assumed to be adiabatic.

When the fire ends at 120 seconds, both the fire and cabinet sides of the panel are assumed to be looking at a uniform 400^oK environment. This corresponds to an incident radiation flux of

1452 W/m^2. Both surfaces re-radiate with a surface emissivity of 0.95. No convection cooling is included in the model. The enclosure is assumed to continue to be adiabatic.

The results of the simulation are shown in Figures 2 and 3. It appears that an appropriate separation length is about 2 inches between the enclosure and component edges. The maximum panel temperature at this point on the panel was 468°K (382°F). This temperature will not damage a component casing constructed of Bakelite.

13.4 Breaker Damage

The breakers are different from the switch and relay components discussed above because their active parts are mounted away from the panel within their mounting boxes and because they have Bakelite covers. The primary path of transfer heat into the breakers active parts is conduction along the steel lever which opens and closes the breaker. This lever is protected from the fire by its Bakelite handle.

A steel breaker level with 0.5 inch thickness covered with a 0.25-inch thick Bakelite handle was modeled using the MERLIN finite element program. The outer Bakelite surface was assumed to be exposed to radiation and convection from the postulated fire for 120 seconds. Re-radiation from the surface with an emissivity of 0.95 is included.

At the end of the fire, the steel lever was found to have a temperature of 336°K (145°F). Only the lever outside of the panel was modeled. Conduction along the level into the breaker

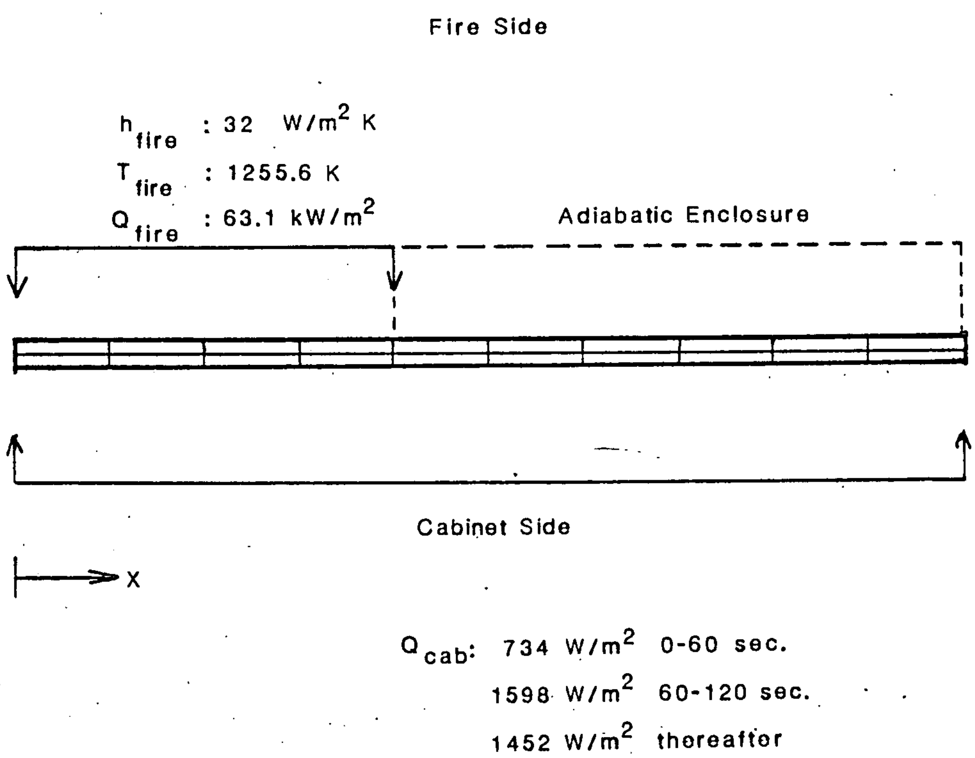

Figure 1 Conduction Model for Determining the Effectiveness of Radiation Shields for Panel Components

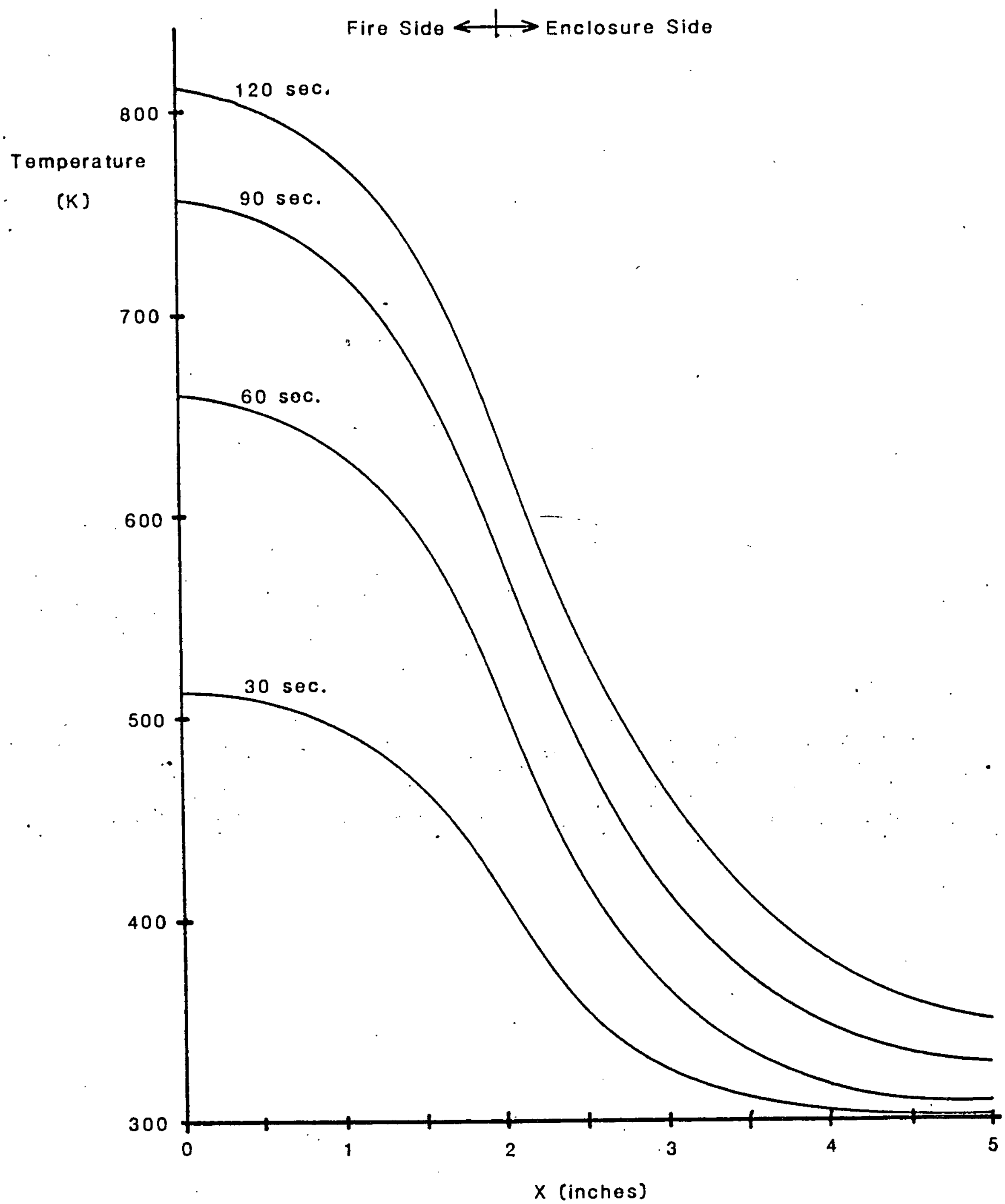

Figure 2 Heating of Panel Under Radiation Shield

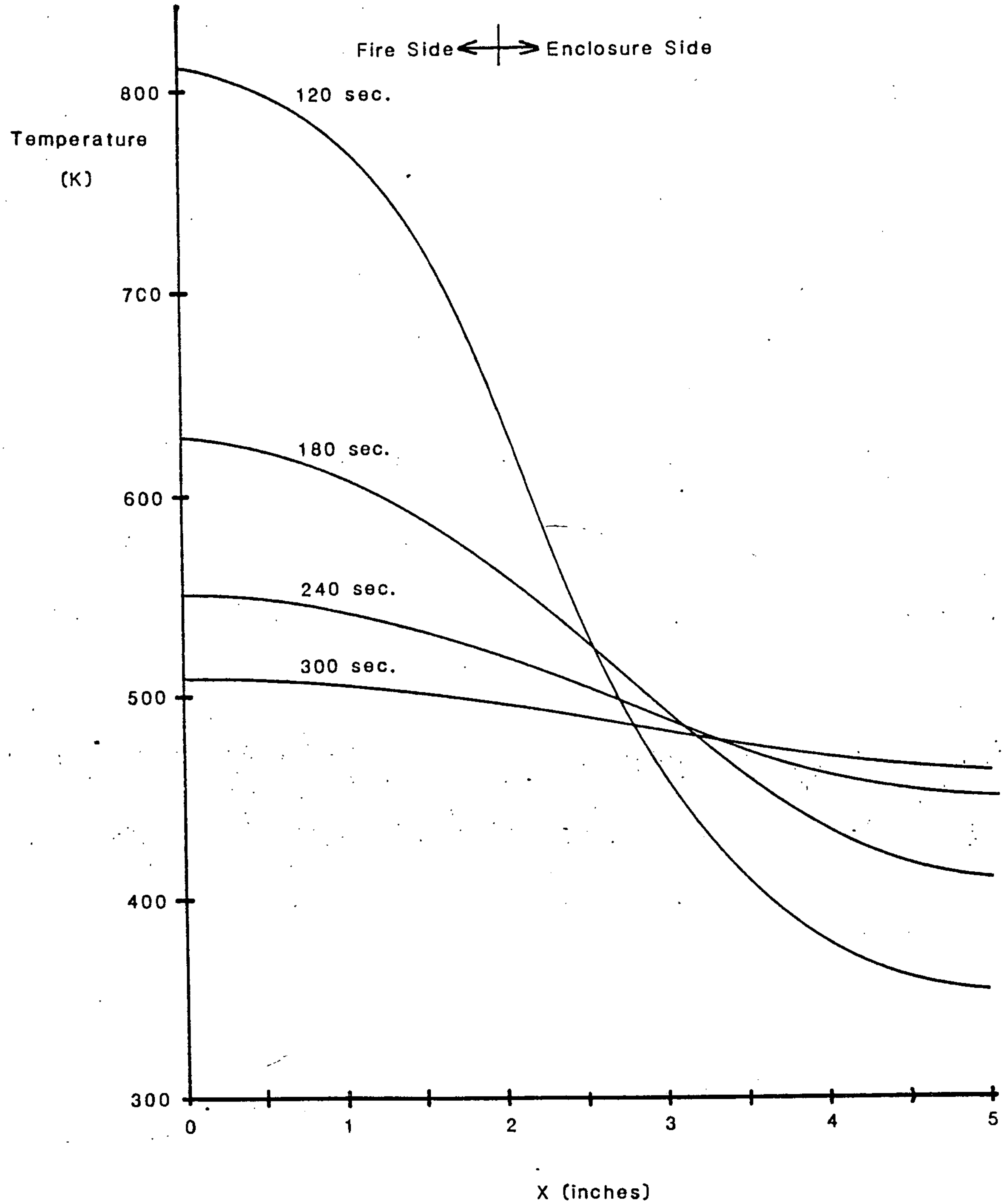

Figure 3 Cooling of Panel Under Radiation Shield

mechanism would reduce this temperature further. It is clear from the results of this analysis that the breakers construction provides significant and sufficient passive fire protection.

14.0 Vertical Tray Radiation Shields

The Staff has questioned the effectiveness of radiation shields in protecting vertical cable trays. These shields have been installed as fire protection modifications for the Cable Spreading Room. The vertical trays are installed in two generic configurations. The first configuration is a tray mounted on the floor next to a room wall. A curb is installed around the base of the tray to prevent spilled flammable liquids from getting into the tray. This curb extends at least 4 inches out from the tray and all the way back to the wall. The second configuration is a tray mounted at the top of an electrical equipment cabinet. In this case, the cabinet itself protects the cable from spilled flammable liquids.

The purpose of the proposed modification is to prevent cable damage from a fire occurring a short distance away from the tray. For the floor-mounted trays, the shield is installed on the side facing away from the wall. For the cabinet-mounted trays, the shield is installed facing the alley separating cabinets for redundant trains.

The postulated fire is the same as that described in Section 13.1. It is a large rectangular acetone fire lasting for 120 seconds. The fire duration was selected for reasons described in Section 13. As shown in Section 13.1, the postulated fire will have a radiation heat flux of 63.1 kW/m^2 and a convection heat transfer coefficient of 32 $W/m^2\ ^oK$.

The installed shield consists of a thin steel sheet backed by 0.5 inches of Kaowool insulation. Transient conduction through the Kaowool was modeled using the MERLIN finite element program. The fire boundary conditions were imposed on the sheet-metal side of the model. Re-radiation from the sheet metal was also included using a surface emissivity of 0.95. The cable insulation was modeled as a thin layer of rubber in good thermal communication with the Kaowool. This configuration was found to maximize cable insulation temperatures.

The simulation described above showed that maximum cable insulation temperature occurring at the end of a 120-second fire was 333^oK (139^oF). This temperature rise will not damage PE/PVC cables. Therefore, the intalled tray protection provides the required protection during the period between fire start and fire extinguishment by the Halon suppression system.