SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FIRE PROTECTION PROGRAM
APPENDIX R
DEVIATION REQUEST NO. 6
NON FIREPROOFED STRUCTURAL STEEL

SUMMARY REPORT
FOR
STRUCTURAL STEEL EVALUATION

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SUMMARY REPORT FOR STRUCTURAL STEEL EVALUATION UNIT 1 & 2 REACTOR BUILDINGS APPENDIX R DEVIATION REQUEST NO. 6

1.0 Introduction

Deviation Request No. 6 was submitted to the NRC in September 1985 (PLA-2529) requesting approval of exposed (non-fireproofed) structural steel which supports fire area barriers in the Unit 1 and 2 Reactor Buildings, and supports elevation 754' of the Control Structure.

After reviewing the Deviation Request, the NRC requested additional justification. In response to the NRC request, PP&L submitted the Structural Steel Action Plan to the NRC for their concurrence on February 10, 1986 (PLA-2592).

The initial submittal, outlined in Revision 0 to this report, was submitted to the NRC on May 19, 1986.

Subsequent to the initial submittal, a meeting was held in the NRC Office in Bethesda, MD on July 30, 1986 to discuss the submittal. During this meeting the NRC requested that PP&L revise their submittal and provide the following:

- o Consideration of the effects of slab openings and the use of a 100% live load criteria.
- o Specific details of the areas required to be fire rated.

Our summary report has been revised to respond to the NRC requests. Methodology changes, different than those proposed in our action plan submitted with PLA-2592, have occurred as a result of NRC comments. These changes are explained in the report.

This report specifically addresses the fire-rated barriers in the Unit 1 and 2 Reactor Buildings. All fire-rated barriers covered by Deviation Request #6, except one, are located in the Unit 1 and 2 Reactor Buildings. The one exception is the ceiling above the main control room in the Control Structure. The write-up within the body of Deviation Request #6 is considered to have adequately addressed the combustible configuration so the subject is not specifically addressed in the report.

Finally, in response to concerns expressed verbally by the NRC staff, we have taken the initiative to review <u>all</u> of the structural steel in the Unit 1 and 2 Reactor Buildings regardless of whether or not the structural steel was part of a fire-rated barrier.

2.0 Methodology

The methodology outlined below, which differs from the methodology outlined in PLA-2592, was used in performing our updated analysis.

All structural steel in both the Unit 1 and Unit 2 Reactor Buildings was reviewed. The structural steel framing plan for each floor elevation in each Reactor Building was reviewed and the minimum set of structural steel framing members required to insure structural integrity was selected. This minimum set of structural steel framing members was selected on the premise that the thick reinforced concrete slabs used in the construction of the Reactor Buildings are able to span significantly longer distances than the normal beam to beam span required by other design basis accident scenarios. Since these other design basis accident scenarios need not be considered in conjunction with a fire, much of the structural steel installed in the Reactor Building is not necessary to maintain structural integrity for the fire scenario. In selecting the minimum set of required structural framing members, the following restrictions were applied:

- The reinforced concrete slab must be able to support 100% of the allowable live load shown on the existing structural framing plan drawings. The loss of structural continuity as a result of hatch openings and penetrations must be considered.

- The selected structural steel framing beams must be capable of carrying any increased loadings caused by the elimination of adjacent members to the building girders and/or columns. Similarily, the building girders and/or columns must be capable of supporting any increased loading.

Each specific concrete slab section was evaluated to assure that the first criteria outlined above was met. Each required structural steel framing member was reviewed for the effects of any additional load imposed on the member and for the effects of the combustible configuration near each member.

Any required structural steel framing member with a maximum of two horizontal cable trays in its vicinity was evaluated to be acceptable. (See Section 3.3 - Two Horizontal Cable Tray Criteria for an explanation of and justification of this criteria.)

Any required structural steel framing member located in areas protected by an NFPA 13 sprinkler systems was evaluated to be acceptable. (See Section 3.4 - NFPA 13 Sprinkler Criteria, for an explanation of and justification for this criteria.)

All remaining required structural steel framing members were evaluated with respect to fire protection on a case-by-case basis. By reviewing each member and the combustible configuration in the vicinity of the

member, the fire protection evaluation determined that structural steel temperatures could not be raised above 1000°F. The case-by-case fire protection evaluation is explained in Section 3.5.

3.0 Criteria and Justification

3.1 General Criteria

In the past it has been common to calculate the average combustible loading by distributing all calculated combustibles uniformly over the entire floor area and comparing the results with the fire rating of the structure. While this method provides a room-to-room comparison, it fails to consider such parameters as combustible concentration, fuel arrangement, and burning rates. These average combustible loadings have traditionally been compared to fire-rated components tested to the Standard Time Temperature Curve (Ref. 2). More recently, this approach has come under attack as being unconservative in certain applications because it fails to address the condition where the majority of the combustibles in an area are concentrated in a small portion of the area.

PP&L based the structural steel evaluation on a comparison of combustible configuration in each area using actual cable tray fire test data. Cable trays are the predominant fire hazard in the Reactor Buildings. The cable tray fire tests referenced take into account the actual fuel arrangement within the cable tray, combustible configuration, and burning rates.

The critical steel failure temperature used in the evaluation criteria was based on the 1000°F average temperature acceptance criteria found in the National Fire Protection Association's standard used for testing fireproofing for structural steel (NFPA-251). Since fireproofing materials are designed to maintain structural steel temperatures below this level, we can conclude that fires which do not heat the structural steel to this critical temperature will not result in loss of structural integrity.

This conclusion is further substantiated by information provided by the American Institute of Steel Construction. The American Institute of Steel Construction Manual (Ref. 8) states that steel maintains approximately 63% of its yield strength at 1000°F and approximately 37% of its yield strength at 1200°F. The normal A.I.S.C. allowable stress in bending is in the range of 60 to 66% of its yield strength. Since it is reasonable to classify the fire condition as an extreme environmental loading combination, it should follow that for this loading combination the allowable stress should be permitted to approach the yield strength of the material. Therefore, by restricting structural steel temperature to 1000°F, we are assuring that approximately 63% of the yield strength of the material is preserved. As a result, when we evaluate the structural members for

100% live and dead load and use the normal A.I.S.C. allowable stresses, we are, in fact, satisfying the conditions which would be imposed by a loading combination consistent with the fire scenario.

In Section 3.2 of this report, the Energy Balance Method outlined in the previous revision has been expanded to include the heat absorption capability of the concrete. In the development of the method it has been assumed that an equilibrium temperature is reached between the structural steel and the first inch of depth of concrete. The assumption of equilibrium concrete heat up to a depth of one inch is considered a reasonable assumption since in actuality the rapid transfer of heat through the air would cause a much larger area than assumed to be heated up. From a structural standpoint heating of the lower 1" of concrete will have a negligible effect on the concrete structural properties since the cover on the reinforcing steel is approximately 4" and in the structural evaluation for slab span capability, the concrete on the underside of the slab is in tension. Tensile concrete is not considered for structural properties.

The following combustibles were generically evaluated, and it was determined that a specific analysis on a case-by-case basis was not required. The remaining combustibles which are represented solely by cable trays are the dominant factor leading to potential high temperatures which would affect structural steel.

3.1.1 Combustible Liquids

Combustible liquids could present fire exposure to structural steel. The most probable location for heat released, however, would be at the floor level and the heat would be released very quickly. The analysis of all fire zones containing combustible liquids, except Fire Zones 1-1G and 2-1G, are bounded by the analysis of Fire Zone 1-1C. Fire Zone 1-1C contains the largest in-situ quantity of oil (155 gallons) in the smallest room (1374 square feet). This oil is associated with the HPCI and RCIC Turbines.

The Susquehanna SES Fire Protection Report (Rev. 2), page 4.1-2, indicated a 4 mm per minute burning rate for oil. Assuming the in-situ 155 gallons and a transient allowance of 155 gallons of oil are spilled on the floor and none of the oil is removed by the floor drains, the calculated fire will last less than three minutes. This is not sufficient time for the critical structural steel to be heated to 1000°F.

The HPCI turbines and RCIC turbine lube oil systems have a maximum oil flow of 60 gpm at 110 psi. The potential for a high pressure leak affecting the steel is low. The piping is seismically designed and automatic open head deluge water spray systems protect the HPCI and RCIC oil systems.

Oil sumps located in Fire Zone 1-1G and 2-1G have a 1120 gallon capacity. The construction of these sumps, however, would prevent the ignition and burning of the oil. The sumps are constructed of a steel liner cast into concrete below the Reactor Building Basement. The cover of the sumps is a 1½' thick concrete slab with a 2' x 2½' manhole constructed of a minimum of 3/4" thick steel plate.

3.1.2 Charcoal

The HVAC units which contain charcoal are provided with fixed deluge systems and are contained within steel enclosures. Because of the physical configuration of the charcoal beds a fire will be slow and smoldering with a low heat release rate. Therefore, these units will not effect building structural steel integrity.

3.1.3 Transient Combustibles

Investigations by Sandia Laboratories (Ref. 8, Table 3) indicate that transient combustibles produce low heat release rates resulting in room temperatures below 500°F.

The presence of transient combustibles is administratively controlled throughout the facility. When present transient combustibles are located at floor level. If transient combustibles are considered along with a cable tray, it would be expected, based on the above referenced Sandia data, that the transient would be an ignition source only if the cable tray was close to the transient combustible. Such a combination of heat release caused by cable trays and transient combustibles at floor level would not effect structural steel located at the ceiling. Additionally, since the structural steel justification was based on 1000°F critical temperature, there still remains a 300°F allowance before transient combustibles would produce a local hot spot of 1300°F (1300°F is the allowable local hot spot temperature during a NFPA 251 test).

3.2 Technical Basis

This section of the report provides the technical basis used to address the effects of each unique combustible configuration on the required structural steel members.

The basic methodology developed in this section is referred to as the Energy Balance Method. The Energy Balance Method provides a means to calculate the energy released from a given combustible configuration, to calculate the energy absorption capability of a given structural mass and to determine by comparing these two calculations whether or not the critical temperature can be exceeded.

As discussed below, the Sandia Laboratories' "Fire Retardant Coating Test" (Ref. 1) provides the data necessary to predict the energy release of a cable tray fire. The Sandia Laboratories' "Fire Protection Research Program Corner Effects Tests" Report (Ref. 4) provides additional data to confirm these predictions and predict the heat release effects of the burning cables as a function of the distance of these cable trays from the corner. The heat release data with increasing distance from the corner suggests that the ability of the cables to burn and the resultant energy release is greatly diminished as the reradiation effects typical of the close corner relationship are removed. The energy release figures provided in the corner effects tests are used to baseline the values measured in the "Fire Retardant Coating Tests" and as a conservative prediction of the heat release value to be used in the methodology outlined below.

<u>Energy Balance Method</u>

<u>Energy Absorption</u>

The energy absorption capability of a given structural mass can be calculated as follows:

$$Ec_T = Er \times Q$$

where:

Ec_T = the critical energy needed to heat all the components in a given area to the critical temperature (BTU)

Er = Energy required to raise a unit amount of a given component from ambient to the critical temperature.

Q = The total quantity of each component in the area.

The typical components in a given area which would be present to absorb heat are structural steel, concrete, ductwork, piping, air, equipment and even the steel cable tray itself. For purposes of our evaluation only structural steel and concrete will be considered as heat absorbing components.

The heat required to raise the temperature of one pound of structural steel to 1000°F can be calculated by the following equation:

$$Er_S = Cp_S \times (Tc - To) \qquad \text{(Eq. 1a)}$$

where:

Er_S = Energy required to raise the temperature of of pound of structural steel from ambient to the critical temperature (BTU/lb)

Cp_S = Specific heat of steel (Cp = .112 BTU/lb °F for steel)

To = Pre-fire room temperature = 100°F

Tc = Critical temperature = 1000°F

Inserting the given values into equation 1a yields:

$$Er_S = \frac{.112 \text{ BTU}}{\text{lb °F}} (1000°F - 100°F) = 100.8 \text{ BTU/lb}$$

Therefore, approximately 100 BTUs per pound of steel are required to heat the steel to the critical temperature. The critical energy required to heat a given structural member to the critical temperature of 1000°F is expressed as:

$$Ec_S = Er_S \times W \times L \qquad \text{(Eq. 2a)}$$

where:

Ec_S = Critical energy needed to heat a given structural steel member to the critical temperature (BTU)

W = weight of structural steel member per foot (lb/ft)

L = length of structural steel member subject to direct energy effects (ft)

The heat required to raise the temperature of one square foot of concrete 1" deep to 1000°F can be calculated by the following equation:

$$Er_C = Cp_C \times (Tc - To) \qquad \text{(Eq. 1b)}$$

where:

Er_C = Energy required to raise the temperature of one square foot of concrete 1" deep from ambient to the critical temperature (BTU/lb)

Cp_C = Specific heat of concrete (Cp = .156 BTU/lb °F for concrete)

To = Pre-fire room temperature = 100°F

Tc = Critical temperature = 1000°F

Inserting the given values into equation 1b yields:

$$Er_C = \frac{.156\ BTU}{lb\ °F}(145\#/ft3)\ (1ft/12\ inch)\ (1000°F - 100°F) = 1696.5\ BTU/ft^2$$

Therefore, approximately 1700 BTUs per square foot of concrete are required to heat the concrete to the critical temperature. The critical energy required to heat a given concrete area to the critical temperature of 1000°F is expressed as:

$$Ec_C = Er_C \times A_c \qquad \text{(Eq. 2b)}$$

Where:

Ec_C = Critical energy needed to heat a given concrete area to the critical temperature (BTU)

A_C = the effected concrete area

Energy Release

The energy released from a cable tray can be developed as follows:

The heat released from a two-cable tray fire can be predicted from data developed during Sandia Laboratories Fire Retardant Coating Tests (Ref. 1). During small scale testing, Sandia (Ref. 1, Table A-XI) determined the maximum Heat Release Rate to be 134 KW/M^2 which is equal to 11.8 BTU/ft^2 sec.

Sandia performed a full scale free burn test of two stacked 18-inch wide cable trays filled with IEEE 383 cable (Ref. 1 Test 20). The total heat released from this test can be predicted by conservatively assuming the Sandia small scale maximum heat release rate was constant during the entire fire test burn period. This is expressed as:

$$Ht = Hr \times At \times T \qquad \text{(Eq. 3)}$$

Ht = Total heat released (BTU)
Hr = Maximum heat release rate (BTU/ft^2 sec)
At = Area of cable tray burned (ft^2)
T = Burn Time (sec)

In this test, the bottom tray was damaged for 24 linear inches and burned 9 minutes. The top tray was damaged for 54 linear inches and burned for 12 minutes. Using this data in equation 3 yields:

$$\text{Heat Release Top Tray} = \frac{11.8 \text{ BTU}}{\text{sec ft}^2} \times \frac{18 \text{ in} \times 54 \text{ in}}{144 \text{ sq in/ft}^2} \times \frac{12 \text{ min}}{1 \text{ min/60 sec}}$$

$$= 57{,}348 \text{ BTU}$$

$$\text{Heat Release Bottom Tray} = \frac{11.8 \text{ BTU}}{\text{sec ft}^2} \times \frac{18 \text{ in} \times 24 \text{ in}}{144 \text{ sq in/ft}^2} \times \frac{9 \text{ Min}}{1 \text{ min/60 sec}}$$

$$= 19{,}116 \text{ BTU}$$

Total Heat Release (Ht) = 57,348 + 19,116 = 76,464 BTU

The maximum total heat release per area can be expressed as follows:

$$Hmax = Ht/At \qquad \text{(Eq. 4)}$$

where:

Hmax = Maximum total heat release per area (BTU/ft^2)

Substituting our previously developed data into equation 4 yields:

$$Hmax = \frac{76{,}464 \text{ BTU}}{\frac{18 \text{ in } (54 \text{ in} + 24 \text{ in})}{144 \text{ in}^2/\text{ft}^2}} = 7842 \text{ BTU/ft}^2$$

This maximum total heat release per area can then be applied to other configurations by the following equation:

$$H' = Hmax \times A' \qquad \text{(Eq. 5)}$$

where:

H' = Predicted heat release for a given configuration (BTU)

A' = Area of cable tray burned for that given configuration (ft^2)

Sandia Laboratories also conducted separate corner effects tests of cable trays (Ref. 4) where calorimeters recorded heat flux above the cable tray fires. This additional test series can be used to confirm the predicted maximum heat release value of 7842 BTU/ft^2 and also to determine the maximum heat release values for configurations with different corner configurations.

The corner effect test data was obtained during full scale free burn fire tests in a corner configuration. The cable tray type, arrangement, fill and contents were similar to the fire retardant coating tests arrangement. During these corner tests the actual maximum heat flux (heat release rate) was measured by determining the heat release directly above the cable tray with the cable tray located at various distances from the corner (Ref. 5 - Table I and II). The maximum heat flux multiplied by burn time would conservatively indicate the total heat at the upper calorimeter as follows:

$$H_{max} = H_f \times T \qquad \text{(Eq. 6)}$$

Where:

H_f = maximum heat flux (BTU/ft^2 hr)

By substituting the data from the actual corner tests the following data can be generated:

Cable Tray* Distance from Corner	Max Heat Flux (Hf) (BTU/ft² x hr)	Burn Time (T) (min)	Max Heat Release/Area (Hmax) (BTU/ft²)
5 in x 10.5 in	18,430	20	6140 BTU/ft^2
10.5 in x 18 in	12,330	24	4932 BTU/ft^2
60 in x 120 in	2,370	25	987 BTU/ft^2

*(See Figure 2.0)

The 6140 BTU/ft^2 is comparable to the 7842 BTU/ft^2 derived from the fire retardant coating test data. This is expected, because at the short corner distance the predicted heat release would nearly equal the measured maximum heat release.

Using this developed data and the results of the Sandia Corner Effects Test (Ref. 4), a determination can be made as to the amount of heat transferred to the structural components in an area due to a fire in a cable tray located some distance below the steel member. It has been determined that 7842 BTU/ft^2 is the maximum heat released at the cable tray or group of cable trays.

Figure 1.0 of this report is a reproduction of Figure 7 from the Sandia corner effects test (Ref. 4). The data in this figure can be used to determine the maximum heat release values as a function of corner configuration.

Acceptance Criteria

The energy required to heat a given structural mass to 1000°F is compared with the energy released by a fire in the vicinity of that

mass to determine whether or not the fire threatens structural integrity.

If the following ratio is satisfied, structural integrity will be assured:

$$\frac{Ec_t}{H'} \geq 1.0 \qquad \text{(Eq. 7)}$$

where (as previously defined)

Ec_t = The critical energy needed to heat all the components in a given area to the critical temperature (BTU).

H' = Predicted heat release for a given configuration (BTU).

Conservatisms

The following demonstrates that the use of this technical basis at Susquehanna is conservative:

o The maximum heat release rates used in our analysis were based on cable tray test conducted by Sandia (Ref. 4). In these tests cross linked PE (polyethylene) cables in a loose packed configuration were tested.

  EPRI conducted a series of full scale fire tests using the following cable types and packing arrangements:

  - Tightly packed ethylene propylene rubber (EPR)/hypalon cables
  - Loosely packed ethylene propylene rubber (EPR)/hypalon cables
  - Tightly packed PE cables
  - Loosely packed PE cables

  The results of the EPRI test demonstrated the following relationships.

  - The tighter the cable packing, the lower the heat release will be.
  - The EPR/hypalon cables have a lower heat release than the PE cables.

  Since Susquehanna SES used EPR/hypalon cables in a tight packed arrangement, the quantative test data indicates that the use of the heat release data from the Sandia test has an inherent factor of safety of approximately 8 when applied to our plant.

- The Sandia observed maximum heat release rate data (Ref. 1, 4) was assumed over the entire burn time. During an actual fire, the heat release rate would gradually increase to the maximum and then decrease.
- All cable trays were assumed to be full.
- Heat transfer to the room air was ignored.
- Steel was assumed to fail if the 1000°F critical temperature was reached. The reduced load capabilities of the structural steel at temperatures above 1000°F were ignored.
- It was assumed that high fire temperatures existed for sufficient time to allow heating of the steel. In many cases the longer heating intervals required for the larger structural steel members will not exist for sufficient time to allow the necessary heat transfer.

3.3 Two Horizontal Cable Tray Criteria

3.3.1 Description

All required structural steel framing members were reviewed. Any member affected by a combustible configuration comprised of no more than two (2) horizontal perpendicular cable trays with no other cable trays within a four (4) foot distance and not less than one foot below the structural steel were determined to be acceptable. (See Figure 3.0.)

3.3.2 Approach

The Energy Balance Method will be used to provide a justification for the criteria by demonstrating that this combustible configuration will not cause temperatures above 1000°F for the lightest member to which the criteria was applied.

3.3.3 Justification

The following justification is provided to quantitatively demonstrate that the combustible effects from two (2) horizontal perpendicular cable trays one foot below the structural steel are insufficient to cause a structural steel member to be heated to 1000°F. (See Figure 3.0.)

Therefore, any structural steel member larger than that member justified is acceptable for the described combustible configuration, because larger quantities of heat are required to heat larger steel members.

The lightest structural steel member to which this criteria was applied is a W21 x 49.

Therefore, a W21 x 49 beam (flange width - 6.52 in, weight - 49 lb/ft) and two 24-in wide cable trays must be justified.

<u>Energy released at the cable tray:</u>

From Figure 3.0 it can be seen that the cable tray is 33" below the ceiling. Using a value of 9500BTU/ft²-HR for a distance from the ceiling of 30" from Figure 1.0 and using 25 minutes, the longest burn time, from the table on page 10, calculate Hmax for this configuration.

Since:

$$H_t = H_r \times A_t \times t \qquad \text{(Eq. 3)}$$

and

$$Hmax = H_t/A_t \qquad \text{(Eq. 4)}$$

Therefore:

$$Hmax = H_r \times t = 9500 \frac{BTU}{ft^2\text{-}Hr} \times 25 \text{ min.} \times \frac{1 \text{ hr}}{60 \text{ min.}}$$

$$Hmax = 3{,}958 \frac{BTU}{ft^2}$$

$$H' = 3{,}958 \frac{BTU}{ft^2} \times \frac{24 \text{ in}}{12 \text{ in/ft}} \times \frac{6.52 \text{ in}}{12 \text{in/ft}} \times 2 \text{ trays} \qquad \text{(Eq.5)}$$

$$H' = 8{,}602 \text{ BTU}$$

<u>Energy required to heat beam to 1000°F:</u>

$$Ec = 49 \frac{lbs}{ft} \times \frac{24 \text{ in}}{12 \text{ in/ft}} \times 100 \frac{BTU}{lb} = 9{,}800 \text{ BTU} \qquad \text{(Eq.2)}$$

Ratio (energy required to energy released):

$$\frac{9{,}800\ BTU}{8{,}602\ BTU} = 1.14 \geq 1.0 \qquad \text{(Eq.7)}$$

Therefore, the criteria is justified.

This justification assumes that the maximum heat release rate of the burning cable tray configuration is a function of the distance of the cable tray from the ceiling rather than from the underside of the structural steel member. This is acceptable because all parts of the cable tray are at least 33" from the ceiling except for a short, 6.5", section beneath the structural steel member. It is unrealistic to assume that the corner effects will dramatically increase in this short distance.

This justification also assumes that only the portion of the cable tray directly beneath the structural steel member contributes to raising the temperature of the steel. This is justified because those portions of cable tray not directly under the steel will cause heat-up of the reinforced concrete slab above them. For each additional foot of cable tray considered 7,916 BTU's is released. Assuming a 45° distribution of this heat into the concrete slab, the additional heat absorbtion afforded by the concrete, using the methodology outlined in Section 3.2, is 12,750 BTU's. Therefore, more energy absorption capability is added than additional heat released.

3.4 NPFA 13 Sprinkler Criteria

3.4.1 Description

The Unit 1 and Unit 2 Reactor Buildings both have areas with automatic sprinkler protection designed, installed and tested to the requirements of NFPA 13. All required structural steel framing members in areas protected by NFPA 13 sprinkler systems and having combustible configurations less than those justified herein were determined to be acceptable.

3.4.2 Approach

For a given quantity of cable trays, an automatic sprinkler system is capable of preventing structural steel damage by controlling a fire and cooling the steel. Six cable trays have been selected as being a combustible configuration which can be protected by a sprinkler system. Branch

Technical Position CMEB 9.5-1 (Rev. 2) lends credence to this criteria in that it requires automatic suppression systems only when an area contains more than six cable trays. Additionally, extensive large scale fire testing of rack storage arrangements, a far more hazardous combustible configuration than cable tray, have demonstrate that ceiling level automatic sprinklers installed in accordance with NFPA 13 are effective in preventing heat damage to unprotected steel beams and columns. The requirements of NFPA Standard 231C, "Standard for Rack Storage of Materials", (Ref. 4) were developed based on the results of these large scale tests. A comparison between the combustible configurations and fire hazards associated with rack storage and cable trays will be used to justify our criteria.

3.4.3 Justification

Our criteria can be justified by comparing the relative fire hazard of a six-cable-tray fire with that of the rack storage fire which meets the NFPA Standard 231C requirements and does not require structural steel protection.

Rack storage of materials, especially most plastic materials, presents a difficult to control fire hazard. The materials and the cardboard packaging holding these materials are easily ignited. Once ignited, the rack storage configuration provides ideal conditions for rapid and intense combustion. In the rack storage configuration the boxes of materials are surrounded on all sides by sufficient oxygen for combustion, and the flue spaces created between adjacent boxes are ideal for reradiation effects which promote fire spread. Also, the palletized materials (4' x 4') present large areas of blockage from sprinkler protection and allow fire growth to a level which can overpower traditional sprinkler systems. Recognition of these conditions led to extensive large scale fire tests. These tests served as the basis for the National Fire Protection Associations's "Standard for Rack Storage of Materials" (NFPA 231C) (Ref. 4).

The rack storage test program and NFPA standard clearly show that when an adequately designed ceiling sprinkler system is installed, fireproofing is not required for steel columns or ceiling steel. (Ref. 4 Sec. 3-2.1, 3-2.3, B-3-2.1, and B-3-2.3.)

In contrast, the cable trays at Susquehanna contain IEEE 383 qualified cables which require at least 70,000 BTU/hr heat input to ignite the cables. Due to the tight packing of cables in cable trays, there is only limited exposure to air. Cable tray fires are slow developing relative to cardboard packaging materials, and unlike other fuel arrays, cable trays present a fuel arrangement which allows fire propagation in only two directions. Finally, the cable tray itself is constructed of non-combustible steel.

In the Reactor Buildings the predominant fire spread is vertically from tray to tray. Horizontal fire spread from cable tray to cable tray is possible, but the majority of the cable trays in the Reactor Building are arranged with spacing which are not ideal for horizontal fire spread.

The following example shows how to determine the required ceiling sprinkler system parameters for a high hazard rack storage configuration when structural steel fireproofing is not provided on either ceiling beams or columns.

3.4.4 NFPA 231C Sprinkler Design Example

The following example uses NFPA 231C requirements to determine sprinkler system parameters for a given rack storage combustible configuration when structural steel fireproofing is not to be used.

a. Problem Definition - Determine the sprinkler density for a ceiling sprinkler system capable of maintaining the building's structural integrity for the following rack storage configuration.

   1) The stored material is palletized cardboard cartons containing foamed polystyrene. The pallets and cartons are not encapsulated with plastic.

   2) The aisle spacing is 8 feet. The rack storage height is 15 feet.

   3) There are no in-rack sprinklers.

   4) Structural steel ceiling beams and columns are not fireproofed.

b. NFPA 231C Requirements

   1) The combustible material described above would be classified as a Class IV commodity per NFPA 231C Section 2-1.1.4.

2) By referring to Table 6-11.1 in NFPA 231C and applying the following conditions:

   i) The rack storage height is over 12 feet but less than 20 feet.

   ii) The combustible material is classified as a Class IV commodity.

   iii) The pallets and cartons are not encapsulated with plastic.

   iv) An 8-foot wide aisle is used between rack configurations.

   v) No in-rack sprinklers are provided.

   it can be determined that Figure 6-8.2 can be used to determine the allowable reduction factor to be applied to the sprinkler design density and that Figure 6-11.1d curve E or F is to be used to determine the unfactored sprinkler design density. (Refer to NFPA 231C for figures.)

3) Using NFPA 231C Table 6-8.2, it is determined that a 60% reduction factor may be applied to the required sprinkler design density determined below.

4) NFPA 231C Table 6-11.d curve F will be used because Susquehanna SES uses 212°F rated sprinkler heads. Curve F applies to 165°F rated heads. Curve E applies to 265°F rated heads. Using the curve for the lower rated heads results in a more conservative sprinkler density. Using 2500 square feet, which was used as the design area for sprinkler coverage used in the design of the SSES Reactor Buildings, it can be determined that the required sprinkler design density for this rack storage example is:

   Required Sprinkler Design Density = .54 GPM/ft^2

5) By applying the 60% reduction factor determined in step 3 above, the final sprinkler density is determined to be:

   Sprinkler Density = .54 x .60 = 0.32 GPM/ft^2

6) The requirements of NFPA 231C sections 3-2.1 and 3-2.3 are satisfied by the storage height limitations of 15 feet and the sprinkler design which conforms to Chapters 6.7.8 and 9. Therefore, fireproofing of structural steel beam and columns is not required for this example.

c. Conclusion

A ceiling sprinkler system with a design density of .32 GPM/ft^2 over 2500 square feet is considered sufficient to protect non-fireproofed structural steel (ceiling beams and columns) from damage when subjected to a rack storage hazard with the above parameters.

3.4.5 <u>Comparison of Our Cable Tray Criteria With the Fire Hazard of the Rack Storage Example</u>

a. Cable Trays

Cable trays present an important fire protection challenge to control damage prior to affecting safe shutdown or station availability, but cable tray fires have low heat release rates, spread slowly, and do not pose the danger to structures that the rack storage materials do.

As discussed in Section 3.2 of this report, the Sandia Laboratories Fire Retardant Cable Test (Ref. 1) Table A-XI indicates a maximum of 11.8 BTU/ft^2 sec (134,690 W/M^2) for non-coated electrical cables. Therefore, it can be concluded that the total heat release rate for six cable trays would be 70.8 BTU/ft^2 sec.

b) Rack Storage

Rack storage stores combustible materials in configurative ideal for combustion (i.e., air space around fuel, and distances ideal for radiant heat transfer). Therefore, rack storage presents an extremely difficult fire to control. Rack storage fires have extremely high heat release rates, spread very quickly, and can threaten structural integrity within minutes unless proper sprinkler protection is provided.

Heat release rate data for the rack storage commodity was obtained from Factory Mutual Data (Ref. 10, Table 2, Page 26) which indicates that a pallet of polystyrene in cartons 14 to 15 feet high has an average heat release rate of 300 BTU/ft^2 sec.

c) As a result of the information in a and b above, the following data comparison of critical fire protection parameters can be presented.

DATA COMPARISON

Hazard	Cable Tray Criteria	Rack Storage Example
Heat Release Rate	70.8 BTU/ft^2 sec	300 BTU/ft^2 sec
Sprinkler Density	.15 GPM/ft^2*	.32 GPM/ft^2

*SSES was designed on the basis of a .15 GPM/ft^2 sprinkler density over a 2500 sq ft area.

d. Conclusion

The dominant mechanism governing a sprinkler system's ability to extinguish fires and also to protect structural steel from damage is the ability of the sprayed water to absorb the heat released from the fire. This absorption occurs as the heat of the fire is used to change liquid water to steam.

The heat release rates of different materials as they are consumed is an indication of the relative fire hazard of the different fires. As the heat release rate increases, larger and larger quantities of water are necessary to absorb the higher heat levels generated.

Therefore, a comparison of the data presented in Item c above on heat release rates and sprinkler densities can be used in demonstrating the adequacy of the Susquehanna sprinkler design for our cable tray configurations. Since the rack storage example above proved that a .32 GPM/ft^2 density sprinkler system could control a fire with a heat release rate of 300 BTU/ft^2 min, using a strictly linear relationship we can predict a .15 GPM/ft^2 density sprinkler system would control a fire with a heat release rate of 140 BTU/ft^2 sec or 12 cable trays (140 BTU/ft^2 sec divided by 11.8 BTU/ft^2 sec per cable tray).

The assumption of linearity applied above would be viewed as being highly unconservative if the light hazard fire test data was used to predict the sprinkler system requirements to protect a

configuration with high fire hazard potential. This is valid because as the level of the combustibles doubles, effects such as reradiation can have an exponential effect. In contrast, however, to extrapolate results from the higher density system to the lower density system on a linear basis is clearly a conservative and supportable approach.

While this comparison predicts a wide margin of safety over the six-tray criteria, the criteria was limited to six cable trays to be conservative, to parallel the Branch Technical Position CMEB 9.5-1 (Rev. 2) requirements, and to assure that specific orientations and arrangements exceeding the criteria would be looked at on a case-by-case basis to ensure the adequacy of the sprinkler system.

Therefore, the existing ceiling level automatic sprinkler system in the Susquehanna SES Reactor Building can be expected to protect structural steel with a wide margin of safety in the event of a fire involving six cable trays.

3.5 Case-By-Case Fire Protection Analysis

3.5.1 Description

For all required structural steel framing members not satisfying either of the two criteria outlined above one of the following approaches was used to justify that structural steel fire proofing was not required:

a) For non-sprinklered areas, a case-by-case evaluation using the Energy Balance Method outlined in Section 3.1 of this report was performed. The most severe cable tray exposure was analyzed for each steel member evaluated. In cases where the most severe exposure was not obvious, several exposures were evaluated.

b) For sprinklered areas, a case-by-case evaluation to determine that the existing combustible configuration would be controlled by the sprinkler system was performed.

4.0 RESULTS

All structural steel in the Unit #1 and #2 Reactor Buildings was reviewed in conjunction with the combustible configuration exposing the structural steel to determine if the combustible configuration would cause structural steel temperatures in excess of the critical temperature.

No situations were found where the addition of fireproofing materials was determined to be necessary to keep structure steel temperatures below the critical temperature.

For areas acting as fire area barriers:

a) The structural steel supporting the roof of the Reactor Building switchgear rooms (Fire Zone 1-4C, 1-4D, 1-5F, 1-5G, 2-4C, 2-4D, 2-5F and 2-5G) were confirmed to already be provided with 3-hour fire rated fireproofing (These are not the subject of deviation request #6).

b) The specific combustible configurations and justifications for each of the remaining fire rated areas is contained in Deviation Request #6, Non-Fireproofed Structural Steel.

5.0 MODIFICATIONS

No modifications are required.

6.0 Schedule

Schedule data for modifications is not applicable. No modifications were identified by this analysis.

7.0 Compensatory Measures

Compensatory measures are not applicable. No deficiencies were identified by this analysis.

8.0 Conclusion

The evaluation of the structural steel in the Susquehanna Steam Electric Station Unit #1 and #2 Reactor Buildings has determined, based on the conservative evaluation criteria outlined in this report, not to require structural steel fire proofing.

With these results, as summarized in Deviation Request #6, Non-Fireproofed Structural Steel, all structural steel is justified.

tg/i327i:clb

APPENDIX A

FIGURES

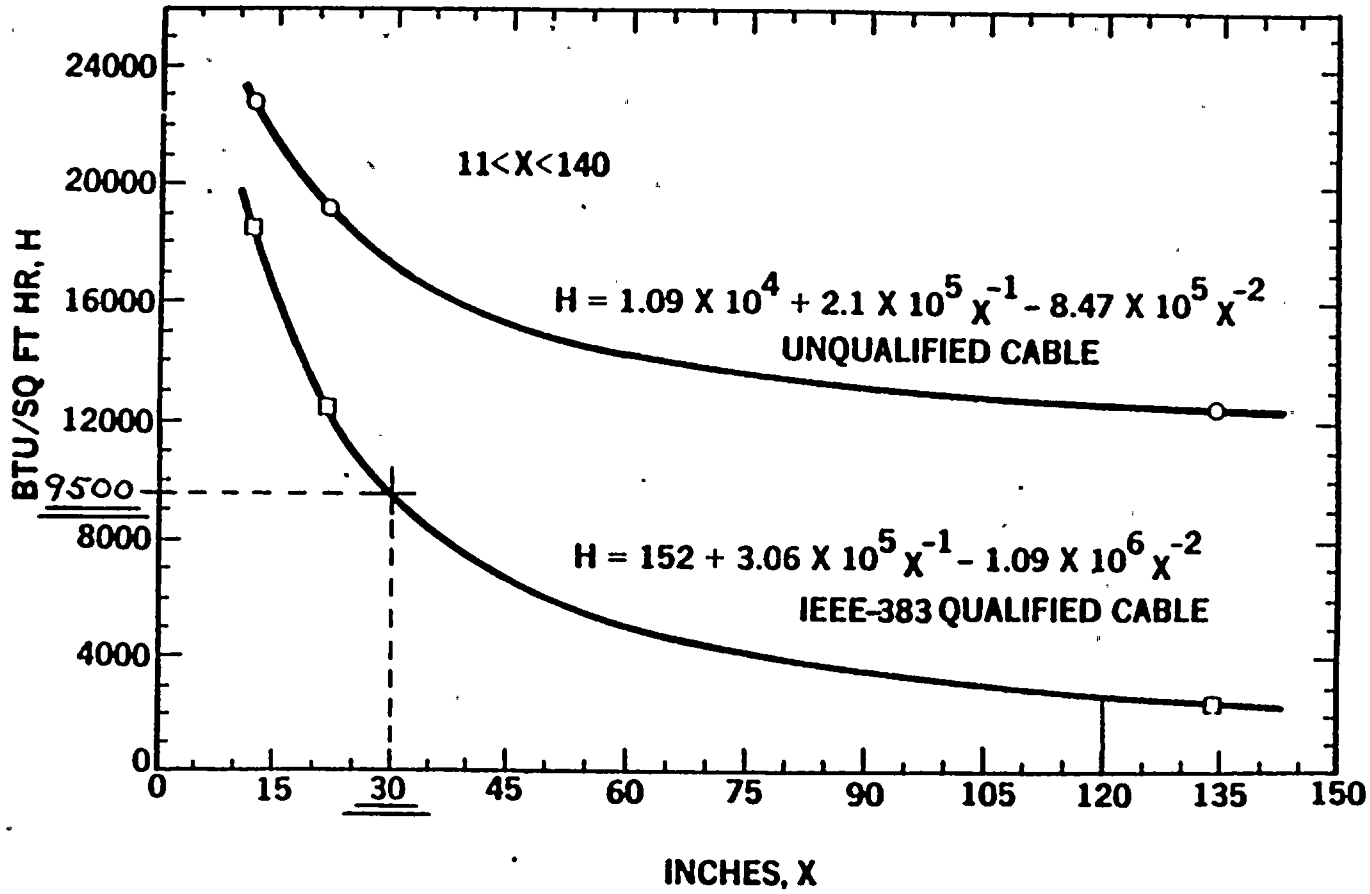
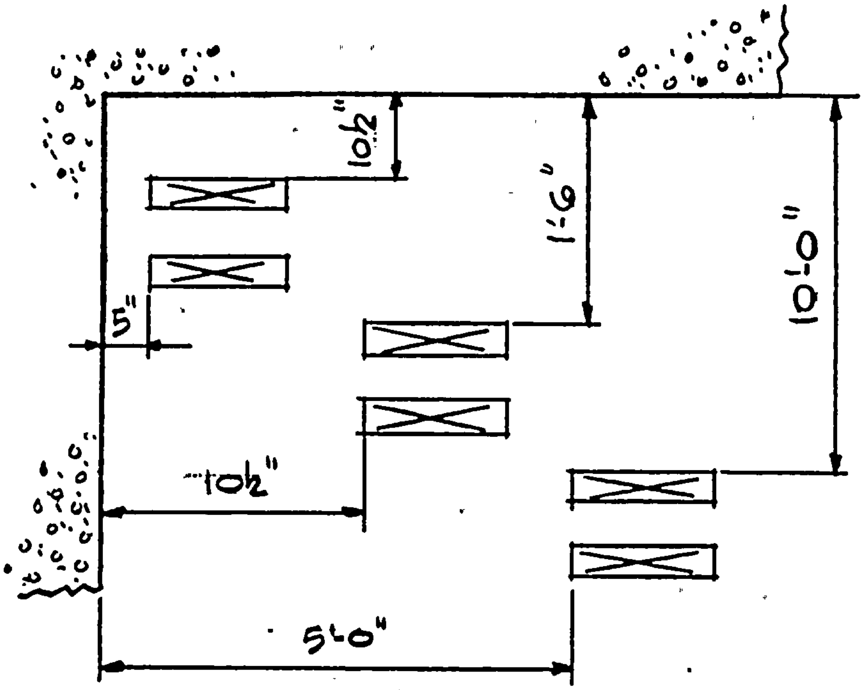


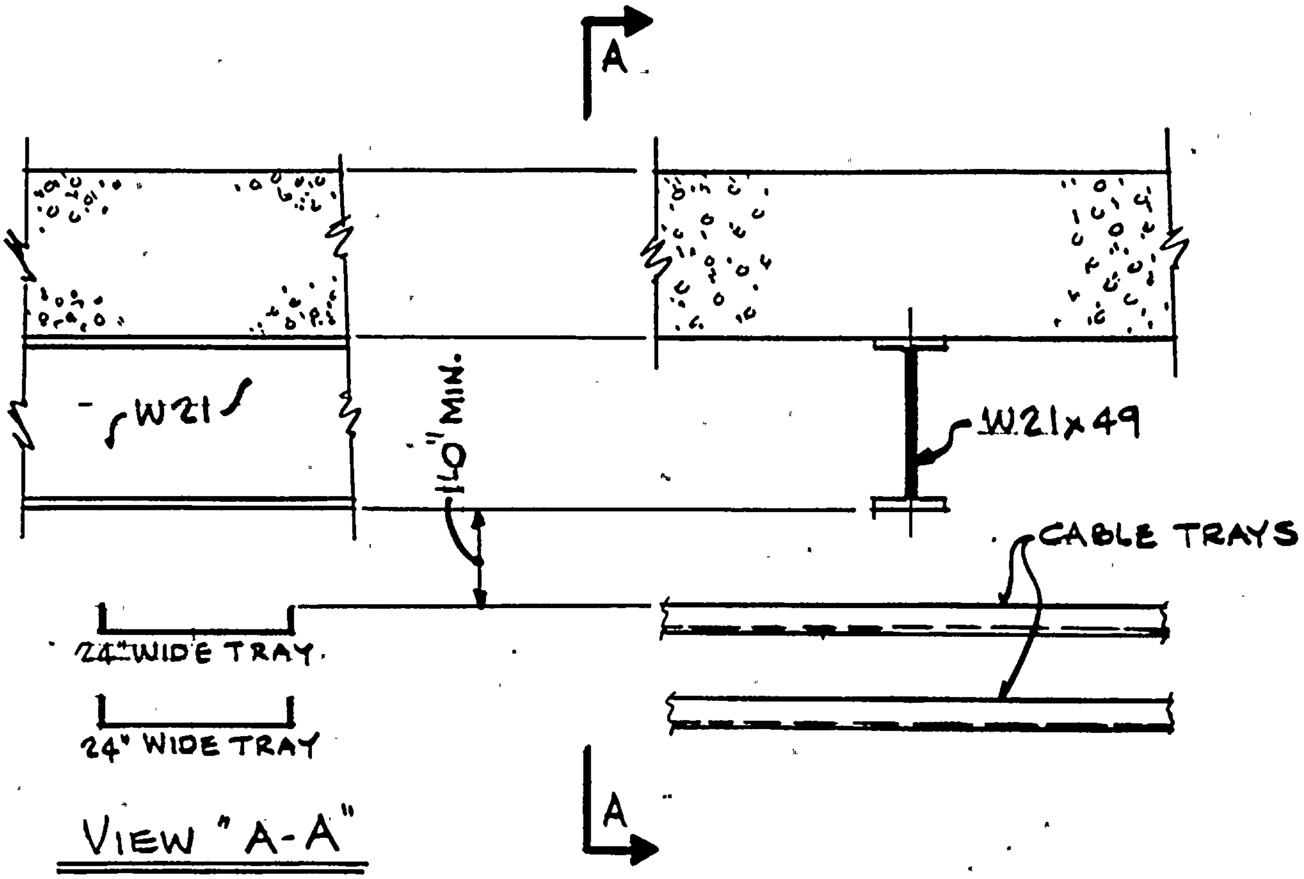
FIGURE 1.0

(From Figure 7 of the Sandia Corner Effects Test-Ref. 4)



SANDIA CORNER TEST
CABLE TRAY ARRANGEMENT.

FIGURE 2.0



VIEW "A-A"

TWO (2) HORIZONTAL
CABLE TRAY CRITERIA.

FIGURE 3.0

APPENDIX B

REFERENCES

1. Sandia Fire Retardant Coating Test
   12-7-77 to 1-31-78 Sand78-0518

2. NFPA Code 251 - Standard Methods of Fire Tests of Building, Construction Materials 1985 Edition

3. NFPA Code 231C - Rack Storage of Materials 1980 Edition

4. Sandia Fire Protection Research Program
   Corner Effects Tests - Sand79-0966

5. Categorization of Cable Flammability Intermediate Scale Fire Tests of Cable Tray Installations - EPRI NP-1881, August 1982.

6. NRC's Branch Technical Position CMEP 9.5-1 (Rev. 2).

7. Sandia Investigation of Twenty-Foot Separation Distance as a Fire Protection Method as Specified in 10CFR50, Appendix R SAND83-0306.

8. Manual of Steel Construction - 8th edition AISC, Inc.

9. Vendor Drawing M-343 layout drawing and hydraulic calculations.

10. Evaluating Upsprinklered Fire Hazards, Alpert and Ward, Factor Mutual Research (RC84-Bt-9).

11. Fire Protection Review Report (Rev. 2) Susquehanna Steam Electric Station.

12. Chemical Engineers' Handbook - 4th edition, J. H. Perry.

13. Building Code Requirements for Reinforced Concrete, ACI 318-83.

UNIT 1 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 1-1F

Reference Drawing C-206006, Sheet 1

Description:

The fire rated floor slab in question is 2'-9" thick and the top of slab is at elevation 683'-0". This reinforced concrete slab acts compositely with the structural steel beams to support this elevation as shown on the reference drawing. The source of combustibles in this area is two horizontal cable trays located approximately 12' beneath the bottom of the structural steel beams.

Evaluation:

Section 3.3 of the Summary Report for Structural Steel Evaluation provides justification for the adequacy of structural steel for a combustible configuration of two horizontally stacked cable trays. The two cable trays in this fire zone are located approximately 12' beneath the bottom of the structural steel beams whereas the cable trays discussed in Section 3.3 of the report are only one foot below the steel beams. This increased distance adds to the margin of safety already contained in the Section 3.3 analysis.

Conclusion:

The fire rated floor slab above Fire Zone 1-1F as shown on Drawing C-206006, Sheet 1, will not be adversely affected by a fire in Fire Zone 1-1F since a postulated fire in Fire Zone 1-1F would not generate sufficient heat to weaken the structural steel beams supporting the fire rated floor slab.

fm/i395i:dek

UNIT 2 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 2-6A

Reference Drawing C-206016, Sht. 1

DESCRIPTION:

The fire rated floor slab in question is 1'-9" thick and the top of slab is at elevation 779'-1". This reinforced concrete slab acts compositely with the structural steel beams to support this elevation as shown on the reference drawing. The source of combustibles in this area is 3 horizontal cable trays stacked on top of each other.

EVALUATION:

The area directly beneath the portion of the floor slab which is fire rated has no cable trays, however, 3 horizontally stacked cable trays are located beneath the W30X190 structural steel beams which support the area floor slab at elevation 799'-1". These structural steel beams were evaluated by the Energy Balance Method described in Section 3.2 of the Summary Report for Structural Steel Evaluation. This analysis demonstrated that the ratio of the critical energy needed to heat each W30X190 structural steel beam to the critical temperature (Ec_t) to the predicted heat release for the combustible configuration surrounding each beam (H') to be greater than the required minimum value of 1.0. This analysis verifies the integrity of the required structural steel beams supporting the fire rated floor slab in question.

CONCLUSION:

Based on the above evaluation and the specific combustible configuration beneath this fire rated floor slab as shown on the reference drawing, a postulated fire in Fire Zone 2-6A would not generate sufficient heat to weaken the structural steel beams supporting the fire rated floor slab.

fm/j092i:mab

UNIT 2 FIRE RATED FLOOR SLAB
ABOVE FIRE ZONES 2-4A-W AND 2-4A-S

Reference Drawing C-206013, Sheet 4

Description:

The fire rated floor slab in question is 1'-9" thick and the top of the slab is at elevation 749'-1". This reinforced concrete slab acts compositely with a series of structural steel beams to support this floor elevation as shown on the reference drawing. The source of combustibles in this area is two horizontal cable trays.

Evaluation:

The portions of Fire Zones 2-4A-W and 2-4A-S located beneath the fire rated floor slab in question is protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in these portions of Fire Zones 2-4A-W and 2-4A-S, actuation of the automatic sprinkler system would mitigate the heat effect the fire would have on the structural steel beams supporting this fire rated floor slab. The basis for this evaluation is presented in Section 3.4 of the Summary Report for Structural Steel Evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

Conclusion:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/i455i:mab

UNIT 2 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 2-4A-W

Reference Drawing C-206013, Sheets 2 & 3

Description:

The fire rated floor slab in question is 1'-9" thick east of column line T and 3'-3" thick west of column line T. The top of slab elevation for the entire slab is at elevation 749'-1". This reinforced concrete slab acts compositely with the structural steel beams to support this elevation as shown on the reference drawing. The combustibles in Fire Zone 2-4A-W located beneath this fire rated floor slab consist of three horizontal cable trays as depicted on the reference drawing.

Evaluation:

The entire section of Fire Zone 2-4A-W located beneath the fire rated floor slab in question is protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in this portion of Fire Zone 2-4A-W, actuation of the automatic fire suppression sprinkler system would mitigate the heat effects on the structural steel beams supporting the fire rated floor slab. The basis for this evaluation is presented in Section 3.4 of the Summary Report for Structural Steel Evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

Conclusion:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/i399i:dek

UNIT 2 FIRE RATED FLOOR SLAB
ABOVE FIRE ZONES 2-4A-S AND 2-4A-W

Reference Drawing C-206013, Sheet 1

Description:

The fire rated floor slab in question is 1'-9" thick and the top of slab is at elevation 749'-1". This reinforced concrete slab acts compositely with the structural steel beams to support this elevation as shown on the reference drawing. The combustibles in Fire Zone 2-4A-S and 2-4A-W located beneath this fire rated floor slab consist of two horizontal cable trays stacked on top of each other as shown on the reference drawing.

Evaluation:

The entire section of Fire Zones 2-4A-S and 2-4A-W located beneath the fire rated floor slab in question is protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in these portions of Fire Zones 2-4A-W and 2-4A-S, actuation of the automatic fire suppression sprinkler system would mitigate the heat effect of the fire on the structural steel beams supporting this fire rated floor slab. The basis for this evaluation is presented in Section 3.4 of the Summary Report for Structural Steel Evaluation. This section of the report provides justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

Conclusion:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/i397i:dek

UNIT 2 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 2-3B-W

Reference Drawing C-206022, Sht. 2

DESCRIPTION:

The fire rated floor slab in question is 2'-3" thick with the top of slab at elevation 719'-1". This reinforced concrete slab acts compositely with the structural steel beams which support this floor elevation. The source of combustibles in this area is cable trays.

EVALUATION:

The portion of Fire Zone 1-3B-W located beneath the fire rated floor slab in question is protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in this portion of Fire Zone 2-3B-W, actuation of the automatic sprinkler system would mitigate the heat effect the fire would have on the structural steel beams supporting the fire rated floor slab. The basis for this evaluation is presented in Section 3.4 of the Summary Report for structural steel evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with regards to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

CONCLUSION:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/j075i:mab

UNIT 2 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 2-3B-W

Reference Drawing C-206022,Sht. 1

DESCRIPTION:

The fire rated floor slab in question is 2'-3" thick with the top of slab at elevation 719'-1". This reinforced concrete slab acts compositely with the structural steel beams which support this floor elevation. The source of combustibles in this area is cable trays.

EVALUATION:

The portion of Fire Zone 1-3B-W located beneath the fire rated floor slab in question is protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in this portion of Fire Zone 2-3B-W, actuation of the automatic sprinkler system would mitigate the heat effect the fire would have on the structural steel beams supporting the fire rated floor slab. The basis for this evaluation is presented in Section 3.4 of the Summary Report for structural steel evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

CONCLUSION:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/j074i:mab

UNIT 2 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 2-3B-N

Reference Drawing C-206012, Sheets 1 and 2

Description:

The fire rated floor slab in question is 4'-9" thick and the top of slab is at elevation 719'-1". This reinforced concrete slab acts compositely with the structural steel beams to support this elevation as shown on the reference drawing. The primary source of combustibles in Fire Zone 2-3B-N located beneath the fire rated floor slab consist of a number of horizontal and vertical cable trays. The location of these cable trays are shown on the reference drawing.

Evaluation:

The entire section of Fire Zone 2-3B-N located beneath the fire rated floor slab in question is protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in this portion of Fire Zone 2-3B-N, actuation of the automatic fire suppression sprinkler system would mitigate the heat effects of the fire on the structural steel beams supporting the fire rated floor slab. The basis for this evaluation is presented in Section 3.4 of the Summary Report for Structural Steel Evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

Conclusion:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/i398i:dek

UNIT 2 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 2-1E

Reference Drawing C-206011, Sheet 2

Description:

The fire rated floor slab in question is 2'-9" thick and the top of slab is at elevation 683'-0". This reinforced concrete slab acts compositely with the structural steel beams to support this elevation as shown on the reference drawing. There are no cable trays in Fire Zone 2-1E located beneath this fire rated floor slab.

Evaluation:

With no cable trays located beneath this fire rated floor slab, sufficient heat to adversely affect the fire rated floor slab would not be generated. Section 3.3 of the Summary Report for Structural Steel Evaluation provides justification for the adequacy of structural steel for a combustible configuration of two horizontally stacked cable trays. This area has no cable trays.

Conclusion:

The fire rated floor slab above Fire Zone 2-1E as shown on Drawing C-206011, Sheet 2, will not be adversely affected by a fire in Fire Zone 2-1E since a postulated fire in Fire Zone 2-1E would not generate sufficient heat to weaken the structural steel beams supporting the fire rated floor slab.

fm/i415i:dek

UNIT 1 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 1-4G

Reference Drawing C-206009, Sheets 1 & 2

Description:

The fire rated slab in question is 1'-2-1/2" thick with the top of slab at elevation 761'-10". This slab acts compositely with a series of structural steel beams as shown on the reference drawing. The source of combustibles beneath the fire rated slab consist of two cable trays which vary in elevation but are no closer than 18' from the bottom of the floor slab.

Evaluation:

Section 3.3 of the Summary Report for Structural Steel Evaluation provides justification that two horizontally stacked cable trays will not adversely affect the integrity of the structural steel beams. The two cable trays in this fire zone are located approximately 16' below the overhead structural steel beams whereas the cable trays discussed in Section 3.3 of the report are only one foot below the steel beams. This increased distance adds to the margin of safety already contained in the Section 3.3 analysis. Furthermore, an analysis using the Energy Balance Method as developed in Section 3.2 of the Summary Report showed the ratio of the critical energy needed to heat the minimum required structural steel members to the critical temperature (Ec_t) to the predicted heat release for this combustible configuration (H') to be 6.4 which is much greater than the required minimum value of 1.0. This analysis substantiates the integrity of the structural steel beams above this combustible configuration.

Conclusion:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the structural steel beams supporting elevation 761'-10" above Fire Zone 1-4G will not be adversely affected as the result of a postulated fire in this area.

fm/i394i:dek

UNIT 1 FIRE RATED FLOOR SLAB
ABOVE FIRE ZONES 1-4A-W AND 1-4A-S

Reference Drawing C-206008, Sht. 4

DESCRIPTION:

The fire rated floor slab in question is 1'-9" thick with the top of slab at elevation 749'-1". This reinforced concrete floor slab acts compositely with the structural steel beams to support this elevation as shown on the reference drawing. The source of combustibles beneath this fire rated floor slab is two vertical cable trays which are separated from each other by approximately 20'.

EVALUATION:

The portions of Fire Zones 1-4A-W and 1-4A-S located beneath the fire rated floor slab in question are protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in these portions of Fire Zones 1-4A-W and 1-4A-S, actuation of the automatic fire suppression sprinkler system would mitigate the heat effect the fire would have on the structural steel beams supporting the fire rated floor slab system. The basis for this evaluation is presented in Section 3.4 of the Summary Report for structural steel evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

CONCLUSION:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/i447i:mab

UNIT 1 FIRE RATED FLOOR SLAB
ABOVE FIRE ZONES 1-4A-W AND 1-4A-N

Reference Drawing C-206008, Sheet 2

Description:

The fire rated floor slab in question is 1'-9" thick and the top of the slab is at elevation 749'-1". This reinforced concrete slab acts compositely with a series of structural steel beams to support this floor elevation as shown on the reference drawing. The primary source of combustibles in this area is two cable trays spaced approximately 12' from each other.

Evaluation:

The portion of Fire Zones 1-4A-W and 1-4A-N located beneath the fire rated floor slab in question is protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in this portion of Fire Zones 1-4A-W and 1-4A-N, actuation of the automatic sprinkler system would mitigate the heat effect the fire would have on the structural steel beams supporting the fire rated floor slab system. The basis for this evaluation is presented in Section 3.4 of the Summary Report for Structural Steel Evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustion configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

Conclusion:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/i393i:dek

UNIT 1 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 1-3B-W

Reference Drawing C-206021, Sht. 1

DESCRIPTION:

The fire rated floor slab in question is 2'-3" thick with the top of slab at elevation 719'-1". This reinforced concrete slab acts compositely with the structural steel beams which support this floor elevation. The source of combustibles in this area is cable trays.

EVALUATION:

The portion of Fire Zone 1-3B-W located beneath the fire rated floor slab in question is protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in this portion of Fire Zone 1-3B-W, actuation of the automatic sprinkler system would mitigate the heat effect the fire would have on the structural steel beams supporting the fire rated floor slab. The basis for this evaluation is presented in Section 3.4 of the Summary Report for Structural Steel Evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

CONCLUSION:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/j062i:mab

UNIT 1 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 1-1E

Reference Drawing C-206006, Sheet 2

Description:

The fire rated floor slab in question is 2'-9" thick and the top of slab is at elevation 683'-0". This reinforced concrete slab acts compositely with the structural steel beams to support this elevation as shown on the reference drawing. There are no cable trays in Fire Zone 1-1E located beneath this fire rated floor slab.

Evaluation:

With no cable trays located beneath this fire rated floor slab, sufficient heat to adversely affect the fire rated floor slab would not be generated. Section 3.3 of the Summary Report for Structural Steel Evaluation provides justification for the adequacy of structural steel for a combustible configuration of two horizontally stacked cable trays. This area has no cable trays.

Conclusion:

The fire rated floor slab above Fire Zone 1-1E as shown on Drawing C-206006, Sheet 2, will not be adversely affected by a fire in Fire Zone 1-1E since a postulated fire in Fire Zone 1-1E would not generate sufficient heat to weaken the structural steel beams supporting the fire rated floor slab.

fm/i414i:dek

UNIT 1 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 1-3A

Reference Drawing C-206007, Shts. 1 and 2

DESCRIPTION:

The fire rated floor slab in question varies in thickness from 2'-9" to 4'-9" as shown on the reference drawing, Sheet 2. The top of the entire slab is at elevation 719'-1". The source of combustibles beneath this fire rated floor slab is a series of horizontal and vertical cable trays as depicted on the reference drawing. It should be noted that the top two trays are committed to be fire wrapped.

EVALUATION:

A structural analysis was performed on the 4'-9" thick portion of the reinforced concrete slab above the fire zone in question. The analysis demonstrated that this reinforced concrete slab is capable of supporting itself without the W21x127 beams which underlie it. The only required structural steel beams beneath the 4'-9" thick slab are the W21X127 steel beams (with a 2" thick steel plate on the bottom flange) which lie directly under the 4'-6" thick walls.

The required steel beam south of column line 25 is protected from the effects of a fire by the NFPA 13 sprinkler system. Section 3.4 of the Summary Report for Structural Steel Evaluation provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this required steel beam is bounded by the analysis in Section 3.4.

The required W21X127 steel beam north of column line 25 was analyzed by the Energy Balance Method as developed in Section 3.2 of the Summary Report. This analysis calculated the ratio of the critical energy needed to heat this structural steel beam to the critical temperature (Ec_t) to the predicted heat release for this combustible configuration (H') to be 1.17 which is greater than the required minimum value of 1.0. This analysis verifies the structural integrity of the required W21X127 steel beam.

A structural analysis was also performed on the 2'-9" thick portion of the reinforced concrete slab above the fire zone in question. This analysis demonstrated that this reinforced concrete slab is capable of supporting itself without the two W24X55 steel beams which underlie it. This slab is supported on the south end by the W21X127 (acceptability as discussed above) and on the north end by the 2'-0" thick concrete wall beneath the slab. Therefore, the heat effect on the W24X55 steel beams is inconsequential since the 2'-9" concrete slab is structurally acceptable without these 2 steel beams.

CONCLUSION:

Based on the above evaluation, the fire rated floor slab above Fire Zone 1-3A will not be adversely affected as the result of a postulated fire in this area.

fm/i448i:mab

UNIT 1 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 1-3B-W

Reference Drawing C-206021, Sht. 2

DESCRIPTION:

The fire rated floor slab in question is 2'-3" thick with the top of slab at elevation 719'-1". This reinforced concrete slab acts compositely with the structural steel beams which support this floor elevation. The source of combustibles in this area is cable trays.

EVALUATION:

The portion of Fire Zone 1-3B-W located beneath the fire rated floor slab in question is protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in this portion of Fire Zone 1-3B-W, actuation of the automatic sprinkler system would mitigate the heat effect the fire would have on the structural steel beams supporting the fire rated floor slab. The basis for this evaluation is presented in Section 3.4 of the Summary Report for Structural Steel Evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

CONCLUSION:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/j076i:mab

UNIT 1 FIRE RATED FLOOR SLAB
ABOVE FIRE ZONE 1-4A-W

Reference Drawing C-206008, Sheets 1 & 3

Description:

The fire rated floor slab in question is 1'-9" thick south of column line 26.5 and 3'-3" thick north of column line 26.5 as depicted on the reference drawing. The top of the entire slab is at elevation 749'-1". This reinforced concrete slab acts compositely with a series of structural steel beams which support this floor elevation. The source of combustibles in Fire Zone 1-4A-W consist of a number of cable trays located throughout the fire zone.

Evaluation:

The portion of Fire Zone 1-4A-W located beneath the fire rated floor slab in question is protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in this portion of Fire Zone 1-4A-W, actuation of the automatic sprinkler system would mitigate the heat effect the fire would have on the structural steel beams supporting the fire rated floor slab. The basis for this evaluation is presented in Section 3.4 of the Summary Report for Structural Steel Evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

Conclusion:

Based on the above evaluation and the specific combustion configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/i392i:dek

UNIT 1 FIRE RATED FLOOR SLAB
ABOVE FIRE ZONES 1-4A-W AND 1-4-N

Reference Drawing C-206008, Sht. 5

DESCRIPTION

The fire rated floor slab in question is 1'-9" thick with the top of slab at elevation 749'-1". This reinforced concrete slab acts compositely with the structural steel beams to support this elevation as shown on the reference drawing. The source of combustibles beneath this fire rated floor slab is cable trays.

Evaluation:

The portions of Fire Zones 1-4A-W and 1-4A-N located beneath the fire rated floor slab in question are protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in these portions of Fire Zones 1-4A-W and 1-4A-N, actuation of the automatic sprinkler system would mitigate the heat effect the fire would have on the structural steel beams supporting the fire rated floor slab system. The basis for this evaluation is presented in Section 3.4 of the Summary Report for Structural Steel Evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

Conclusion:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/i453i:mab

UNIT 1 FIRE RATED FLOOR SLAB
ABOVE FIRE ZONE 1-5A-S

Reference Drawing C-206010, Sheets. 1 & 2

Description:

The fire rated slab in question is 3'-0" thick approximately 5-1/2' south of column line 27.5 and 1'-9" thick north of this point. The top of the entire slab is at elevation 779'-1". This slab acts compositely with a series of structural steel beams as shown on the reference drawing. The combustibles in Fire Zone 1-5A-S consist of a number of horizontal and vertical cable trays located throughout the fire zone.

Evaluation:

The portion of Fire Zone 1-5A-S located beneath the fire rated slab in question is protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in this portion of Fire Zone 1-5A-S, actuation of the automatic suppression system would mitigate the effects of the fire on the structural steel beams supporting this fire rated floor slab. The basis for this evaluation is presented in Section 3.4 of the Summary Report for Structural Steel Evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

Conclusion:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/i383i:dek

UNIT 2 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 2-1F

Reference Drawing C-206011, Sheet 1

Description:

The fire rated floor slab in question is 2'-9" thick and the top of slab is at elevation 683'-0". This reinforced concrete slab acts compositely with the structural steel beams to support this elevation as shown on the reference drawing. The source of combustibles in this area is two horizontal cable trays located approximately 11' beneath the bottom of the structural steel beams.

Evaluation:

Section 3.3 of the Summary Report for Structural Steel Evaluation provides justification for the adequacy of structural steel for a combustible configuration of two horizontally stacked cable trays. The two horizontally stacked cable trays in this fire zone are located approximately 11' beneath the bottom of the structural steel beams whereas the cable trays discussed in Section 3.3 of the report are only one foot below the steel beams. This increased distance adds to the margin of safety already contained in the Section 3.3 analysis.

Conclusion:

The fire rated floor slab above Fire Zone 2-1F as shown on Drawing C-206011, Sheet 1, will not be adversely affected by a fire in Fire Zone 2-1F since a postulated fire in Fire Zone 2-1F would not generate sufficient heat to weaken the structural steel beams supporting the fire rated floor slab.

fm/i396i:dek

UNIT 2 FIRE RATED FLOOR SLAB
ABOVE FIRE ZONES 2-5C, 2-5A-S AND 2-5B

Reference Drawing C-206015, Shts. 1, 2 and 3.

DESCRIPTION:

The fire rated floor slab in question varies in thickness from 1'-9" to 2'-3" as shown on the reference drawing. The top of the entire slab is at elevation 779'-1". This reinforced concrete slab acts compositely with the structural steel beams to support this elevation as shown on the reference drawing. The combustibles in these fire zones located beneath the fire rated floor slab are cable trays of varying elevation and location as shown on the reference drawing.

EVALUATION:

The portion of the fire rated floor slab located north of column line 34.5 has only two horizontal cable trays. Section 3.3 of the Summary Report for Structural Steel Evaluation provides the justification for the adequacy of structural steel for a combustible configuration of two horizontally stacked cable trays. The condition analyzed in the summary report bounds this combustible configuration of two side-by-side horizontal cable trays.

The portion of the fire rated floor slab in question located south of column line 34.5 has been structurally evaluated to determine which steel beams are the minimum required to support this entire floor slab area. The results of this analysis concluded that five structural steel beams are necessary to support the floor slab. These steel beams are noted on Sht. 1 of the reference drawing. The other beams are not required since the 2'-9" thick reinforced concrete slab is capable of spanning between these five required members.

These five required steel beams were then analyzed by the Energy Balance Method as developed in Section 3.2 of the Summary Report for Structural Steel Evaluation. This analysis determined the ratio of the critical energy needed to heat each required structural steel beam to the critical temperature (Ec_t) to the predicted heat release for the combustible configuration surrounding each beam (H'). In all five instances this ratio "(Ec_t/H')" was determined to be greater than the required minimum value of 1.0. This analysis verifies the integrity of the required structural steel beams in the area in the event of a postulated fire.

CONCLUSION:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, a postulated fire in Fire Zones 2-5C, 2-5A-S and 2-5B would not generate sufficient heat to adversely impact the required structural steel beams supporting the fire rated floor slab.

fm/j089i:mab

UNIT 2 FIRE RATED FLOOR SLAB ABOVE FIRE ZONE 2-4G

Reference Drawing C-206014, Sheets 1 & 2

Description:

The fire rated floor slab in question is 1'-2-1/2" thick with the top of slab at elevation 761'-10". This reinforced concrete slab acts compositely with the structural steel beams to support this elevation as shown on the reference drawing. The source of combustibles in this fire zone is two cable trays located greater than 16' below the structural steel supporting this elevation.

Evaluation:

Section 3.3 of the Summary Report for Structural Steel Evaluation provides justification that two horizontally stacked cable trays will not adversely affect the integrity of the structural steel beams. The two cable trays in this fire zone are located approximately 14' below the overhead structural steel beams whereas the cable trays discussed in Section 3.3 of the report are only one foot below the steel beams. This increased distance adds to the margin of safety already contained in the Section 3.3 analysis. Furthermore, an analysis using the Energy Balance Method as developed in Section 3.2 of the Summary Report showed the ratio of the critical energy needed to heat the structural steel to the critical temperature (Ec_t) to the predicted heat release for this combustible configuration (H') to be approximately 6.4 which is much greater than the required minimum value of 1.0. This analysis substantiates the integrity of the structural steel beams above this combustible configuration.

Conclusion:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the structural steel beams supporting elevation 761'-10" above Fire Zone 2-4G will not be adversely affected as the result of a postulated fire in this area.

fm/i413i:dek

UNIT 2 FIRE RATED FLOOR SLAB
ABOVE FIRE ZONES 2-4A-W AND 2-4A-N

Reference Drawing C-206013, Sheet 5

Description:

The fire rated floor slab in question is 1'-9" thick and the top of the slab is at elevation 749'-1". This reinforced concrete slab acts compositely with a series of structural steel beams to support this floor elevation as shown on the reference drawing. The source of combustibles in this area is cable trays located throughout the fire zones.

Evaluation:

The portions of Fire Zones 2-4A-W and 2-4A-N located beneath the fire rated floor slab in question is protected by an automatic fire suppression sprinkler system which has been installed in accordance with NFPA 13. In the event of a fire in these portions of Fire Zones 2-4A-W and 2-4A-N, actuation of the automatic sprinkler system would mitigate the heat effect the fire would have on the structural steel beams supporting this fire rated floor slab. The basis for this evaluation is presented in Section 3.4 of the Summary Report for Structural Steel Evaluation. This section of the report provides the justification for the NFPA 13 sprinkler system's heat absorption capability with respect to cable tray fires. The combustible configuration beneath this fire rated floor slab is bounded by the analysis in Section 3.4.

Conclusion:

Based on the above evaluation and the specific combustible configuration beneath the fire rated floor slab in question, the existing automatic fire suppression sprinkler system can be expected to protect the structural steel beams with a wide margin of safety in the event of a postulated fire in this area.

fm/i456i:mab