From: Naeem IQBAL HQ
To: Caswell Smith R2
Date: Thu, Feb 19, 2004 3:09 PM
Subject: Re: Hatch Fire Model

Caswell,

Attached is your document with my markups in red color.

Please call me if you have any questions.

Naeem

>>> Caswell Smith 02/19/04 01:59PM >>>
Naeem, attached is the fire model analysis you performed that I have edited based on our continuing discussions. I have also incorporated the revised version of Table 4 that you sent me.

Please review it to ensure that I have not introduced any technical errors. Thank you for your assistance

Caswell

CC: Charles R. Ogle; Gerald Wiseman; Kathleen O'Donohue

T-17

FIRE MODELING FOR FIRE AREA 2104 EAST CABLEWAY
EDWIN I. HATCH NUCLEAR PLANT UNIT 1

Scope and Objectives

Fire modeling of the of the Edwin I. Hatch Nuclear Plant, Fire Area 2104, Unit 2 East Cableway; Control and Turbine Building El. 130 feet 0 inches, (Appendix R, III.G.2 area) have been performed to predict the potentially hazardous conditions (increased temperature) that could exist during postulated fire and to assess the associated damage potential to safe shutdown components and circuits or equipment of redundant trains of systems for safe shutdown in accordance with the guidelines provided in National Fire Protection Association, NFPA 805, Appendix C, 2001 Edition. The multi-zone fire model CFAST (Consolidated Model of Fire Growth and Smoke Transport) was used to determine the Eeast Ceableway conditions for the credible fire scenario.

Assumptions and Limitations

(1) The results of this analysis are predicated on the assumption that ignition of the lubricating oil occurs. A credible ignition source is the Reactor Feed Pump (RFP) Conditioner Lube Oil Circulating Pump motor which is located close to the concrete pad on which the RFP Turbine Oil Conditioner is mounted. This motor is installed in the diked area where spilled lubricating oil would accumulate in the event of an oil leak. Another potential ignition source is a motor blower assembly that is mounted directly on top of the RFP Turbine Oil Conditioner. Both motors are fractional horse power motors with 120 Volts AC power supplies. Additionally, there are two level switches installed on the oil conditioner which are credible ignition sources based on the 120 Volts AC control circuits in which they are installed.

(2) The CFAST model does not allow the user to specify vent location in the corridor.

(3) The concrete dike (curb) area to retain lube oil spill = (9 ft x 9 ft) - (foot print of oil conditioner)

$$= 81\ ft^2 - (53\ in \times 52\ in)\ /144\ \text{square in per square ft} = 62\ ft^2$$

(4) The bounding fire scenario is developed for a fire developing from a 255 gallon of combustible lubricating oil spilled from the RFP Turbine Oil Conditioner assuming that all available fuel burn. This event allows the fuel contents of the conditioner (heated lubricating oil) to spill and spread over the floor. For the purpose of evaluating the ability of the pool fire to ignite safe shutdown cables and circuits in Fire Area 2104, the worst case scenario is the largest pool area which can burn long enough to cause ignition to cables.

(5) Mechanical ventilation off.

(6) In keeping with sound engineering practice in the absence of technical information, conservative "worst case" assumptions are made regarding fuel loading, fuel package burning rates, fire spread, and thermophysical effects.

(7) The fire characteristics were estimated using draft NUREG-1805, Fire Dynamics Tools (FDT^s). Heat release rate (HRR), burning duration, and flame height was calculated for a lube pool fire.

Combustible Liquid Spill in Fire Area 2104 from Reactor Feed Pump Turbine Oil Conditioner

Accidental spills of combustible liquid fuel and resulting fires depend on a number of parameters, including the composition of the fuel, the size and the shape of the fire, the duration of the fire, its proximity to the object (target) at risk, and the thermal characteristics of the object exposed to the fire.

A liquid with a relatively high flash points requires localized heating to achieve ignition. Once ignited however, a pool fire will spread rapidly over the surface of the liquid spill area. The area of burning will be a function of the leak rate or the confinement of the spill area. While the burning rate of a given fuel can be affected by its substrate in a spill, any absorption characteristics of the substrate was not considered since the floor is smooth finished concrete. In this analysis it is conservatively assumed that the fuel spills over the surface of the dike and forms a pool with the region of burning maintained at its depth. The effect of this initiating fire event in Fire Area 2104 is evaluated.

Fire Growth Rate

Testing has shown that the overall HRR during the fire growth phase of many fires can often be characterized by the simple time dependent polynomial or exponential function (Heskestad and Delichatsios 1978). The total heat release of fuel packages can be reasonably approximated by the power law fire growth model for both a single item burning and for multiple items involved in a fire. The proposed model of the environment generated by fire in an enclosure is dependent on the assumption that the fire grows according to:

$$\dot{Q} = \alpha t^2 \qquad (1)$$

where

$\dot{Q}$ = the rate of heat release of fire (kW),
t = the time (sec), and
α = a constant governing the speed of fire growth (kW/sec^2)

The growth rate approximately follows a relationship proportional to time squared for flaming and radially spreading fires and is referred to as t-squared (t^2) fires. The t^2 fires are classed by speed of growth, labeled ultra-fast, fast, medium, and slow. Where these classes are used, they are defined on the basis of the time required for the fire to grow to a rate of heat release of 1,000 kW (1 MW). The intensity α, and growth time t, related to each of these classes is shown in Table 1.

Table 1 Summary of t^2 Fire Parameter		
Type of Fire Growth	Intensity Constant α (kW/sec^2)	Growth Time t (sec)
Slow	0.00293	600
Medium	0.01172	300
Fast	0.0469	150
Ultra-fast	0.1876	75

The t^2 relationship has proven to be useful and has been adopted into the National Fire Protection Association NFPA 72 to categorize fires for detector spacing requirements and into NFPA 92B for design of smoke control system.

The modeled fire can be represented as one where the HRR per unit area is constant over the entire ignited surface and the flame is spreading with a steadily increasing area. In such cases, the burning area increases as the square of the steadily increasing fire radius. Fires that do not have a regular fuel array and consistent burning rate might or might not actually produce a t^2 curve; however, the t^2 approximation appears to be reasonable for use in this case to produce a realistic approximation of the expected fire growth.

Test data on large pool fires demonstrated that the peak HRR per unit area will grow fast or ultra fast. For the purpose of this analysis a t^2 fast growth rate for the lube oil fire was assumed based on the experiments.

Heat Release Rate, Burning Duration and Flame Height Estimate

This analysis is used to determine the extent of potential fire damage associated with a realistic, potential fire scenario in Fire Area 2104. The analysis evaluates whether the postulated fire can lead to failure of safety-related cables, or equipment of redundant trains of systems for safe shutdown. The impact of the fire scenario is analyzed using fire dynamics principles or fire model (e.g., CFAST). The lube oil spill fire is modeled using the HRR depicted in Figure 1. The computer program then develops HRR based on the ventilation and other limitations. For pool fire scenario the calculated HRR, burning duration, and flame height were determined using FDT[s]. Table 2 summarizes the results of the calculations.

Table 2 Fire Characteristics of RFP Turbine Oil Conditioner Pool Fire		
Heat Release Rate $\dot{Q}$ kW (Btu/sec)	Burning Duration t_b sec (min.)	Flame Height H_f m (ft)
10,333 (9,794)	3,266 (55)	5.2 (17)

CFAST - Consolidated Model of Fire Growth and Smoke Transport

The multi-zone computer fire model CFAST was used to calculate the temperature in Fire Area 2104 [Peacock *et al.*, 1997; Peacock *et al.*, 1993]. CFAST was developed by the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST) for the development of fire models having both steady and unsteady state burning rates in multiple compartment configurations (multiple room capability, up to 15 rooms can be modeled). The initiating fire is user specified, but adjusted by CFAST based on the available supply of oxygen. CFAST allows fires to be constrained or unconstrained. A fire specified as unconstrained in CFAST will not be limited by the availability of oxygen. When a constrained fire is specified, the chemically required oxygen is calculated and the available oxygen and unburned gases are tracked. A mass balance calculation of individual species is performed for each zone to track the available oxygen and unburned gases. Multiple compartments and vents can be modeled as well as the mechanical ventilation. Mechanical ventilation is addressed by CFAST in terms of fan/ductwork that includes consideration of fan pressure/flow characteristic curves and duct friction losses. The model divides each compartment into two zones, an upper zone containing the hot gases produced by the fire and a lower zone containing all space beneath the upper zone. The lower zone is a source of air for combustion and is usually the location of the fire source.

The upper zone can expand to occupy virtually all of the space in the compartment. The upper zone is considered a control volume that receives both mass and energy from the fire and loses energy to the surfaces in contact with the upper zone by conduction and radiation, by radiation to the floor, and by convection or mass movement of gases through openings. The two layer zone approach used by the CFAST has evolved from observations of such layering in full-scale fire experiments (Jones et al., 2000). While these experiments show some variation in conditions within the layers, they are small compared to the differences in conditions between the layers themselves. Thus, the zone model can produce a fairly realistic simulation of the fire environment within a compartment under most conditions. CFAST has the capability to calculate the upper and lower layer temperature, the smoke density, the vent flow rate, the gas concentrations, and compartment boundary temperatures, the heat flux from the smoke layer to objects, the internal compartment pressure, and the interface elevation, all as a function of time.

A number of efforts of CFAST model comparison, verification and validation have been undertaken. Many of these efforts involved comparisons between measured and calculated parameters, primarily temperatures, mass flow rates and smoke layer interface positions. Duong, 1990, Peacock, et al., 1988, Mowrer and Gautier, 1997, Nelson and Deal, 1991, and EPRI TR-108875, 1998, compared CFAST model predictions with experimental data.

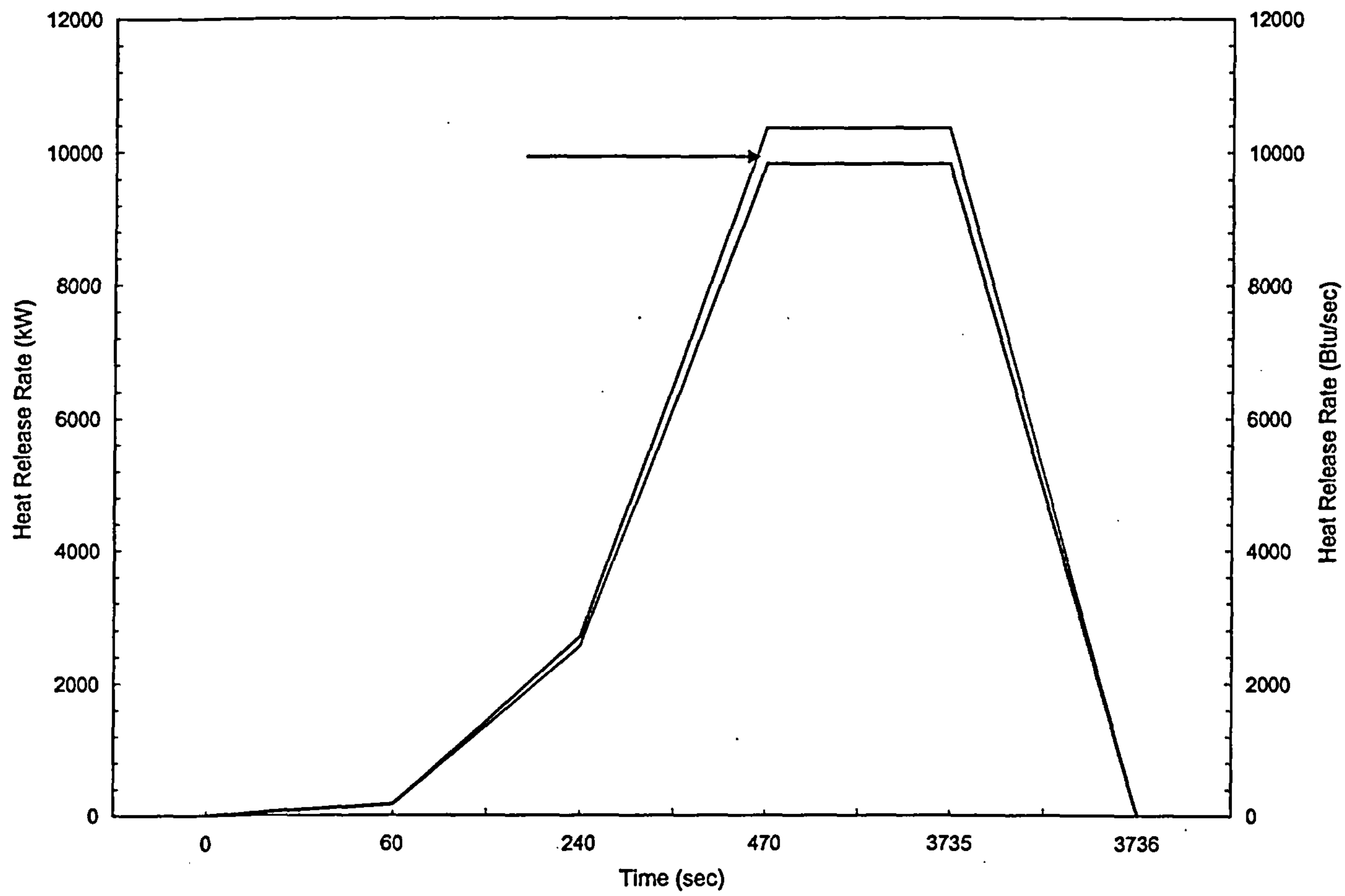

FIGURE 1

Figure 1 shows the ~~heat release rate~~ HRR for a fire in Fire Area 2104 with a maximum ~~heat release rate~~ HRR of 10,333 ~~K~~kW (9,794 Btu/sec).

Limitations and Uncertainties Associated with Fire Modeling

Fire models permit development of a better understanding of the dynamics of building fires and can aid in the fire safety decision-making process. There are certain limitations and uncertainties associated with the current fire modeling predictions. Extreme care must be exercised in the interpretation of the fire modeling results. For scenarios where the level of predicted hazard is well below the damage threshold, the results can be used with high level of confidence provided there is a high level of confidence that all risk-significant scenarios have been considered. For scenarios where the level of predicted hazard is near the damage threshold, the results should be used with caution in view of the uncertainties that exist.

A primary method of handling modeling uncertainties is the use of engineering judgment. Among other things, this judgment is reflected in the selection of appropriate fire scenario, hazard criteria, and fire modeling techniques. A slightly more formal application of engineering judgment is the use of safety factors. The safety factors can be applied in the form of fire size, increased or decreased fire growth rate, or conservative hazard criteria (Custer and Meacham, 1997). Experimental data obtained from fire test, statistical data from actual fire experience, and other expert judgment can be used improve the judgment and potentially decrease the level of uncertainty.

CFAST Modeling of Fire Area 2104 East Cableway

Fire modeling of Fire Area 2104 using CFAST was performed. A list of necessary inputs for CFAST is provided in Table 3. Additionally, Table 4 documents the input data file for the CFAST computer model. CFAST input data includes the physical dimensions of the compartment, the compartment construction materials, the opening dimensions and their elevations, the fire HRR and the position of the fire in the specified room, gas species production rate, and exterior wind conditions (see input file, Table 4). With the parameter chosen, CFAST provided information on the temperature in the room, the smoke interface height, and species concentration. This information was used in order to gain insights into the different possible fire scenario.

Table 3 Description of the CFAST Input Data File	
1	Compartment geometry: Width x Depth x Height = 5.20 m x 26.82 m x 4.72 m
2	Natural ventilation - Vent connection (horizontal and vertical flow connections between compartment in the structure including doors between compartment or window in the compartment between compartment or to the outside: Opening Width = 3.65 m, Height = 4.26 m
3	Mechanical Ventilation: Off
4	Compartment construction and thermal properties of the enclosing surfaces, i.e., ceiling, wall, and ceiling - 24" thick Concrete
5	Fire specification: information on the source of fire location, area of source fire, chemical properties of the fuel, heat of combustion of the fuel, species yields, fuel mass loss rate, and heat release of the fire (input HRR Figure 1) with fire time.

The peak upper gas layer temperature in the East Cableway , at the cable tray target location, calculated by CFAST is shown in Figure 2. Figure 2 shows that the average hot gas layer temperature of 625 °F (330 °C) would be achieved in approximately 400 seconds. This temperature of 625 °F ~~degrees Fahrenheit~~ is the threshold damage temperature of the two targeted 4-20 milliamp instrumentation circuit cables which are thermoset cables. The results of this analysis demonstrates that the temperature of the hot gas layer, and the duration of the fire, is sufficient to cause fire induced damage to safety-related cables and circuits that are routed in the East Cableway, between ~~c~~Column T19 and Column T16 (Drawing ------------). The target cable tray is located between ~~c~~Column T16 and ~~c~~Column T17, approximately 8.5 feet from ~~c~~Column T16. Therefore, it is reasonable to conclude that the bounding pool fire scenario will result in the two 4-20 milliamp instrumentation circuits reaching failure conditions. Additionally, if both instrumentation circuits fail non-conservatively because of increased leakage current caused by insulation damage, this condition will simulate a high nuclear boiler pressure condition and will result in logic being initiated to simultaneously open all eleven Safety Relief Valves (SRVs). Simultaneous opening of all eleven SRVs is the equivalent of a large break Loss of Coolant Accident (LOCA). Also, spurious opening of all eleven SRVs will result in the sudden depressurization of the nuclear boiler, and failure to maintain the suppression pool heat capacity temperature limit. The suppression pool heat capacity temperature limit is required to be maintained in order to ensure that safe shutdown equipment credited for mitigating this event will be capable of performing their design function.

Table 4 CFAST Input Data File

```
VERSN  3   HATCH Plant-Fire Area 2104, Oil Conditioner Pool Fire
TIMES 4000  60  60  60   0
TAMB  298. 101300. 0.0
EAMB  298. 101300. 0.0
HI/F   0.0  0.0   0.0   0.0
WIDTH  5.20
DEPTH  26.82
HEIGH  4.72
HVENT  1  2  1  3.65 4.26  0.0  0.0  0.0  0.0
CVENT  1  2  1  1.0  1.0   1.0  1.0  1.0  1.0
CEILI  CONCRETE
WALLS  CONCRETE
FLOOR  CONCRETE
CHEMI 16. 10. 10.  46000000.  298.  388. 0.2
LFBO  1
LFBT  2
FPOS  1.0  1.0  0.0
FTIME 60.0   240.0  470.0  3735.0  3736.0
FHIGH 0.5  0.5  0.5  0.5  0.5  0.5
FAREA 0.5  0.5  0.5  0.5  0.5  0.5
FQDOT 0.0  168840.0  2701440.0  10333000.0   10333000.0   0.0
CJET OFF
CO    0.03  0.03  0.03  0.03  0.03  0.03
OD    0.08  0.08  0.08  0.08  0.08  0.08
HCR   0.13  0.13  0.13  0.13  0.13  0.13
STPMAX  1.00
DUMPR HATCH1.Hi
DEVICE 1
WINDOW   0  0. -100. 1280. 1024. 1100.
GRAPH 1  170.  300.   0. 625.   820.  10.  5  TIME CELSIUS
GRAPH 2  765.  300.   0. 1220.  820.  10.  5  TIME FIRE_SIZE (kW)
LABEL 1  970.  960.   0. 1231.  1005. 10.  15 00:00:00    0.   0.
LABEL 2  690.  960.   0. 987.   1005. 10.  13 TIME_ [SEC] 0.   0.
TEMPERA  0  0  0  0  1   1 U
HEAT     0  0  0  0  2   1 U
```

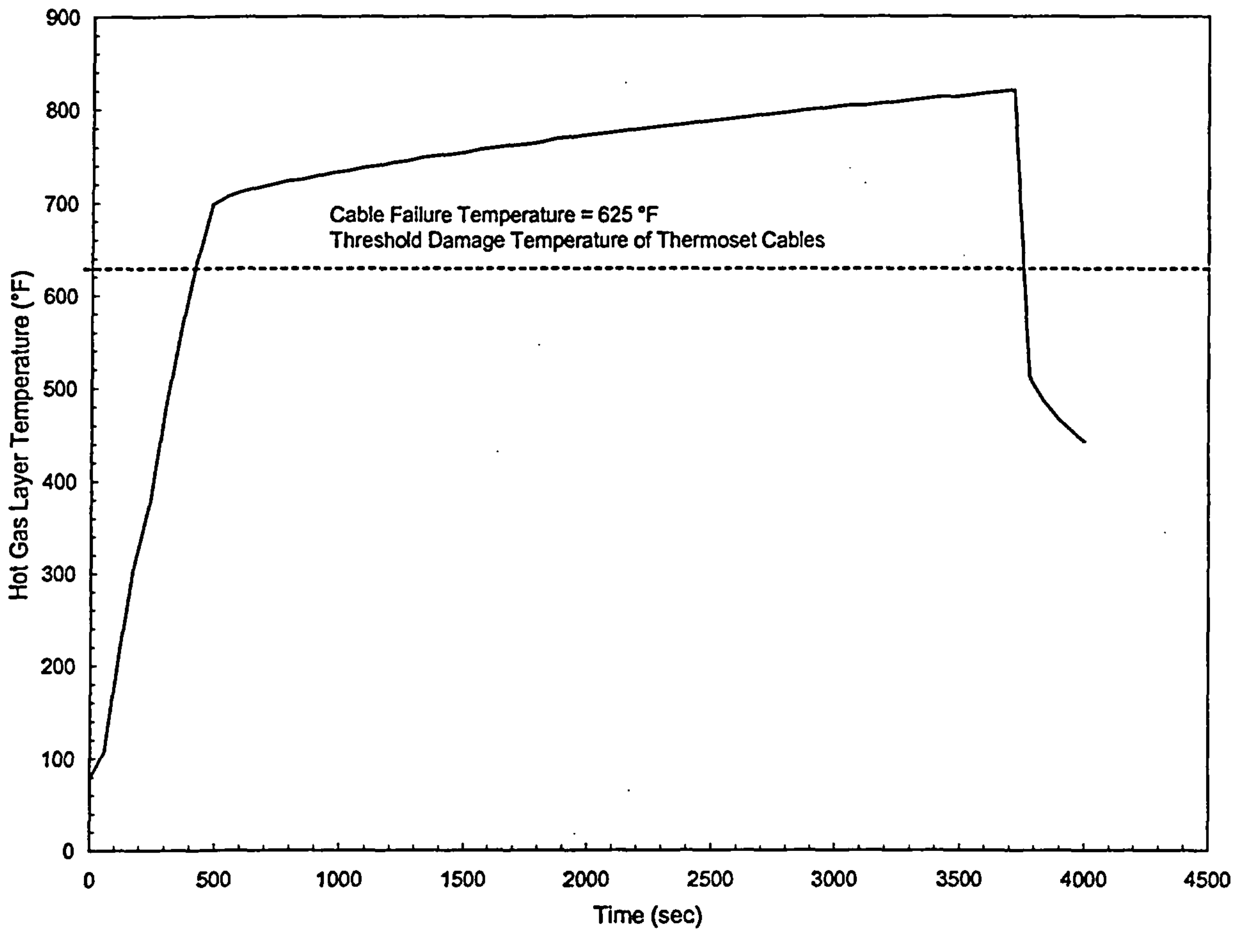

FIGURE 2

Figure 2 shows the peak upper gas layer temperature in the East Cableway, at the cable tray target location, for a fire in Fire Area 2104. The average hot gas layer temperature of 625 °F ~~degrees Fahrenheit~~ would be reached in approximately 400 seconds (7 minutes).

References

Custer, R. L., and Meacham, B. J., "Uncertainty and Safety Factors," Chapter 9, Introduction to Performance-Based Fire Safety, Society of Fire Protection Engineers (SFPE) and National Fire Protection Association (NFPA), Quincy, Massachusetts, 1997.

Duong, D. Q., "Accuracy of Computer Fire Models: Some Comparisons with Experimental Data From Australia," *Fire Safety Journal*, Volume 16, No. 6, 1990, pp. 415-431.

EPRI, TR-108875, "Fire Modeling Code Comparisons," Electric Power Research Institute, Palo Alto, California, 1998.

Heskestad,. G., and Delichatsios, M. A., "The Initial Convective Flow in Fire," Seventeenth Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, Pennsylvania, 1978, pp.1113-1123.

Jones, W. W., Forney, G. P., Peacock, R. D., and Reneke, P. A., "A Technical Reference for CFAST: An Engineering Tool for Estimating Fire and Smoke Transport," NIST TN 1431, U.S. Department of Commerce, National Institute of Standards and Technology (NIST), Building and Fire Research Laboratory (BFRL), Gaithersburg, Maryland, January 2000.

Jones, W. W., Forney, G. P., Peacock, R. D., and Reneke, P. A., "A Technical Reference for CFAST: An Engineering Tool for Estimating Fire and Smoke Transport," NIST TN 1431, U.S. Department of Commerce, National Institute of Standards and Technology (NIST), Building and Fire Research Laboratory (BFRL), Gaithersburg, Maryland, January 2000.

Nelson, H. E., and Deal, S., "Comparing Compartment Fires with Compartment Fire Models," Fire Safety Science-Proceedings of the Third International Symposium, International Association of Fire Safety Science (IAFSS), Scotland, UK., Cox and Langford, Editors, Elsevier Applied Science London and New York, July 8-12, 1991, pp. 719-728.

NFPA 72, "National Fire Alarm Code®," National Fire Protection Association, Quincy, Massachusetts, 1999 Edition.

NFPA 92B, "Guide for Smoke Management Systems in Malls, Atria, and Large Areas," National Fire Protection Association, Quincy, Massachusetts, 2000 Edition.

NFPA 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants," National Fire Protection Association, Quincy, Massachusetts, 2001 Edition.

Peacock, R. D., Forney, G.P., Reneke, P. A., Portier, R., and Jones, W. W., "CFAST, the Consolidated Model of Fire Growth and Smoke Transport," NIST Technical Note 1299, U.S. Department of Commerce, Building and Fire Research Laboratory (BFRL), National Institute of Standards and Technology (NIST), Gaithersburg, Maryland, February 1993.

Peacock, R. D., Davis, S., and Lee, B. T., "An Experimental Data Set for the Accuracy Assessment of Room Fire Model," NBSIR 88-3752, National Bureau of Standards, Gaithersburg, Maryland, 1988.

Peacock, R. D., Reneke, P. A., Jones, W. W., Bukowski, R. W., and Forney, G. P., "A User's Guide for FAST: Engineering Tools for Estimating Fire Growth and Smoke Transport," Special Publication 921, U.S. Department of Commerce, Building and Fire Research Laboratory (BFRL), National Institute of Standards and Technology (NIST), Gaithersburg, Maryland, October 1997.

FIRE MODELING FOR FIRE AREA 2104 EAST CABLEWAY
EDWIN I. HATCH NUCLEAR PLANT UNIT 1

Scope and Objectives

Fire modeling of the of the Edwin I. Hatch Nuclear Plant, Fire Area 2104, Unit 2 East Cableway; Control and Turbine Building El. 130 feet 0 inches, (Appendix R, III.G.2 area) have been performed to predict the potentially hazardous conditions (increased temperature) that could exist during postulated fire and to assess the associated damage potential to safe shutdown components and circuits or equipment of redundant trains of systems for safe shutdown in accordance with the guidelines provided in National Fire Protection Association, NFPA 805, Appendix C, 2001 Edition. The multi-zone fire model CFAST (Consolidated Model of Fire Growth and Smoke Transport) was used to determine the East Cableway conditions for the credible fire scenario.

Assumptions and Limitations

(1) The results of this analysis are predicated on the assumption that ignition of the lubricating oil occurs. A credible ignition source is the Reactor Feed Pump (RFP) Conditioner Lube Oil Circulating Pump motor which is located close to the concrete pad on which the RFP Turbine Oil Conditioner is mounted. This motor is installed in the diked area where spilled lubricating oil would accumulate in the event of an oil leak. The RFP Conditioner Lube Oil Circulating Pump motor is rated at 0.75 HP with a power supply voltage of 208 Volts AC. Another potential ignition source is a motor blower assembly that is mounted directly on top of the RFP Turbine Oil Conditioner. The motor blower assembly has a motor rated at 0.25 Hp with a power supply voltage of 120 Volts AC.

(2) The CFAST model does not allow the user to specify vent location in the corridor.

(3) The concrete dike (curb) area to retain lube oil spill = (9 ft x 9 ft) - (foot print of oil conditioner)

$$= 81\ ft^2 - (53\ in \times 52\ in)/144 \text{ square in per square ft} = 62\ ft^2$$

(4) The bounding fire scenario is developed for a fire developing from a 255 gallon of combustible lubricating oil spilled from the RFP Turbine Oil Conditioner assuming that all available fuel burn. This event allows the fuel contents of the conditioner (heated lubricating oil) to spill and spread over the floor. For the purpose of evaluating the ability of the pool fire to ignite safe shutdown cables and circuits in Fire Area 2104, the worst case scenario is the largest pool area which can burn long enough to cause ignition to cables.

(5) Mechanical ventilation off.

(6) In keeping with sound engineering practice in the absence of technical information, conservative "worst case" assumptions are made regarding fuel loading, fuel package burning rates, fire spread, and thermophysical effects.

(7) The fire characteristics were estimated using draft NUREG-1805, Fire Dynamics Tools (FDT^s). Heat release rate (HRR), burning duration, and flame height was calculated for a lube pool fire.

Combustible Liquid Spill in Fire Area 2104 from Reactor Feed Pump Turbine Oil Conditioner

Accidental spills of combustible liquid fuel and resulting fires depend on a number of parameters, including the composition of the fuel, the size and the shape of the fire, the duration of the fire, its proximity to the object (target) at risk, and the thermal characteristics of the object exposed to the fire.

A liquid with a relatively high flash points requires localized heating to achieve ignition. Once ignited however, a pool fire will spread rapidly over the surface of the liquid spill area. The area of burning will be a function of the leak rate or the confinement of the spill area. While the burning rate of a given fuel can be affected by its substrate in a spill, any absorption characteristics of the substrate was not considered since the floor is smooth finished concrete. In this analysis it is conservatively assumed that the fuel spills over the surface of the dike and forms a pool with the region of burning maintained at its depth. The effect of this initiating fire event in Fire Area 2104 is evaluated.

Fire Growth Rate

Testing has shown that the overall HRR during the fire growth phase of many fires can often be characterized by the simple time dependent polynomial or exponential function (Heskestad and Delichatsios 1978). The total heat release of fuel packages can be reasonably approximated by the power law fire growth model for both a single item burning and for multiple items involved in a fire. The proposed model of the environment generated by fire in an enclosure is dependent on the assumption that the fire grows according to:

$$\dot{Q} = \alpha t^2 \qquad (1)$$

where

$\dot{Q}$ = the rate of heat release of fire (kW),
t = the time (sec), and
α = a constant governing the speed of fire growth (kW/sec^2)

The growth rate approximately follows a relationship proportional to time squared for flaming and radially spreading fires and is referred to as t-squared (t^2) fires. The t^2 fires are classed by speed of growth, labeled ultra-fast, fast, medium, and slow. Where these classes are used, they are defined on the basis of the time required for the fire to grow to a rate of heat release of 1,000 kW (1 MW). The intensity α, and growth time t, related to each of these classes is shown in Table 1.

Table 1 Summary of t^2 Fire Parameter		
Type of Fire Growth	Intensity Constant α (kW/sec^2)	Growth Time t (sec)
Slow	0.00293	600
Medium	0.01172	300
Fast	0.0469	150
Ultra-fast	0.1876	75

The t^2 relationship has proven to be useful and has been adopted into the National Fire Protection Association NFPA 72 to categorize fires for detector spacing requirements and into NFPA 92B for design of smoke control system.

The modeled fire can be represented as one where the HRR per unit area is constant over the entire ignited surface and the flame is spreading with a steadily increasing area. In such cases, the burning area increases as the square of the steadily increasing fire radius. Fires that do not have a regular fuel array and consistent burning rate might or might not actually produce a t^2 curve; however, the t^2 approximation appears to be reasonable for use in this case to produce a realistic approximation of the expected fire growth.

Test data on large pool fires demonstrated that the peak HRR per unit area will grow fast or ultra fast. For the purpose of this analysis a t^2 fast growth rate for the lube oil fire was assumed based on the experiments.

Heat Release Rate, Burning Duration and Flame Height Estimate

This analysis is used to determine the extent of potential fire damage associated with a realistic, potential fire scenario in Fire Area 2104. The analysis evaluates whether the postulated fire can lead to failure of safety-related cables, or equipment of redundant trains of systems for safe shutdown. The impact of the fire scenario is analyzed using fire dynamics principles or fire model (e.g., CFAST). The lube oil spill fire is modeled using the HRR depicted in Figure 1. The computer program then develops HRR based on the ventilation and other limitations. For pool fire scenario the calculated HRR, burning duration, and flame height were determined using FDT^s. Table 2 summarizes the results of the calculations.

Table 2 Fire Characteristics of RFP Turbine Oil Conditioner Pool Fire		
Heat Release Rate $\dot{Q}$ kW (Btu/sec)	Burning Duration t_b sec (min.)	Flame Height H_f m (ft)
10333 (9794)	3266 (55)	5.2 (17)

CFAST - Consolidated Model of Fire Growth and Smoke Transport

The multi-zone computer fire model CFAST was used to calculate the temperature in Fire Area 2104 [Peacock *et al.*, 1997; Peacock *et al.*, 1993]. CFAST was developed by the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST) for the development of fire models having both steady and unsteady state burning rates in multiple compartment configurations (multiple room capability, up to 15 rooms can be modeled). The initiating fire is user specified, but adjusted by CFAST based on the available supply of oxygen. CFAST allows fires to be constrained or unconstrained. A fire specified as unconstrained in CFAST will not be limited by the availability of oxygen. When a constrained fire is specified, the chemically required oxygen is calculated and the available oxygen and unburned gases are tracked. A mass balance calculation of individual species is performed for each zone to track the available oxygen and unburned gases. Multiple compartments and vents can be modeled as well as the mechanical ventilation. Mechanical ventilation is addressed by CFAST in terms of fan/ductwork that includes consideration of fan pressure/flow characteristic curves and duct friction losses. The model divides each compartment into two zones, an upper zone containing the hot

gases produced by the fire and a lower zone containing all space beneath the upper zone. The lower zone is a source of air for combustion and is usually the location of the fire source.

The upper zone can expand to occupy virtually all of the space in the compartment. The upper zone is considered a control volume that receives both mass and energy from the fire and loses energy to the surfaces in contact with the upper zone by conduction and radiation, by radiation to the floor, and by convection or mass movement of gases through openings. The two layer zone approach used by the CFAST has evolved from observations of such layering in full-scale fire experiments (Jones *et al.*, 2000). While these experiments show some variation in conditions within the layers, they are small compared to the differences in conditions between the layers themselves. Thus, the zone model can produce a fairly realistic simulation of the fire environment within a compartment under most conditions. CFAST has the capability to calculate the upper and lower layer temperature, the smoke density, the vent flow rate, the gas concentrations, and compartment boundary temperatures, the heat flux from the smoke layer to objects, the internal compartment pressure, and the interface elevation, all as a function of time.

A number of efforts of CFAST model comparison, verification and validation have been undertaken. Many of these efforts involved comparisons between measured and calculated parameters, primarily temperatures, mass flow rates and smoke layer interface positions. Duong, 1990, Peacock, et al., 1988, Mowrer and Gautier, 1997, Nelson and Deal, 1991, and EPRI TR-108875, 1998, compared CFAST model predictions with experimental data.

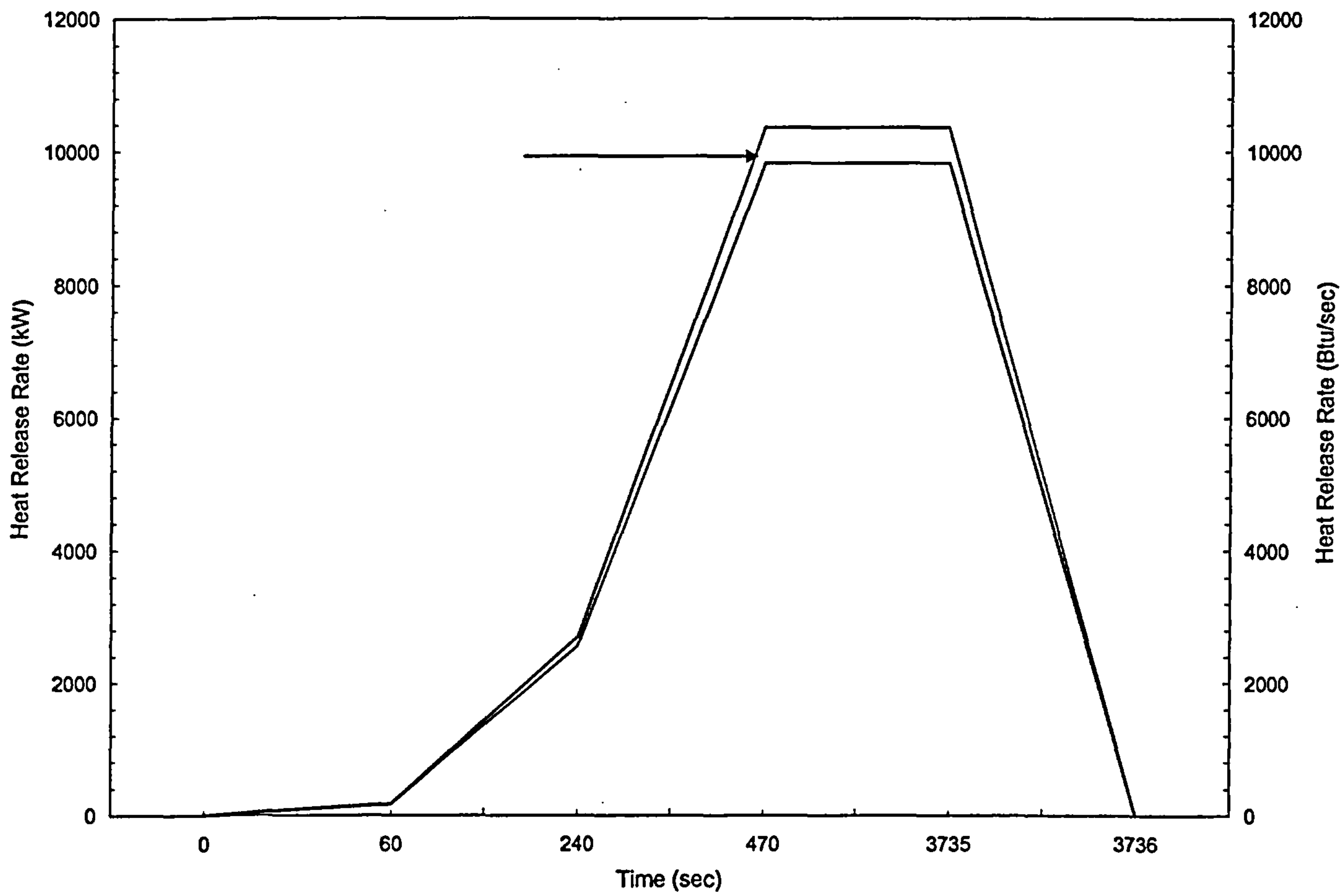

FIGURE 1

Figure 1 shows the HRR for a fire in Fire Area 2104 with a maximum HRR of 10333 kW (9,794 Btu/sec).

Limitations and Uncertainties Associated with Fire Modeling

Fire models permit development of a better understanding of the dynamics of building fires and can aid in the fire safety decision-making process. There are certain limitations and uncertainties associated with the current fire modeling predictions. Extreme care must be exercised in the interpretation of the fire modeling results. For scenarios where the level of predicted hazard is well below the damage threshold, the results can be used with high level of confidence provided there is a high level of confidence that all risk-significant scenarios have been considered. For scenarios where the level of predicted hazard is near the damage threshold, the results should be used with caution in view of the uncertainties that exist.

A primary method of handling modeling uncertainties is the use of engineering judgment. Among other things, this judgment is reflected in the selection of appropriate fire scenario, hazard criteria, and fire modeling techniques. A slightly more formal application of engineering judgment is the use of safety factors. The safety factors can be applied in the form of fire size, increased or decreased fire growth rate, or conservative hazard criteria (Custer and Meacham, 1997). Experimental data obtained from fire test, statistical data from actual fire experience, and other expert judgment can be used improve the judgment and potentially decrease the level of uncertainty.

CFAST Modeling of Fire Area 2104 East Cableway

Fire modeling of Fire Area 2104 using CFAST was performed. A list of necessary inputs for CFAST is provided in Table 3. Additionally, Table 4 documents the input data file for the CFAST computer model. CFAST input data includes the physical dimensions of the compartment, the compartment construction materials, the opening dimensions and their elevations, the fire HRR and the position of the fire in the specified room, gas species production rate, and exterior wind conditions (see input file, Table 4). With the parameter chosen, CFAST provided information on the temperature in the room, the smoke interface height, and species concentration. This information was used in order to gain insights into the different possible fire scenario.

The peak upper gas layer temperature in the East Cableway , at the target cable tray location, calculated by CFAST is shown in Figure 2. Figure 2 shows that the average hot gas layer temperature of 625 °F (330 °C) would be achieved in approximately 400 seconds. This temperature of 625 °F is the threshold damage temperature of the two targeted 4-20 milliamp instrumentation circuit cables which are thermoset cables. The results of this analysis demonstrates that the temperature of the hot gas layer, and the duration of the fire, is sufficient to cause fire induced damage to safety-related cables and circuits that are routed in the East Cableway, between Column T19 and Column T16, (Drawing Number H-24610, Edwin I. Hatch Nuclear Plant Unit No. 2, 10 CFR 50 Appendix "R" Fire Zones and Safe Shutdown Raceway Plan, East Cableway El. 130' 0"). The target cable tray is located between Column T16 and Column T17, approximately 8.5 feet from Column T16. Therefore, it is reasonable to conclude that the bounding pool fire scenario will result in the two 4-20 milliamp instrumentation circuits reaching failure conditions. Additionally, if both instrumentation circuits fail non-conservatively because of increased leakage current caused by insulation damage, this condition will simulate a high nuclear boiler pressure condition and will result in logic being initiated to simultaneously open all eleven Safety Relief Valves (SRVs). Simultaneous opening of all eleven SRVs is the equivalent of a large break Loss of Coolant Accident, (LOCA). Also, spurious opening of all eleven SRVs will result in the sudden depressurization of the nuclear boiler, and failure to maintain the suppression pool heat capacity temperature limit. The suppression pool heat capacity temperature limit is required to be maintained in order to ensure that safe shutdown equipment credited for mitigating this event will be capable of performing their design function.

Table 3 Description of the CFAST Input Data File	
1	Compartment geometry: Width x Depth x Height = 5.20 m x 26.82 m x 4.72 m
2	Natural ventilation - Vent connection (horizontal and vertical flow connections between compartment in the structure including doors between compartment or window in the compartment between compartment or to the outside: Opening Width = 3.65 m, Height = 4.26 m
3	Mechanical Ventilation: Off
4	Compartment construction and thermal properties of the enclosing surfaces, i.e., ceiling, wall, and ceiling - 24" thick Concrete

5	Fire specification: information on the source of fire location, area of source fire, chemical properties of the fuel, heat of combustion of the fuel, species yields, fuel mass loss rate, and heat release of the fire (input HRR Figure 1) with fire time.

Table 4 CFAST Input Data File

```
VERSN  3   HATCH Plant-Fire Area 2104, Oil Conditioner Pool Fire
TIMES 4000  60  60  60   0
TAMB  298. 101300. 0.0
EAMB  298. 101300. 0.0
HI/F   0.0  0.0   0.0   0.0
WIDTH  5.20
DEPTH  26.82
HEIGH  4.72
HVENT  1  2  1  3.65 4.26  0.0  0.0  0.0  0.0
CVENT  1  2  1  1.0  1.0   1.0  1.0  1.0  1.0
CEILI  CONCRETE
WALLS  CONCRETE
FLOOR  CONCRETE
CHEMI 16. 10. 10.  46000000.  298.  388. 0.2
LFBO  1
LFBT  2
FPOS  1.0  1.0  0.0
FTIME 60.0    240.0  470.0  3735.0  3736.0
FHIGH 0.5  0.5  0.5  0.5  0.5  0.5
FAREA 0.5  0.5  0.5  0.5  0.5  0.5
FQDOT 0.0  168840.0  2701440.0  10333000.0   10333000.0   0.0
CJET OFF
CO     0.03  0.03  0.03  0.03  0.03  0.03
OD     0.08  0.08  0.08  0.08  0.08  0.08
HCR    0.13  0.13  0.13  0.13  0.13  0.13
STPMAX  1.00
DUMPR HATCH1.Hi
DEVICE 1
WINDOW    0  0. -100. 1280. 1024. 1100.
GRAPH 1  170.  300.   0. 625.   820.  10.  5  TIME CELSIUS
GRAPH 2  765.  300.   0. 1220.  820.  10.  5  TIME FIRE_SIZE (kW)
LABEL 1  970.  960.   0. 1231.  1005. 10.  15 00:00:00    0.   0.
LABEL 2  690.  960.   0. 987.   1005. 10.  13 TIME_ [SEC] 0.   0.
TEMPERA  0  0  0  0  1   1 U
HEAT     0  0  0  0  2   1 U
```

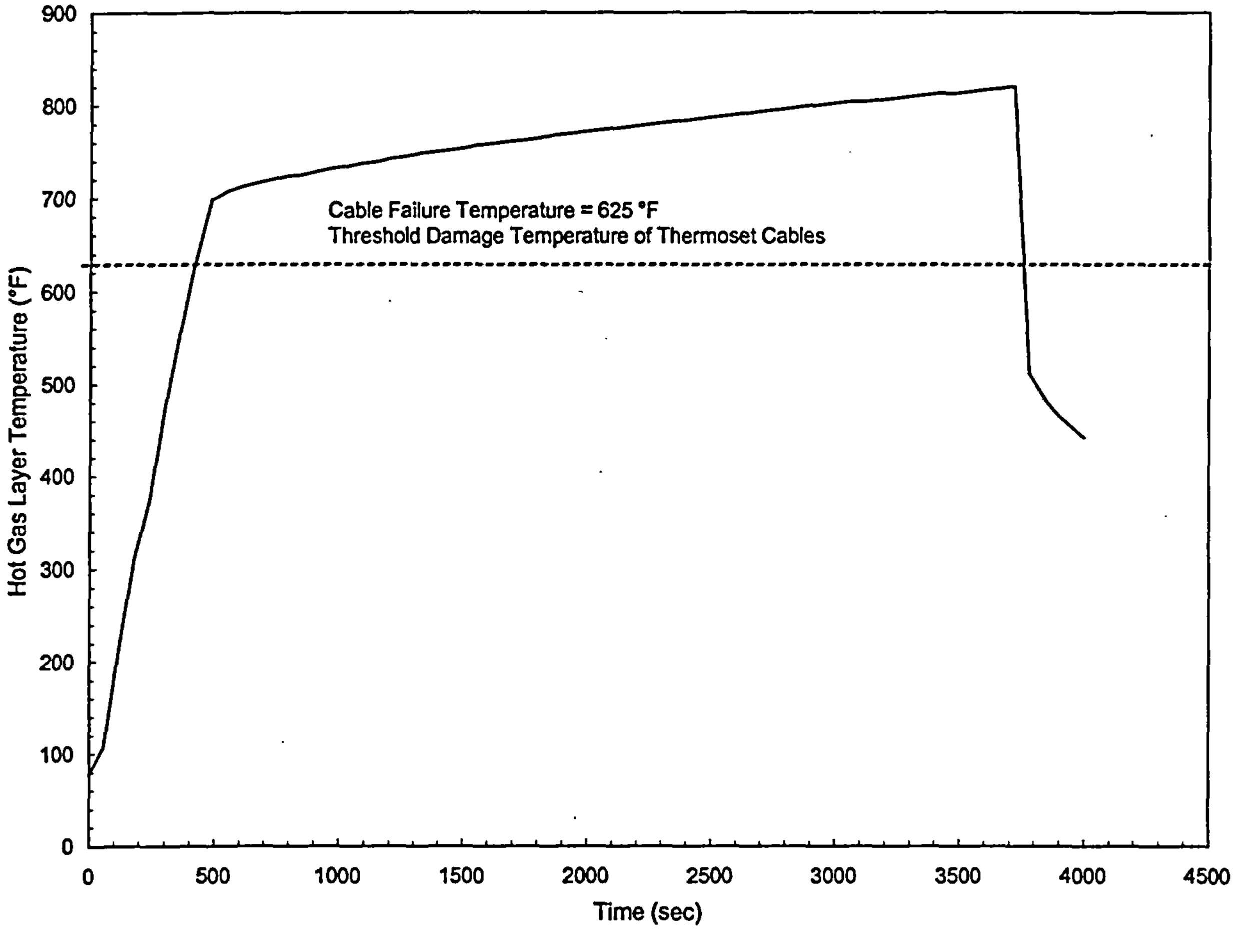

FIGURE 2

Figure 2 shows the peak upper gas layer temperature in the East Cableway, at the target cable tray location, for a fire in Fire Area 2104. The average hot gas layer temperature of 625 °F would be reached in approximately 400 seconds (7 minutes).

References

Custer, R. L., and Meacham, B. J., "Uncertainty and Safety Factors," Chapter 9, Introduction to Performance-Based Fire Safety, Society of Fire Protection Engineers (SFPE) and National Fire Protection Association (NFPA), Quincy, Massachusetts, 1997.

Duong, D. Q., "Accuracy of Computer Fire Models: Some Comparisons with Experimental Data From Australia," *Fire Safety Journal*, Volume 16, No. 6, 1990, pp. 415-431.

EPRI, TR-108875, "Fire Modeling Code Comparisons," Electric Power Research Institute, Palo Alto, California, 1998.

Heskestad,. G., and Delichatsios, M. A., "The Initial Convective Flow in Fire," Seventeenth Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, Pennsylvania, 1978, pp.1113-1123.

Jones, W. W., Forney, G. P., Peacock, R. D., and Reneke, P. A., "A Technical Reference for CFAST: An Engineering Tool for Estimating Fire and Smoke Transport," NIST TN 1431, U.S. Department of Commerce, National Institute of Standards and Technology (NIST), Building and Fire Research Laboratory (BFRL), Gaithersburg, Maryland, January 2000.

Jones, W. W., Forney, G. P., Peacock, R. D., and Reneke, P. A., "A Technical Reference for CFAST: An Engineering Tool for Estimating Fire and Smoke Transport," NIST TN 1431, U.S. Department of Commerce, National Institute of Standards and Technology (NIST), Building and Fire Research Laboratory (BFRL), Gaithersburg, Maryland, January 2000.

Nelson, H. E., and Deal, S., "Comparing Compartment Fires with Compartment Fire Models," Fire Safety Science-Proceedings of the Third International Symposium, International Association of Fire Safety Science (IAFSS), Scotland, UK., Cox and Langford, Editors, Elsevier Applied Science London and New York, July 8-12, 1991, pp. 719-728.

NFPA 72, "National Fire Alarm Code®," National Fire Protection Association, Quincy, Massachusetts, 1999 Edition.

NFPA 92B, "Guide for Smoke Management Systems in Malls, Atria, and Large Areas," National Fire Protection Association, Quincy, Massachusetts, 2000 Edition.

NFPA 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants," National Fire Protection Association, Quincy, Massachusetts, 2001 Edition.

Peacock, R. D., Forney, G.P., Reneke, P. A., Portier, R., and Jones, W. W., "CFAST, the Consolidated Model of Fire Growth and Smoke Transport," NIST Technical Note 1299, U.S. Department of Commerce, Building and Fire Research Laboratory (BFRL), National Institute of Standards and Technology (NIST), Gaithersburg, Maryland, February 1993.

Peacock, R. D., Davis, S., and Lee, B. T., "An Experimental Data Set for the Accuracy Assessment of Room Fire Model," NBSIR 88-3752, National Bureau of Standards, Gaithersburg, Maryland, 1988.

Peacock, R. D., Reneke, P. A., Jones, W. W., Bukowski, R. W., and Forney, G. P., "A User's Guide for FAST: Engineering Tools for Estimating Fire Growth and Smoke Transport," Special Publication 921, U.S. Department of Commerce, Building and Fire Research Laboratory (BFRL), National Institute of Standards and Technology (NIST), Gaithersburg, Maryland, October 1997.

24

Mail Envelope Properties (403517F3.9E1 : 0 : 37820)

Subject:	Re: Hatch Fire Model
Creation Date:	Thu, Feb 19, 2004 3:09 PM
From:	Naeem IQBAL
Created By:	NXI@nrc.gov

Recipients
nrc.gov
ATL_PO.ATL_DO
CFS1 (Caswell Smith)
CRO CC (Charles R. Ogle)
GRW CC (Gerald Wiseman)
KFO CC (Kathleen O'Donohue)

Post Office	**Route**
ATL_PO.ATL_DO	nrc.gov

Files	**Size**	**Date & Time**
Hatch TFPI FireArea 2104 Analysis.wpd	80605	Thursday, February 19, 2004 3:07 PM
MESSAGE	1453	Thursday, February 19, 2004 3:09 PM

Options

Expiration Date:	None
Priority:	Standard
Reply Requested:	No
Return Notification:	None
Concealed Subject:	No
Security:	Standard